MACINTOSH ASSEMBLY LANGUAGE

AN INTRODUCTION

JAN L. HARRINGTON

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PREFACE

It seems as though there is a flood of Macintosh software hitting the market these days, most of it written in Pascal on a Lisa (the Macintosh's now defunct big brother, most recently known as the Macintosh XL) or in assembly language on either a Lisa or a Macintosh. Some commercial software developers are also beginning to work in Forth and C. No language, however, gives a programmer more control over the Macintosh than assembly language.

People who learn to program the Macintosh in assembly language gain in four ways:

1. They learn the basic principles of microcomputer architecture;
2. They learn how computers store and manipulate numbers;
3. They learn the basics of using an assembly language instruction set;
4. They learn to focus on creating applications with a standard, user-friendly interface.

This book was written to teach the four areas listed above to both students in a classroom situation and an individual working alone. It is designed to take someone who knows Pascal and get that person functioning in an assembly language environment. It assumes no background in computer architecture or assembly language. By the same token, it is not a definitive work. One of its primary goals is to give a programmer the tools needed to understand documentation so that he or she can independently go beyond what this book covers. Therefore, while it presents material common to assembly language programming on all computers, this is also a practical book, aimed at *doing* assembly language programming on the Macintosh. It was designed to teach assembly language programming specifically *on the Macintosh* and is not intended to be a general 68000 assembly language text.

Programming the Macintosh in assembly language isn't an easy task. In fact, it can be complex and tedious since access to the Macinotsh's internal ROM routines

is really designed for Pascal, and assembly language programmers must simulate the Pascal syntax. Nonetheless, working in assembly language does give a programmer computing power that no other language can deliver.

Learning to program in assembly language on the Macintosh presents two challenges: A person must not only master the microprocessor's instruction set, but also must be able to interact with the ToolBox and operating system routines that reside in Macintosh's ROM. All I/O is done through those routines. In fact, Macintosh assembly language programs are often little more than a series of calls to the ROM routines. The instruction set itself takes a back seat; it is used primarily to set up parameters before issuing a call.

Because assembly language on the Macintosh is a rather complex task, this book is not intended to be an exhaustive treatment of the subject, but it will:

1. Provide the technical background needed to function in assembly language
2. Introduce the commonly used instructions in the Macintosh's instruction set
3. Demonstrate how to use the ToolBox and operating system routines necessary to create basic assembly language applications.

This book does not deal specifically with producing Macintosh graphics. Creating spectacular graphics takes two kinds of knowledge: knowing how to use the ROM graphics routines and knowing how to sequence calls to those routines to draw the desired images. This book teaches the former, how to read the documentation that describes the graphics routines, and provides the skills needed to call the routines from assembly language. Sequencing calls to graphics routines to produce some particular picture, however, is beyond the scope of this book. The effective use of Macintosh graphics is an extensive subject that deserves a book all its own.

Resources for Learning

This book is based on Apple's *Macintosh 68000 Development System* (MDS), a package of software tools that supports the development of either stand-alone assembly language applications or assembly language routines that can be called by high-level language programs. While it is not the only such package available for the Macintosh, it is the most complete and the most convenient to use. If not available from your regular software supply house, it can be ordered directly from Apple:

Macintosh Technical Support
Apple Computer
MS 4-T
20525 Mariani Avenue
Cupertino, CA 95014

To obtain an exact price and details on ordering, call the customer service line at 408-973-2222 between 9:30 A.M. and 1:30 P.M. Pacific time.

Complete documentation for all Macintosh ROM routines can be found in *Inside Macintosh*, now available at computer retailers and bookstores or through direct order from Apple. Though the book you are reading right now is independent of *Inside Macintosh*, programmers inevitably will wish to go beyond what this book presents and it may be difficult to teach a course in Macintosh assembly language without at least one copy of that manual available for reference. This book teaches people how to interpret what they find in *Inside Macintosh*, how to decipher the Pascal syntax for the ToolBox and operating system calls and turn it into assembly language. It also focuses on understanding the sequence in which they should use the ROM routines.

There is one other reference that students should use in conjunction with this book and *Inside Macintosh—The MC68000 Programmer's Reference Manual* (hereafter referred to as the PRM). The PRM, which is included with the Macintosh 68000 Development System, is a reference work detailing the instruction set of the Macintosh's 68000 microprocessor.

Developing assembly language programs is much easier with the aid of a number of utility programs that Apple has written. These include programs that dump the contents of a disk file in hexadecimal, print a spooled print file, and aid in creating screen formats and alert and dialog boxes. For a while Apple was distributing these utilities with the Software Supplement to *Inside Macintosh*. Now that *Inside Macintosh* is available in bookstores, however, the utilities can be downloaded from a number of dial-up information systems, such as CompuServe, and from public bulletin boards. They are also available from most Macintosh users groups.

Reader Background

This book assumes that the reader has knowledge equivalent to a one-semester course in Pascal, though not necessarily on the Macintosh. It also assumes that the reader has some experience working with the Macintosh itself. In particular, he or she should have used a Macintosh word processor such as MacWrite. Though Chapter 1 discusses in detail the characteristics of the Macintosh user interface, the book assumes that people are familiar with mouse-driven applications that use pull-down menus and overlapping windows.

Overview of the Book

The introduction found in Chapter 1 lays a foundation for the Macintosh assembly language environment. It discusses the differences between assembly language and high-level languages and explains what is to be gained by working in assembly language. The chapter also examines the characteristics of the standard Macintosh user interface, emphasizing that all successful Macintosh software adheres to that interface.

Chapter 2 presents technical background information. This includes a look at the binary, octal and hexadecimal numbering systems, the architecture of the Macintosh's microprocessor (in particular, its registers), how the Macintosh uses its available RAM (including the stack), and addressing memory from assembly language.

Chapter 3 contains a short assembly language program to type in. This will provide practice in using the Macintosh 68000 Development System. Working through the exercise early in the course will make it easier for students to concentrate on programming without worrying about how to use the Editor, Assembler, and Linker.

Chapters 4 and 5 present an introduction to the assembly language instructions that form the backbone of a Macintosh assembly language program. This chapter has numerous blocks of sample code, each of which is to be inserted into a ToolBox "shell" that is created out of the program in Chapter 3.

Although this book deals with assembly language, it's a fact of life that access to ToolBox and operating system routines is based in Pascal. If people are going to be able to read the documentation of those routines in *Inside Macintosh*, they must understand Pascal data types, data structures, and procedures and functions. Therefore, Chapter 6 reviews the necessary Pascal concepts. It also describes the structure of the ToolBox and operating system routines and how an assembly language program gains access to them.

The remainder of the book deals with the ToolBox and operating system routines that are needed to create a Macintosh assembly language application. Chapter 7 dicussses setting up the desktop (managing windows and pull-down menus). Chapter 8 discusses managing program operation by monitoring the keyboard and mouse. Chapter 9 handles entering and editing text. Printing from an application (tedious but not difficult) is presented in Chapter 10. File I/O (not as complicated as it looks) is discussed in Chapter 11.

Chapter 12 discusses floating point arithmetic. Even if an application does no significant amount of math, it will at least need to use the routines that convert a string of numeric characters into a binary number and a binary number to a string of characters for numeric I/O.

The Video Tape Index Program

The major application that is developed throughout most of the book is a video tape index. The program is a specialized database system that could be used in a home to catalog which program has been recorded on which video tape or in a video rental outlet for inventory control. The video tape index program first appears in Chapter 5 in the discussion of handling arrays in main memory and is used to explore sorting and searching techniques for such arrays. It is presented in bits and pieces throughout the book. Complete source code for the program can be found in Appendix A.

To most students the source code for the video tape index program may look a bit forbidding at first. It is long — about 3,000 lines of code — far longer than most of the Pascal programs that are written in programming classes. Nonetheless, it assembles to only about 12K and uses another 12K of space for data storage. It will therefore run on a 128K Mac.

Why use such a large example? Certainly the sample programs that come with the Macintosh 68000 Development System are much shorter. First, the very simplicity of those examples creates a problem. The features of a Macintosh application interact in many unexpected ways. While Apple provides a sample program that creates a window, the video tape index uses multiple, overlapping windows to demonstrate more extensive window management. One of Apple's sample programs demonstrates text editing, but only in one window. The video tape index uses multiple windows for text editing to explore a more complex, meaningful environment.

Secondly, meaningful Macintosh assembly language programs do become very large, generally occupying 25 to 400K. Apple's short examples really don't do any meaningful work. The video tape index program is a complete, useful application that can easily be customized to meet individual needs. It is also available, along with other sample programs, on disk from the publisher of this book.

CHAPTER ONE

INTRODUCTION

Chapter Objectives

1. To explore the advantages and disadvantages of programming in assembly language
2. To become familiar with the characteristics of the standard Macintosh user interface

Assembly Language: Why Bother?

Back in the early days (that means anything before 1964), people who wanted to learn about computers studied logical circuit design and then a mysterious language called "assembly." Once they had mastered assembly language programming, they moved on to high-level languages like FORTRAN.

It doesn't work that way any more. For most people today, their first exposure to programming is through a high-level (English-like) language, usually BASIC or Pascal. Pascal doesn't require much knowledge about the internal workings of your computer; not necessarily a bad thing, since knowing the internal organization of a microprocessor doesn't automatically make you a good programmer.

There are, though, some things that assembly language can do better than BASIC, Pascal and other high-level languages. Primarly, assembly language

programs run faster than high-level language programs. To understand why, you must first realize that there is only one language that a computer can run directly—*machine language*. Machine language consists of a series of binary codes (0's and 1's) which make perfect sense to a computer but very little sense to a human.

Assembly language was created to free programmers from having to program in machine language. Each command that the computer could understand (an *instruction*) was given a short mnemonic code consisting of two to five letters. Programmers could then use the mnemonics rather than the complex binary. Once the source code was finished, it had to be translated into machine language so the computer could run it. The translation was (and still is) accomplished by a program called an *assembler*. The resulting machine language version is called *object code* and can be run directly by the computer.

High-level languages also require translation to object code. Most versions of BASIC are *interpreted*. That means that the conversion to object code occurs line by line as the program is being run; no permanent machine language version of the program is ever created. If you have a FOR/NEXT loop that repeats 100 times, every statement in that loop will be translated to machine language 100 times. Intepreted BASIC programs are just about the slowest programs around.

Most other high-level languages are *compiled*. All of the translation to machine language occurs at one time. Just like an assembler, a compiler gives you a machine language version of your program. Object code derived from a compiler usually cannot be run alone, though. It needs to be linked to *run-time libraries* (a collection of standard programs that handle functions such as input and output). While compiled programs can run almost as fast as assembled programs, they tend to be bigger. This becomes a major concern when you are writing software for a machine with limited RAM such as the first edition Macintosh (with only 128K).

In addition to increasing the speed of program execution, assembly language gives you more control over your computer than high-level language. When you use an interpreted language, you have little opportunity to determine where your program or its variable tables are placed in main memory. Though some compilers do allow you to specify where large blocks of code should begin (e.g., your program's object code and run-time libraries), you are still extremely limited. With assembly language, you can access RAM locations directly and determine exactly what will be placed in each location. A well-written assembly language program is generally more efficient than an interpreted or compiled program; in other words, it makes better use of available main memory.

In order to gain the speed and efficiency of assembly language programs, you must in turn know something about the internal physical organization of your computer. You need to know not only how RAM is used, but you must also have some knowledge of the "architecture" of its microprocessor.

Assembly language has one major drawback, assuming that you don't consider having to acquire technical knowledge about your computer a drawback.

High-level languages are more or less portable between different computers. Consider, for example, all the different microprocessors and operating systems that run Microsoft BASIC. Languages such as Pascal and FORTRAN differ only minimally between computers. Assembly language, however, is specific to one particular microprocessor; the mnemonics are different for each one. Therefore, learning assembly language on one computer does not automatically prepare you to write assembly language programs on another. Each microprocessor has its own *instruction set* (the entire group of instructions that a microprocessor can understand).

Nonetheless without programming in assembly language it is very difficult to do serious program development *on a Macintosh*. With BASIC you are limited to very small, very slow programs. For example, after the Microsoft interpreter is loaded, you have only 14K left in the 128K machine for programs. Though this limitation has no relevance for the 512K Macintosh, a significant number of 128K machines have been purchased and much software is designed to run in that more restrictive environment.

Many Macintosh programs have been written in Pascal, but they were developed on a Lisa. Lisa Pascal for the Macintosh is very different from MacPascal. MacPascal is interpreted, like BASIC. That means that while it is an excellent tool for learning about Pascal, programs written in MacPascal will run nearly as slowly as interpreted BASIC programs.

There is another disadvantage to developing Macintosh applications completely in a high-level language which relates to the nature of Macintosh software. Successful Macintosh applications are designed around the standard Macintosh user interface (discussed in the second part of this chapter). To implement that interface, the Macintosh uses a set of over 500 prewritten routines. Some are in *ROM* (read only memory); others are on disk as part of the system files. The routines fall into two major groups: those that are part of the operating system and those that constitute the *ToolBox*. (For an overview of Macintosh's built-in routines, see Chapter 6.)

No language currently available gives you access to *all* of the ToolBox and operating system routines within the standard language environment. (*Lisa* Pascal can call all of the Macintosh's internal routines, but MacPascal cannot.) Some, like Microsoft BASIC 2.0, allow a programmer to build assembly language libraries that can be called from the high-level language program. Others, like MacPascal, have an interface to many of the routines which require assembly language knowledge to set up the calls. A programmer who wishes to exploit a Macintosh high-level language to its maximum must therefore have at least some knowledge of the Macintosh assembly language interface.

What it all boils down to is this — if you want to be able to tap the full power of a Macintosh, then you will find that being able to use assembly language is the most valuable tool available.

The Standard Macintosh User Interface

The Macintosh has made most of us redefine what it means when we say a program is easy to use. When we open a brand-new piece of Macintosh software, we expect to be able to run it by simply double-clicking on its icon from the Finder. We also expect to find that program actions are controlled by menus and that the mouse controls placement of the cursor. These are all characters of the standard Macintosh user interface. They have the effect of making Macintosh applications programs very easy to learn and use. By the same token, they increase the burden on the programmer.

Macintosh software packages that stray from the standard user interface have not fared well with reviewers or users. During the first six to nine months after Macintosh was released, many independent software developers rushed to market Macintosh versions of software that was running on other systems without completely adapting it to the Macintosh environment. Few of those early efforts are still being sold; most have been significantly upgraded to adhere to the Macintosh interface. The moral of the story is. . .if you're going to program the Macintosh, do it Apple's way when it comes to the user interface. In terms of that interface, creativity wins few prizes.

The Macintosh standard user interface is characterized by the following:

1. Use of the mouse as the primary input device to control menu selections, window manipulation, cursor placement and text selection
2. Pull-down menus, including the standard Apple, File, and Edit menus
3. Multiple, overlapping windows
4. Text editing with **cut, copy, paste** and **clear** functions
5. Control of program actions with alert and dialog boxes

Macintosh Cursors

The Macintosh's mouse is "hard wired" to a moveable cursor that appears on the screen; it lays on top of everything else that is displayed. The cursor's shape will vary with particular program actions. It may be:

1. An arrow (used when making menu selections, dragging windows, closing windows, sizing windows, scrolling windows contents, etc.)
2. A straight line (used to mark the place where text characters will be inserted)
3. An I-beam (used to aid in positioning the cursor in text documents)

4. A wrist watch (used to indicate long waits)

Other special cursors include the cross for sizing and positioning graphics objects, and an outlined cross used for making array selections. Applications may also design their own cursors.

Menus

Menus were certainly not invented by the Macintosh development team; they are used in a great deal of commerical software. Most users consider menu-driven software as easier to learn and easier to use than software that requires learning a set of commands. Menus on other computers, however, not only look different from Macintosh menus but accept input about menu selections in a very different way.

A typical non-Macintosh menu appears in Figure 1.1. A program using this menu will usually clear the screen, print the menu, and issue an input statement (e.g., a Pascal **read**). The user makes a selection by entering a number that corresponds to the appropriate menu option. Program execution is suspended until the menu selection is made; the user has no way to escape from making a menu choice, save perhaps resetting the computer.

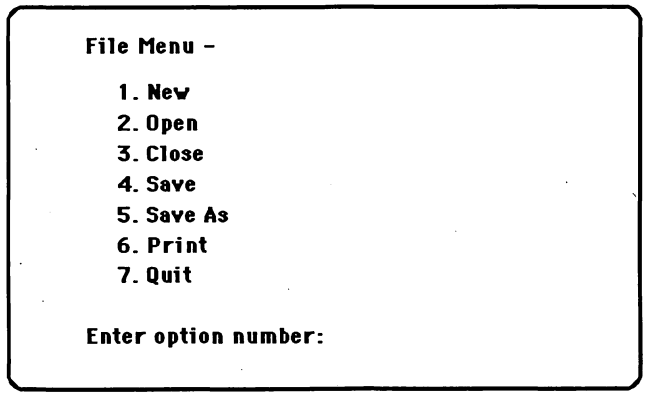


Figure 1.1 A Standard Microcomputer Menu

Macintosh menus also present the user with a list of options. Figure 1.2 presents the Macintosh version of the menu from Figure 1.1 The menu's title appears above the part of the screen where program actions take place; this is known as the *menu bar*. To see the menu options, the user positions the arrow cursor on the menu title, presses the mouse button, and drags the arrow down.

Options are *highlighted* (displayed in inverse video—white letters on a black background) as the arrow cursor is dragged. The user indicates a menu selection by releasing the mouse button when the cursor is positioned on the appropriate option.

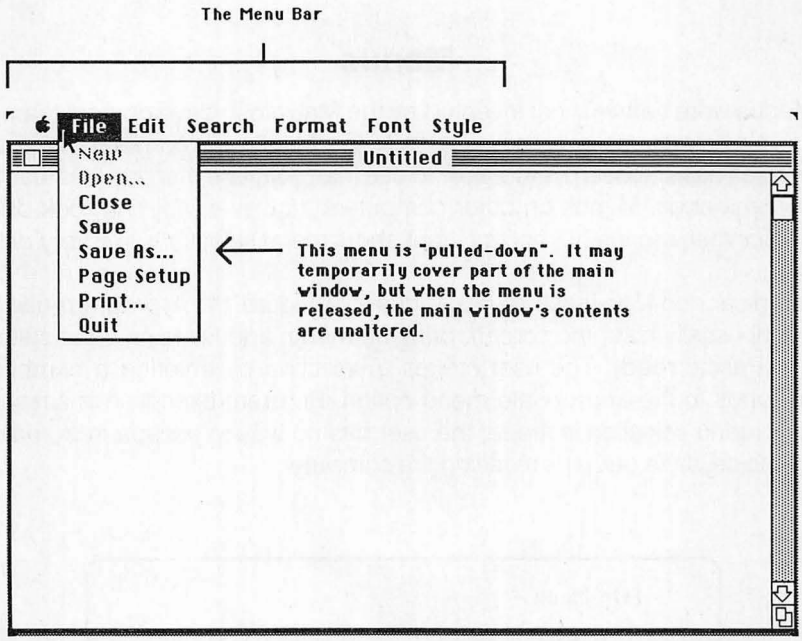


Figure 1.2 The Macintosh's Standard File Menu

Two things make the Macintosh menu selection process very different from standard menu selections. In the first place, the user can escape from the menu by either returning the arrow cursor to the menu title or by dragging the cursor off the bottom of the menu. Secondly, pulling down the menu doesn't require erasing what appears on the main portion of the screen, though part of the screen may be temporarily covered by the menu options. Selections from Macintosh menus can therefore be made while text and/or graphics are present on the Macintosh screen.

Most Macintosh applications will support three standard menus plus any additional menus the application requires. The leftmost menu in the menu bar has the silhouette of an apple with a bite out of it for a title. This "Apple" menu (see Figure 1.3) supports the Macintosh desk accessories and may also include an "about" feature that describes the software in which the menu appears. A desk accessory is a stand-alone program that can be run at any time without exiting the major application (e.g., MacWrite or MacPaint) being executed.

The second menu from the left is the File menu (see Figure 1.2). A standard file menu provides options for opening new and existing files, saving files, closing files, printing files, and exiting the program. The third standard menu, the Edit menu (Figure 1.4), implements editing operations: cut, paste, copy, and clear (delete). Note that clear is often not supported as a menu item (that is the case in Figure 1.4).

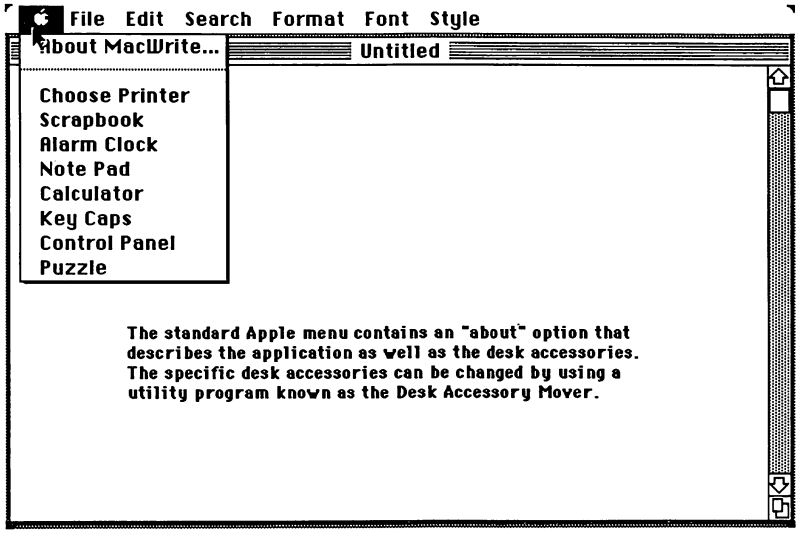


Figure 1.3 The Macintosh Standard Apple Menu

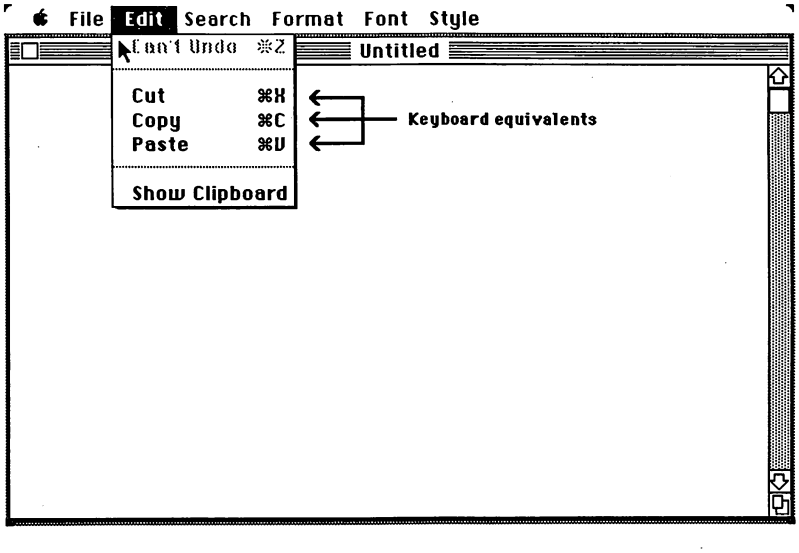


Figure 1.4 The Macintosh Standard Edit Menu

Users who are very familiar with a piece of software often prefer to issue menu selections from the keyboard. To make this possible, an application can associate a pair of keystrokes with any or all options in a menu. Known as *keyboard equivalents*, they appear to the right of the menu options as the cloverleaf symbol followed by a single key. Keyboard equivalents for the File and Edit menus are standard and should not be changed. Note that identifying which option has been selected from which menu, regardless of whether the selection is made by mouse or keyboard equivalent, is not automatic; it must be programmed into an application.

An application has complete control over which menus appear in the menu bar. The three standard menus should usually be present. Nonetheless, there are times when it makes no sense in terms of program function to allow selection from a particular menu. In that case, an application should disable that menu. Titles of windows that have been disabled appear dimmed; their titles are printed in light grey rather than black (Figure 1.5). If it makes sense to disable only specific options rather than an entire menu, the application should do so. Options that have been disabled appear dimmed, while the menu title is still printed in black (Figure 1.6).

Details on creating menus, manipulating the menu bar, and disabling and enabling menus can be found in Chapter 7. Information of identifying menu selections is part of Chapter 8.

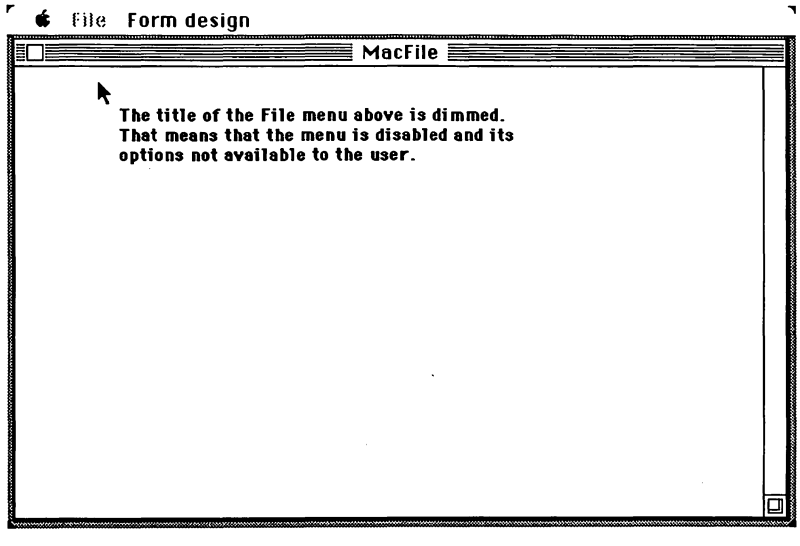


Figure 1.5 A Disabled Menu

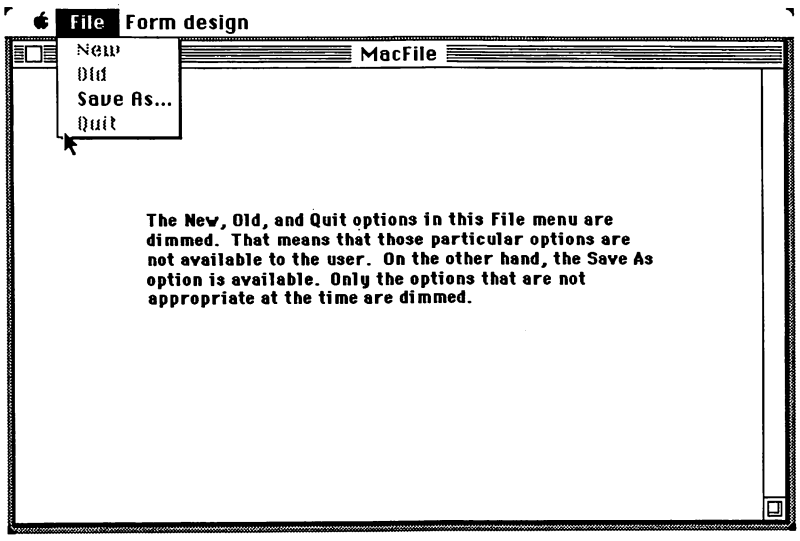


Figure 1.6 A Macintosh Menu with Disabled Items

Windows

Windows are rectangles that appear on the Macintosh screen. They are used to display text and graphics, to collect data essential to program function, and to warn the user about the consequences of specific actions.

The Macintosh supports six different types of windows. Depending on its type, a window may have one or more of the following features (see Figure 1.7):

1. A title displayed in a title bar
2. A drag region (the entire title bar except for the GoAway box)
3. A GoAway box (at the left of the title bar)
4. Controls (e.g., scroll bars, push buttons, radio button, check buttons)
5. A grow icon (located in the lower right corner of the window) - note that an *icon* is nothing more than a small picture that represents an object or a function within the computer.

A window that accepts user input, regardless of whether that input is text or graphics, has the same title as the document file which contains the material on disk. If the document has not yet been saved, the window title is "Untitled." Other windows, such as the desk accessories, have titles that reflect their function. For example, the note pad desk accessory's window has the title "Note Pad." Windows that warn users (alerts) and windows that collect data (dialogs) have no titles.

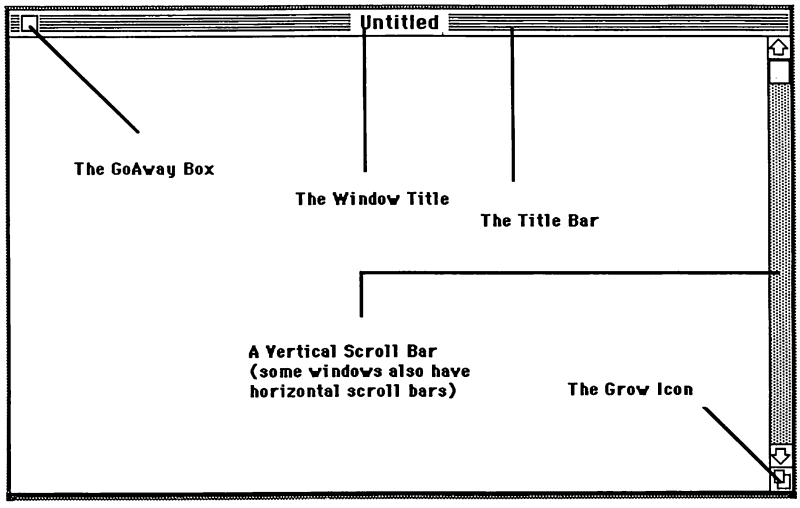


Figure 1.7 The Parts of a Macintosh Window

The drag region consists of the entire title bar except the GoAway box. It allows the user to move the window around the screen. When a user positions the cursor in the drag region and presses the mouse button, an outline of the window will follow the arrow cursor as the user drags it around the screen. The final position of the window is determined by the location of the arrow cursor when the mouse button is released.

A GoAway box is the small rectangle that appears in the left-hand corner of the title bar. If the mouse button is clicked while the arrow cursor is within the GoAway box, the application should close the window. If the window contains a document that has been modified since it was last saved to disk, the application will ask the user whether or not the document should be saved before closing.

The term "controls" refers to a group of things that can appear in a window. They include scroll bars, push buttons, radio buttons, and check boxes. (The latter three are illustrated in Figure 1.8.) Scroll bars are used to change the portion of a large document that is visible at any time within a window. Scrolling is discussed in Chapters 7 and 8. The other types of controls appear primarily in dialog and alert boxes (see Chapter 9).

A grow icon appears in the lower right-hand corner of document windows. It allows a user to change the size of a window. When the user positions the arrow cursor in the grow icon and presses the mouse button, an outline of the window will follow the cursor as it is dragged about the screen. The final size of the window is determined by the position of the cursor when the mouse button is released. Sizing windows is discussed in Chapter 8.

Windows are not restricted to changing their size and position within a single plane. They can change positions relative to any other windows present on the screen. If we assume that windows are stacked on the screen like sheets of paper

might be piled on a desk, then we can say that windows can change their location in that pile. In Macintosh terminology, windows move from front to back. Like pieces of paper, Macintosh windows can overlap. Windows to the back may be obscured by those in front of them.

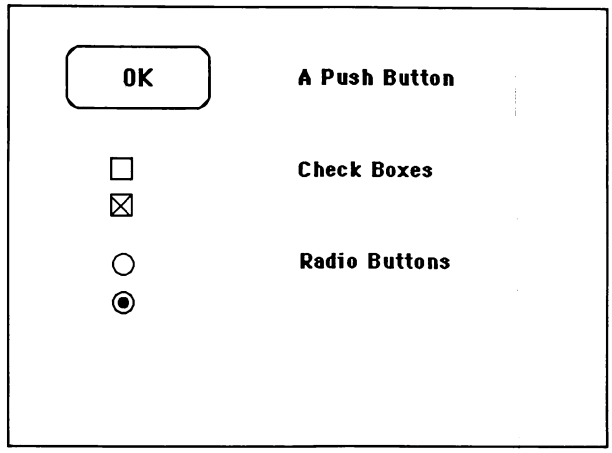


Figure 1.8 Macintosh Controls

The front-most window on the screen is the *active* window; an application can only work in an active window. Active windows are highlighted in some way, though the actual details of the highlighting depend on the type of window. For example, the highlighting in standard document windows like the one in Figure 1.7 includes horizontal lines in the title bar and a pattern in the scroll bars. When a standard document window is inactive, its title bar will contain only the title.

Text Editing

Throughout a Macintosh application, entry and modification of text is managed in a single, consistent manner. The place where new characters are added (indicated by a single, straight-line cursor) is known as the *insertion point*.

Cut, paste, copy, and **clear** – the editing operations – affect one or more contiguous characters in a block known as the *selection range*. The selection range is highlighted (see Figure 1.9) by displaying white characters on a black background.

A user selects text in two major ways:

1. By holding down the mouse button and dragging the cursor across the text. (In this case, if a selection goes beyond what is currently visible in the text

window, the text should scroll.) All text over which the cursor is dragged will be included in the selection range.

2. By clicking the mouse button while the shift button is down (known as *shift-clicking*). All text between the current position of the cursor and the place where the shift-click occurred will be selected.

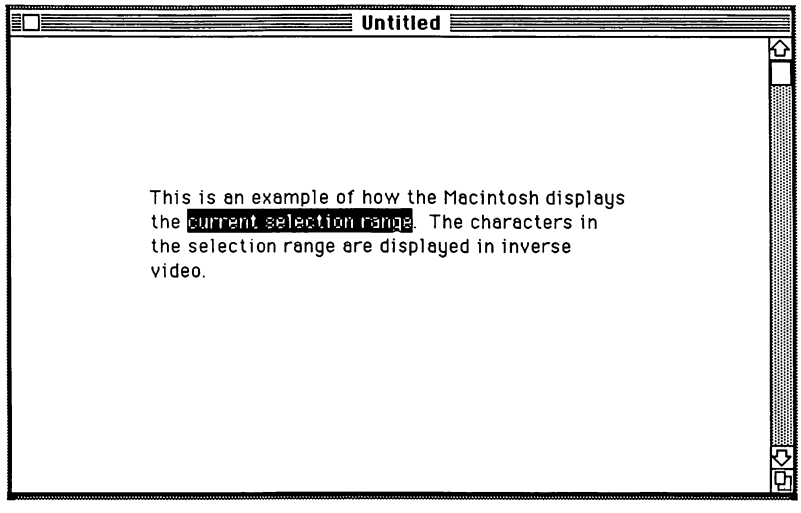


Figure 1.9 The Selection Range in a Text Document

The editing operations (**cut, paste,** and **copy**) affect what is known as the *clipboard*. The clipboard is a holding area for text and/or graphics images. It may be kept in main memory or may be saved to disk if it becomes very large. Executing a **cut** deletes the current selection range and places it on the clipboard; **copy** merely places the selection range on the clipboard without deleting it from the document. **Paste** takes whatever is on the clipboard and places it in the document just after the current selection range. Generally, the selection range for **paste** operations will simply be an insertion point. Note that the clipboard can only hold one thing at a time. While **paste** does not disturb the contents of the clipboard, each **cut** or **copy** replaces what was previously there.

Clear does not affect the clipboard. It merely deletes the current selection range. The backspace key has the same effect as **clear**.

The implementation of Macintosh text editing is discussed in detail in Chapter 9.

Alerts and Dialog Boxes

Alerts and dialog boxes are specialized windows. They are used by an application to either warn the user about the consequences of a particular action (an alert) or to collect information essential to program function (dialog boxes).

Alerts contain the text of a warning and one or more push buttons (see Figure 1.10). One button is selected as the default button; it is heavily outlined. Pressing either the Enter or Return key will have the same effect as positioning the arrow cursor over the button and clicking the mouse button. Most alert boxes have an OK button which simply closes the alert and continues with program action. Some also have a Cancel button which permits a user to escape from some action he or she may have inadvertantly requested.

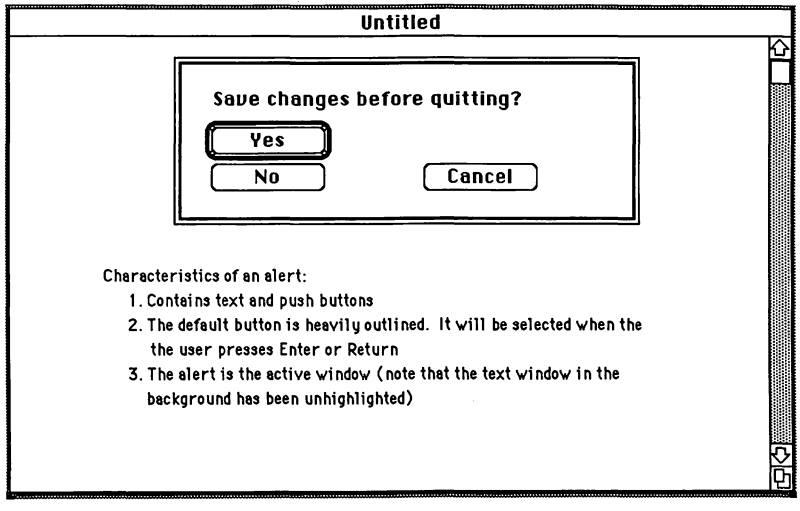


Figure 1.10 An Alert

Dialog boxes come in two varieties: *modal* and *modeless*. A modal dialog box prevents the user from working anywhere but within the box. They are used to collect information that the application must have before it can continue. For example, a modal dialog box is used to collect that name of a file before saving it to disk for the first time. Modal dialog boxes display messages, have areas for entering text, and can contain push buttons, radio buttons, and check boxes (see Figure 1.11). They are removed completely from the screen when the user has finished with them.

Modeless dialog boxes are much more like other windows. They permit the user to work outside the dialog box while the dialog box is still on the screen. Modeless dialog boxes are most commonly used to implement Find and Search operations (see Figure 1.12).

Alerts and dialog boxes are discussed in Chapter 9.

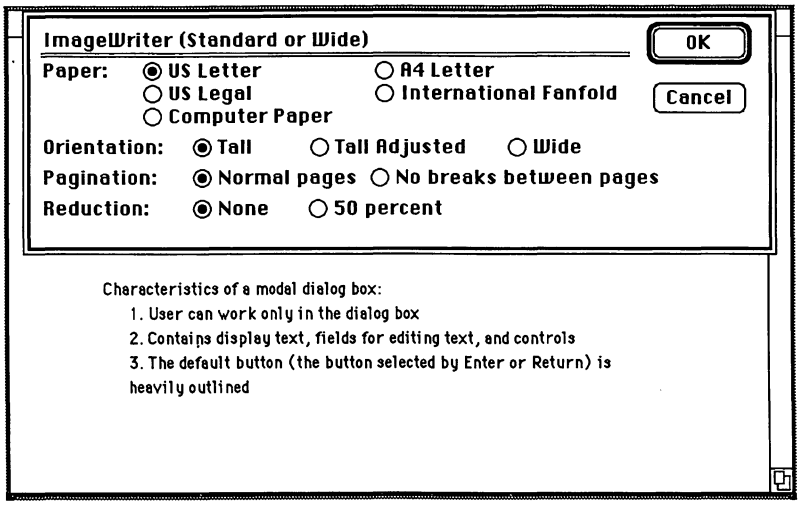


Figure 1.11 A Modal Dialog Box

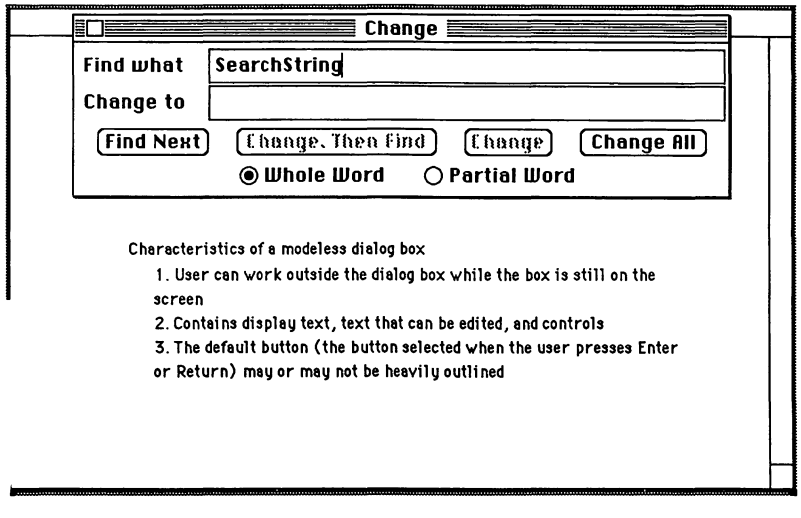


Figure 1.12 A Modeless Dialog Box

CHAPTER TWO

NUMBERING SYSTEMS: MACINTOSH'S MICROPROCESSOR AND MEMORY

Chapter Objectives

1. To learn the three major numbering systems used to represent instructions, characters, and quantities in a computer
2. To understand the organization of the Macintosh's microprocessor and, in particular, its registers
3. To understand the purpose of a stack and how it works
4. To understand how the Macintosh's main memory is distributed between the operating system and an application program
5. To get an overview of the ways in which a Macintosh assembly language program specifies the location of data in main memory (addressing modes)
6. To understand the use of symbolic addresses

Computer Numbering Systems and How Information is Represented in a Computer's Memory

When we talk about a computer's memory, we use either the hexadecimal (base 16) or octal (base 8) numbering systems. Both are used as a shorthand for

binary numbers, which get very clumsy very quickly. To understand hexadecimal and octal, we must first look at binary numbers.

Binary Numbers

Base 2 (binary) is a natural for describing the internal state of a computer. Anything we want to put in a computer must be represented by groups of integrated circuits. Each one of those circuits can carry either a high voltage (by convention, assigned a value of 1) or a low voltage (assigned a value of 0). As it so happens, 0 and 1 are the digits that make up the binary numbering system.

As you probably remember from junior-high math, binary numbers work on a place-value system, just like the base 10 numbers we use every day. Instead of representing a power of 10, though, each binary place represents a power of 2.

Figure 2.1 shows you a sample binary number and the base 10 value of each place. There is one group of 128, one group of 64, one group of 32, one group of 8, and a single 1. In base 10, this number would be 233. To convert a binary number to a base 10 number, all you have to do is add up the base 10 place values of each binary place that has a 1 in it.

1	1	1	Ø	1	Ø	Ø	1	a binary number
2^7	2^6	2^5	2^4	2^3	2^2	2^1	$2^Ø$	Base Two place values
128	64	32	16	8	4	2	1	Base Ten equivalents

To covert Base Two (binary) to Base Ten (decimal):

Add up the decimal place values of each binary place that contains a one:

128 + 64 + 32 + 8 + 1 = 233

Figure 2.1 A Binary Number

Each binary place is called a binary digit, or *bit*. A bit can stand for one of two different things and therefore takes a value of either 0 or 1.

We certainly need to be able to have more than two values in the computer (there are 53 letters, 10 digits, and a number of punctuation marks and special characters), so we group a series of bits together. Eight bits are called a *byte*. A

byte can represent the binary equivalent of 0 through 255 (you get 255 when you put a 1 in each of the eight places). Those values are used as codes for whatever we want to store in the computer. The bits in a byte are numbered from 0 through 7, starting at the right.

Though there are a number of coding schemes, most microcomputers (including the Macintosh) use *ASCII* code to represent characters and instructions. (Numbers intended for mathematical operations are usually not coded, but stored as binary quantities.) ASCII stands for American Standard Code for Information Interchange.

When you studied Pascal, one important thing you had to know was the difference between storing a digit as a CHAR or as an INTEGER or a REAL. If you stored the digit in a CHAR variable, then you couldn't do arithmetic operations with it unless you first converted it to an INTEGER or a REAL. You are now in a position to understand why.

The binary ASCII codes for the digits 0 through 9 are 0110000 (48 in base 10) to 0111001 (57 in base 10). That's what will be stored in main memory when you assign a digit to a CHAR variable. The value of these codes bears no relation to the actual quantity the digits represent, and trying to use them in arithmetic operations would certainly produce ridiculous results. On the other hand, storing one of the quantities 0 through 9 in a numeric variable stores 0000 to 1001, the exact binary equivalent of the digit.

Storing digits as a CHAR requires one byte per digit. For example, "28" would be stored as 0011010 and 0111000. Numbers, though, can hold up to 255 in a single byte. 28 would be 00011100.

You've probably noticed that the ASCII codes for the digits are only 7 bits long. Standard ASCII is a 7-bit code. The eighth bit in the byte is usually not used.

The Macintosh, though, uses an extended ASCII code which lets you use a combination of the shift and option keys to generate characters which are not usually available from the keyboard. These additional characters are created by using bit seven (the eighth bit) to provide additional code combinations. Standard ASCII codes end at 01111111, but Macintosh codes go all the way through 10001001. You can see Macintosh's character codes in Table 2.1

Most assemblers, including the MDS Assembler, will accept binary numbers as part of the source code. To indicate that a quantity is binary, preface it with a percent sign (%). For example, the Assembler will recognize %1100011 as a binary number having the decimal value 99. Without the percent sign, the number will be interpreted as base 10 with the value of one hundred ten thousand and eleven.

The binary system is used in computers for one other major purpose besides specifying ASCII codes; it is used to count the bytes in the computer's memory. The number given to each byte is called its *address*. In the 128K Macintosh, there are 131,072 bytes of RAM (one kilobyte = 1024 bytes), so the binary equivalent of the maximum address is 1111111111111111. Such a number is too long for most people to handle easily. Therefore, we use hexadecimal as a shorthand.

Table 2.1 Macintosh Extended ASCII Character Set

NON-PRINTING CHARACTERS*

What you Press	Binary Code	Hex Code	Meaning of the code
	ØØØØØØØØ	ØØ	Null
	ØØØØØØØ1	Ø1	Start of header
	ØØØØØØ1Ø	Ø2	Start of text
Enter key	ØØØØØ11	Ø3	Enter
	ØØØØ1ØØ	Ø4	End of tape
	ØØØØ1Ø1	Ø5	Enquiry
	ØØØØ11Ø	Ø6	Acknowledge
	ØØØØ111	Ø7	Bell
Backspace key	ØØØ1ØØØ	Ø8	Backspace
Tab key	ØØØ1ØØ1	Ø9	Horizontal tab
	ØØØ1Ø1Ø	ØA	Line feed
	ØØØ1Ø11	ØB	Vertical tab
	ØØØ11ØØ	ØC	Form feed
Return key	ØØØ11Ø1	ØD	Carriage return
	ØØØ111Ø	ØE	Shift out
	ØØØ1111	ØF	Shift in
	ØØ1ØØØØ	1Ø	Data link escape
	ØØ1ØØØ1	11	Open Apple
	ØØ1ØØ1Ø	12	Check mark
	ØØ1ØØ11	13	Filled diamond
	ØØ1Ø1ØØ	14	Filled circle
	ØØ1Ø1Ø1	15	Closed Apple
	ØØ1Ø11Ø	16	Synchronous idle
	ØØ1Ø111	17	End transmission block
	ØØ11ØØØ	18	Cancel
	ØØ11ØØ1	19	End of medium
	ØØ11Ø1Ø	1A	Substitute
Clear key†	ØØ11Ø11	1B	Clear
Left arrow†	ØØ111ØØ	1C	Move left
Right arrow†	ØØ111Ø1	1D	Move right
Up arrow†	ØØ1111Ø	1E	Move up
Down arrow†	ØØ11111	1F	Move down

*Non-printing characters generally cannot be generated from the keyboard (exceptions are noted in the "What you Press" column).
†These keys appear on the Macintosh keypad.

(continued)

PRINTING CHARACTERS

What you Press	What you See	Binary Code	Hex Code	What you Press	What you See	Binary Code	Hex Code
Space bar	A space	ØØ1ØØØØØ	2Ø	SHIFT-2	@	Ø1ØØØØØØ	4Ø
SHIFT-1	!	ØØ1ØØØØ1	21	SHIFT-a	A	Ø1ØØØØ1	41
SHIFT-'	"	ØØ1ØØØ1Ø	22	SHIFT-b	B	Ø1ØØØ1Ø	42
SHIFT-3	#	ØØ1ØØ11	23	SHIFT-c	C	Ø1ØØØ11	43
SHIFT-4	$	ØØ1ØØ1ØØ	24	SHIFT-d	D	Ø1ØØ1ØØ	44
SHIFT-5	%	ØØ1ØØ1Ø1	25	SHIFT-e	E	Ø1ØØ1Ø1	45
SHIFT-7	&	ØØ1ØØ11Ø	26	SHIFT-f	F	Ø1ØØ11Ø	46
'	'	ØØ1ØØ111	27	SHIFT-g	G	Ø1ØØ111	47
SHIFT-9	(	ØØ1Ø1ØØØ	28	SHIFT-h	H	Ø1Ø01ØØØ	48
SHIFT-0	)	ØØ1Ø1ØØ1	29	SHIFT-i	I	Ø1Ø01ØØ1	49
SHIFT-8	*	ØØ1Ø1Ø1Ø	2A	SHIFT-j	J	Ø1Ø01Ø1Ø	4A
SHIFT-=	+	ØØ1Ø1Ø11	2B	SHIFT-k	K	Ø1Ø01Ø11	4B
,	,	ØØ1Ø11ØØ	2C	SHIFT-l	L	Ø1Ø011ØØ	4C
-	-	ØØ1Ø11Ø1	2D	SHIFT-m	M	Ø1Ø011Ø1	4D
.	.	ØØ1Ø111Ø	2E	SHIFT-n	N	Ø1Ø0111Ø	4E
/	/	ØØ1Ø1111	2F	SHIFT-o	O	Ø1ØØ1111	4F
0	0	ØØ11ØØØØ	3Ø	SHIFT-p	P	Ø1Ø1ØØØØ	5Ø
1	1	ØØ11ØØØ1	31	SHIFT-q	Q	Ø1Ø1ØØØ1	51
2	2	ØØ11ØØ1Ø	32	SHIFT-r	R	Ø1Ø1ØØ1Ø	52
3	3	ØØ11ØØ11	33	SHIFT-s	S	Ø1Ø1ØØ11	53
4	4	ØØ11Ø1ØØ	34	SHIFT-t	T	Ø1Ø1Ø1ØØ	54
5	5	ØØ11Ø1Ø1	35	SHIFT-u	U	Ø1Ø1Ø1Ø1	55
6	6	ØØ11Ø11Ø	36	SHIFT-v	V	Ø1Ø1Ø11Ø	56
7	7	ØØ11Ø111	37	SHIFT-w	W	Ø1Ø1Ø111	57
8	8	ØØ111ØØØ	38	SHIFT-x	X	Ø1Ø11ØØØ	58
9	9	ØØ111ØØ1	39	SHIFT-y	Y	Ø1Ø11ØØ1	59
SHIFT-;	:	ØØ111Ø1Ø	3A	SHIFT-z	Z	Ø1Ø11Ø1Ø	5A
;	;	ØØ111Ø11	3B	[	[	Ø1Ø11Ø11	5B
SHIFT-,	<	ØØ1111ØØ	3C	\	\	Ø1Ø1111ØØ	5C
=	=	ØØ1111Ø1	3D	]	]	Ø1Ø1111Ø1	5D
SHIFT-.	>	ØØ1111Ø	3E	SHIFT-6	^	Ø1Ø11111Ø	5E
SHIFT-/	?	ØØ111111	3F	SHIFT--	_	Ø1Ø11111	5F

(continued)

Table 2.1 (continued)

PRINTING CHARACTERS

What you Press	What you See	Binary Code	Hex Code	What you Press	What you See	Binary Code	Hex Code
‘	‘	Ø11ØØØØØ	6Ø	OPT-u/SHFT-a	Ä†	1ØØØØØØØ	8Ø
a	a	Ø11ØØØØ1	61	SHFT-OPT-a	Å	1ØØØØØ1	81
b	b	Ø11ØØØ1Ø	62	SHFT-OPT-c	Ç	1ØØØØ1Ø	82
c	c	Ø11ØØ11	63	OPT-e/SHFT-e	É	1ØØØ11	83
d	d	Ø11ØØ1ØØ	64	OPT-n/SHFT-n	Ñ	1ØØØ1ØØ	84
e	e	Ø11ØØ1Ø1	65	OPT-u/SHFT-o	Ö	1ØØØ1Ø1	85
f	f	Ø11ØØ11Ø	66	OPT-u/u	ü	1ØØØ11Ø	86
g	g	Ø11ØØ111	67	OPT-e/a	á	1ØØØ111	87
h	h	Ø11Ø1ØØØ	68	OPT-‘/a	à	1ØØ1ØØØ	88
i	i	Ø11Ø1ØØ1	69	OPT-i/a	â	1ØØ1ØØ1	89
j	j	Ø11Ø1Ø1Ø	6A	OPT-u/a	ä	1ØØ1Ø1Ø	8A
k	k	Ø11Ø1Ø11	6B	OPT-n/a	ã	1ØØ1Ø11	8B
l	l	Ø11Ø11ØØ	6C	OPT-a	å	1ØØ11ØØ	8C
m	m	Ø11Ø11Ø1	6D	OPT-c	ç	1ØØ11Ø1	8D
n	n	Ø11Ø111Ø	6E	OPT-e/e	é	1ØØ1111Ø	8E
o	o	Ø11Ø1111	6F	OPT-‘/e	è	1ØØ1111	8F
p	p	Ø1111ØØØ	7Ø	OPT-i/e	ê	1ØØ1ØØØ	9Ø
q	q	Ø1111ØØ1	71	OPT-u/e	ë	1ØØ1ØØ1	91
r	r	Ø1111ØØ1Ø	72	OPT-e/i	í	1ØØ1ØØ1Ø	92
s	s	Ø1111ØØ11	73	OPT-‘/i	ì	1ØØ1ØØ11	93
t	t	Ø1111Ø1ØØ	74	OPT-i/i	î	1ØØ1Ø1ØØ	94
u	u	Ø1111Ø1Ø1	75	OPT-u/i	ï	1ØØ1Ø1Ø1	95
v	v	Ø1111Ø11Ø	76	OPT-n/n	ñ	1ØØ1Ø11Ø	96
w	w	Ø1111Ø111	77	OPT-e/o	ó	1ØØ1Ø111	97
x	x	Ø11111ØØØ	78	OPT-‘/o	ò	1ØØ11ØØØ	98
y	y	Ø11111ØØ1	79	OPT-i/o	ô	1ØØ11ØØ1	99
z	z	Ø11111Ø1Ø	7A	OPT-u/o	ö	1ØØ11Ø1Ø	9A
SHIFT-[	{	Ø11111Ø11	7B	OPT-n/o	õ	1ØØ11Ø11	9B
SHIFT-\	|	Ø111111ØØ	7C	OPT-e/u	ú	1ØØ111ØØ	9C
SHIFT-]	}	Ø111111Ø1	7D	OPT-‘/u	ù	1ØØ111Ø1	9D
SHIFT-‘	~	Ø1111111Ø	7E	OPT-i/u	û	1ØØ1111Ø	9E
delete*		Ø1111111	7F	OPT-u/u	ü	1ØØ11111	9F

*A non-printing character
†Accented characters which are useful for foreign languages are generated by a two-key sequence. You must first press the OPTION key and the modifier (‘,i,u,n, or e) together; nothing will appear on the screen. Then press the key above which you wish the accent to appear.

(continued)

PRINTING CHARACTERS

What you Press	What you See	Binary Code	Hex Code	What you Press	What you See	Binary Code	Hex Code
OPT-t	†	1Ø1ØØØØØ	AØ	SHFT-OPT-/	¿	11ØØØØØØ	CØ
SHFT-OPT-8	°	1Ø1ØØØØ1	A1	OPT-1	¡	11ØØØØØ1	C1
OPT-4	¢	1Ø1ØØØ1Ø	A2	OPT-l	¬	11ØØØØ1Ø	C2
OPT-3	£	1Ø1ØØØ11	A3	OPT-v	√	11ØØØØ11	C3
OPT-6	§	1Ø1ØØ1ØØ	A4	OPT-f	ƒ	11ØØØ1ØØ	C4
OPT-8	•	1Ø1ØØ1Ø1	A5	OPT-x	≈	11ØØØ1Ø1	C5
OPT-7	¶	1Ø1ØØ11Ø	A6	OPT-j	Δ	11ØØØ11Ø	C6
OPT-s	ß	1Ø1ØØ111	A7	SHFT-OPT-\	»	11ØØØ111	C7
OPT-r	®	1Ø1Ø1ØØØ	A8	OPT-\	«	11ØØ1ØØØ	C8
OPT-g	©	1Ø1Ø1ØØ1	A9	OPT-;	…	11ØØ1ØØ1	C9
OPT-2	™	1Ø1Ø1Ø1Ø	AA	(unused)		11ØØ1Ø1Ø	CA
OPT-e	´	1Ø1Ø1Ø11	AB	OPT-'/SHFT-a	À	11ØØ1Ø11	CB
OPT-u	¨	1Ø1Ø11ØØ	AC	OPT-n/SHFT-a	Ã	11ØØ11ØØ	CC
OPT-=	≠	1Ø1Ø11Ø1	AD	OPT-n/SHFT-o	Õ	11ØØ11Ø1	CD
SHFT-OPT-'	Æ	1Ø1Ø111Ø	AE	SHFT-OPT-q	Œ	11ØØ111Ø	CE
SHFT-OPT-o	Ø	1Ø1Ø1111	AF	OPT-q	œ	11ØØ1111	CF
OPT-5	∞	1Ø11ØØØØ	BØ	OPT--	–	11Ø1ØØØØ	DØ
SHFT-OPT-=	±	1Ø11ØØØ1	B1	SHFT-OPT--	—	11Ø1ØØØ1	D1
OPT-,	≤	1Ø11ØØ1Ø	B2	OPT-[	"	11Ø1ØØ1Ø	D2
OPT-.	≥	1Ø11ØØ11	B3	SHFT-OPT-[	"	11Ø1ØØ11	D3
OPT-y	¥	1Ø11Ø1ØØ	B4	OPT-]	'	11Ø1Ø1ØØ	D4
OPT-{	"	1Ø11Ø1Ø1	B5	SHFT-OPT-]	'	11Ø1Ø1Ø1	D5
OPT-d	∂	1Ø11Ø11Ø	B6	OPT-/	+	11Ø1Ø11Ø	D6
OPT-w	Σ	1Ø11Ø111	B7	SHFT-OPT-v	◊	11Ø1Ø111	D7
SHFT-OPT-p	Π	1Ø111ØØØ	B8	OPT-u/y	ÿ	11Ø11ØØØ	D8
OPT-p	π	1Ø111ØØ1	B9	SHFT-OPT-'	Ÿ*	11Ø11ØØ1	D9
OPT-b	∫	1Ø111Ø1Ø	BA				
OPT-9	ª	1Ø111Ø11	BB				
OPT-0	º	1Ø1111ØØ	BC				
OPT-z	Ω	1Ø1111Ø1	BD				
OPT-'	æ	1Ø11111Ø	BE				
OPT-o	ø	1Ø111111	BF				

*The picture that appears on the screen varies with the type font in use.

Hexadecimal Numbers

Base 16 (hexadecimal or simply "hex") presents a unique challenge to we human beings. This numbering system should be able to express the quantities 0 through 15 in a single place, but we only have ten digits available (0 through 9). Therefore, we use the letters A–F to represent 10 through 15 respectively. Figure 2.2 shows some hexadecimal place values. The sample number has a decimal (base 10) value of 77,631.

1	2	F	3	F	a hexadecimal number
16^4	16^3	16^2	16^1	16^0	Base Sixteen place values
65,536	4Ø96	256	16	1	Base Ten equivalents

To covert Base Sixteen (Hexadecimal) to Base Ten (decimal):

Multiply each hexadecimal digit by its decimal equivalent and add:

(65,536 * 1) + (4Ø96 * 2) + (256 * 15) + (16 * 3) + 15 = 77,631

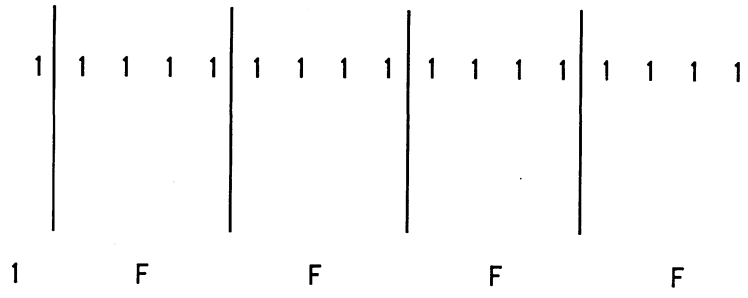
Figure 2.2 A Hexadecimal Number

How hex can give us a shorthand for large binary numbers is probably not instantly obvious, but consider this: the maximum quantity that a four-digit binary number can represent is 15 (in binary, 1111), which, "by coincidence," is the maximum value of a single hex digit.

Converting a binary to hex number becomes very simple. First, divide the binary number into groups of 4 digits, working from the right. Then substitute the hexadecimal equivalent for each group of 4 binary digits. That's all there is to it.

As we saw above, the maximum RAM address in the 128K Macintosh is 1111111111111111 in binary. Figure 2.3 shows its conversion to hexadecimal. Now the maximum address appears as $1FFFF. The $ in front of the number alerts us (and the Assembler) that what follows is hexadecimal. The hex figure is certainly more manageable than that string of seventeen 1's. Though the MDS assembler will accept quantities and codes in binary, octal (Base 8), decimal, and hex, we generally specify addresses and character codes in hexadecimal and quantities in base 10.

Hexadecimal is also used as a shorthand for binary when representing ASCII codes. The digits have codes of $30 through $39; 0 has a code of $30, 1 of $31, 2 of $32, and so on. The hexadecimal values of the codes seem much more logical than the base 10 codes of 48–57.



To do the conversion:

1. Divide the binary number into groups of four, starting from the right.
2. Substitute the corresponding hexadecimal digit for each group of four binary digits.

Figure 2.3 Converting Binary to Hexadecimal

By this point it has probably occurred to you that if the maximum RAM address is $1FFFF, there is no way to specify such an address in one byte (the maximum hex value for one byte is $FF); it will take three bytes. We also would like to be able to do arithmetic on numbers more than one byte in length (e.g., with values greater than 255, occupying more than eight binary places). The microprocessor used in the Macintosh conveniently allows us to work with *words* and *longwords*.

A word refers to two bytes (16 bits) and always begins on a byte with an even address. For example, a word could occupy the bytes at $33AA and $33AB but not the bytes at $33AB and $33AC. We number the bits in a word 0–15, starting from the right. Bits 0–7 are referred to as the "low-order" byte; 8–15 are called the "high-order" byte.

A longword is 4 bytes (32 bits). Like a word, it must begin on a byte with an even address. The bits are numbered 0–31, starting at the right. Bits 0–15 are the low-order bits and 16–31 the high-order bits.

Octal Numbers

The octal numbering system (also known as base 8) has been around computers as long as hex, but it isn't used a great deal any more. Like hex, octal became popular as a shorthand for binary. It was useful when the largest bit grouping was a byte and when data codes were only 6 bits. Why resurrect octal here, then? Because the MDS assembler will accept octal numbers as well as binary, decimal, and hexadecimal numbers.

Since octal is base 8, it uses the digits 0 through 7. Each octal place therefore represents a power of 8 (just like binary places are powers of 2 and hex places are powers of 16). A sample octal number can be found in Figure 2.4. Its decimal value is 36,545.

1	Ø	7	3	Ø	1	an octal number
8^5	8^4	8^3	8^2	8^1	$8^Ø$	Base Eight equivalents
32,768	4096	512	64	8	1	Base Ten equivalents

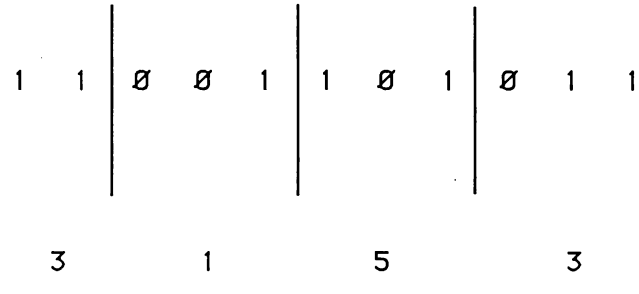
To convert Base Eight (octal) to Base Ten (decimal):

Multiply each octal digit by its decimal equivalent
and add:

(32,768 * 8) + (4096 * Ø) + (512 * 7) + (64 * 3) + (8 * Ø) + 1 = 36,545

Figure 2.4 An Octal Number

Converting binary to octal is very much like converting binary to hex. While it takes four binary places to represent the full range of hex digits (0–F), it takes only three binary places to get the octal digits (111 base 2 = 7 base 8). Therefore, to do the conversion, divide a binary number into groups of three (starting from the right, just as when converting to hex), then substitute the appropriate octal digit for each group of three binary digits. An example of a binary to octal conversion appears in Figure 2.5.



To do the conversion:
1. Divide the binary number into groups of three, starting from the right.
2. Substitute the corresponding octal digit for each group of four binary digits.

Figure 2.5 Converting Binary to Octal

Macintosh's Microprocessor

A microprocessor is not a microcomputer. The term *microcomputer* refers to the whole machine, while the *microprocessor* is only a part of a microcomputer. In fact, a microcomputer needs not only a microprocessor, but also some RAM, enough code in ROM to boot the machine, pathways—known as *buses*—to carry data and addresses from one place to the other, some provision for I/O, and a clock.

The microprocessor, though, is truly the brain of the computer. The Macintosh's microprocessor is Motorola's MC68000 (or just "68000"). You may read in some publicity releases that it is a "32-bit microprocessor." That assertion is not completely true. While the 68000 has 32-bit registers (we'll get to registers shortly), its buses are smaller.

The 68000's data bus is only 16 bits wide (this is the path along which data travel between RAM, ROM, and the microprocessor). The address bus (the path along which addresses travel from the microprocessor to RAM and ROM) is 24 bits wide.

The 24-bit address bus sets the limit on the maximum amount of memory Macintosh can address directly. These 24 bits (3 bytes) allow us to have a maximum address of $FFFFFF — 16 megabytes. Not all of this can be used for RAM, though. In order to access anything stored in ROM, the ROM must have its own address range, distinct from RAM. Macintosh has 64K of ROM which resides at $400000-$40FFFF.

Registers

Registers are special storage locations within a microprocessor. Almost all the actions a program performs on data occur while the data or their addresses are in the registers. The Macintosh's 68000 microprocessor has four different kinds of registers: eight *data registers*, eight *address registers*, one *status register*, and one *program counter* (see Figure 2.6).

The data registers (numbered D0-D7) are used primarily for data manipulation. Because they are 32 bits wide, they can accommodate byte, word, and longword operations. The address registers (numbered A0-A7) are also 32 bits wide. In addition to allowing the data manipulation (though only on words and longwords), they can be used for addressing RAM (much more on this to come). Register A7 also has a special use with regard to the stack (see next section).

The status register is an extremely useful tool. While it is only 16 bits wide, it carries more than two bytes worth of information; the bits act individually as flags.

We say a bit is *set* if it has a value of 1; when we *clear* a bit, we make sure its value is 0. The bits in the status register are set at the end of many microcomputer operations. A program can check the condition of the bits in the status register to discover the result of executing an instruction.

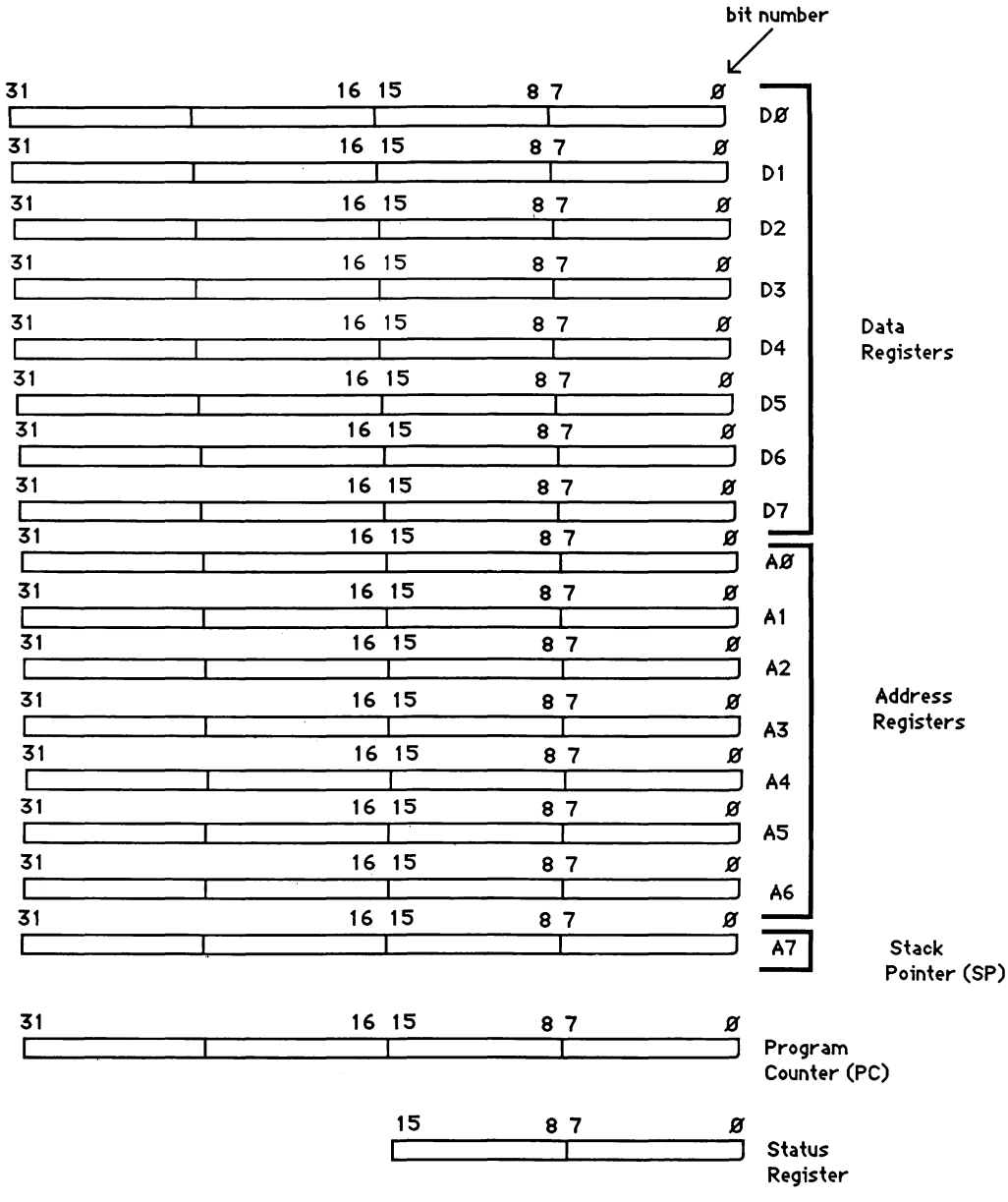


Figure 2.6 Macintosh 68000 Registers

Figure 2.7 shows the 68000's status register. The eighth high-order bits are used by the computer itself and are therefore called the *system byte*. It contains a supervisor bit, a trace bit, and three bits which form an interrupt mask. Macintosh assembly language programmers will rarely use the system byte.

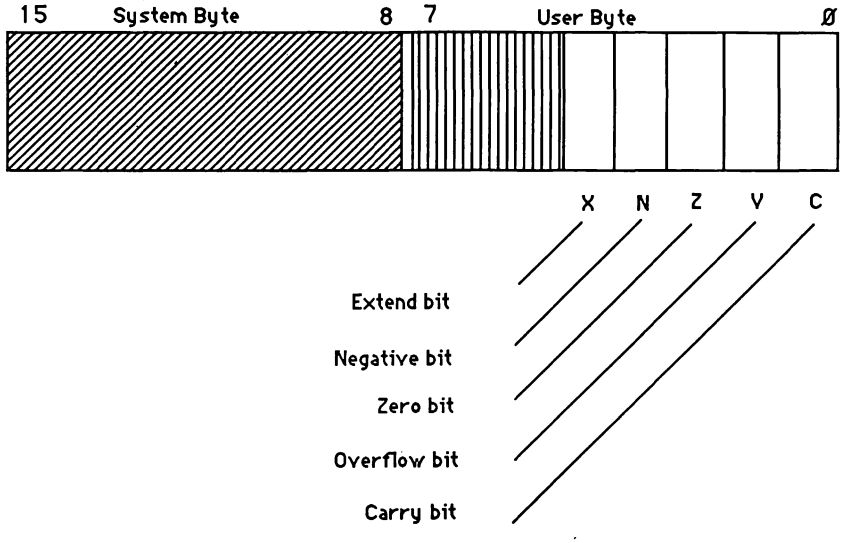


Figure 2.7 Macintosh 68000 Status Register

The supervisor-state bit is unnecessary because the Macintosh uses its Microprocessor in a slightly unusual way. The standard 68000 microprocessor has two "modes": a user mode and a supervisor mode. A program running in the user mode is prohibited from using some of the microprocessor's instructions. The Macintosh, however, runs only in the supervisor mode. Therefore, the bit in the system byte which would ordinarily be used to switch between the user and supervisor modes is irrelevant.

The Macintosh does not recognize the 68000's trace mode. In fact, if the trace bit is set, the Macintosh will consider it a system error. (See Chapter 3 for more details on system errors.)

The interrupt mask bits are used to control which peripheral device (e.g., disk drives) can signal the CPU that they are in need of attention. The signal sent from the device is known as an *interrupt*, since it forces the CPU to interrupt whatever it is doing and take care of the device. Macintosh programs do not need to control interrupts through the system byte of the status register; they have a more powerful way to monitor what happens to the system. These are what the Macintosh calls *events* (discussed in detail in Chapter 8). Though some events are caused by hardware interrupts (e.g., inserting a disk into a disk drive, clicking the mouse

button, striking a key on the keyboard), others are generated by the operating system. The event mechanism is therefore more powerful and flexible than relying on an interrupt mask in the status register.

While a Macintosh application will probably never look at the system byte of the status register, it is virtually impossible to write an assembly language program without, at some time, consulting the *user byte* of the status register; the user byte is comprised of the eight low-order bits of the status register.

In the user byte, bit 0 is the carry bit. It is affected by integer addition and subtraction instructions as well as some other, less frequently used instructions. If the execution of an arithmetic instruction causes a carry out of the left-most bit (known as the *most significant bit*), the carry flag will be set. If there is no carry out, then the flag will be cleared.

To understand how the carry flag works, let's consider some simple binary addition. The binary addition table is very simple:

```
    0 + 0 = 0
    0 + 1 = 1
    1 + 1 = 0 with a carry out of 1
1 + 1 + 1 = 1 with a carry out of 1
```

Computers add only two numbers together at a time, working from the right-most (*least significant*) bit to the left, just as we do when performing decimal addition. A carry out from one bit position will cause a carry in to the bit position directly to its left. Therefore, the fourth expression above is the result of adding two 1's with a carry in from the previous bit.

Assume that a computer is executing the following addition:

```
  101010   Value 1
+ 010010   Value 2
--------
  111100   Result
```

When the addition is peformed on bit 1 (the second bit from the right) a carry is generated into bit 2, but this operation will nevertheless clear the carry bit. The most significant bit, bit 5 (since this is only a six-bit number), doesn't generate a carry. The carry bit will be set only if the carry is out of the most significant bit.

Consider, however, a slight modification to the problem:

```
  101010   Value 1
+ 110010   Value 2
--------
 1011100   Result
```

The only change was in the most significant bit of Value 2 (it is a 1 rather than a 0 in this case). Now there is a carry out of the most significant bit. The carry flag will be set.

Another way to think of the carry bit is to visualize it as holding the value of a carry. In the first addition example above, there was actually a carry out of 0.

Therefore the carry bit is cleared. The second example caused a carry out of 1, setting the bit.

The second bit in the status register (bit 1) is the overflow flag. It is set whenever the result of an integer addition, subtraction, or division is too large to fit in the location where the result of the operation was to be stored. Other, less frequently used instructions also affect the overflow bit. While this at first may seem to be the same as the carry bit, it is not. The major difference is that the carry flag holds the value of a carry, while the overflow flag is a true flag, signaling the fact that an overflow occurred.

In many microprocessors, by the way, the distinction between the operation of the carry and overflow flags is different from that of the 68000. The carry bit is affected by operations on unsigned numbers, while the overflow flag monitors operations on signed numbers. That is not true with the 68000. The 68000's addition and subtraction instructions work only on signed numbers and affect both overflow and carry flags. While there are separate instructions for signed and unsigned multiplication and division, the multiplication instructions always *clear* the overflow and carry flags, regardless of the result of the operation. The division instructions, both signed and unsigned, clear the carry flag and affect the overflow flag based on the result of the operation.

Bit 2 is called the negative flag. It is set (i.e., gets a value of 1) whenever an operation produces a negative result. Note that other operations besides arithmetic ones can produce negative results. This most importantly includes comparison operations where you are trying to decide whether one quantity or character is larger than another.

The zero bit (bit 3) works very much like the negative bit. It is set whenever an operation gives a result of zero. Though it may seem a bit confusing at first, you need to remember that when bit 3 is 1, the result was 0; when bit 3 is 0, the result was non-zero. (You need to check bit 2, the negative bit, to know whether the result was negative or positive.)

Bit 4 is known as the extend bit. The extend bit functions, in most cases, just like the carry bit. It is used primarily for multiple-precision arithmetic operations (computations that span more than one longword).

Different instructions affect the status register differently. Therefore, as you learn the 68000 instruction set, you must not only be aware of what the instruction does, but also how it changes the user byte of the status register.

The Stack

As well as the registers just described, the 68000 microprocessor uses a special sort of storage area in RAM known as a *stack*. (Actually, the 68000 has two stacks, but the Macintosh uses only one.)

You can think of the stack as a tall silo that is 32 bits wide. Many pieces of data and address can be stored in the stack, one on top of the other (see Figure 2.8). Access to the stack is in last in, first out order.

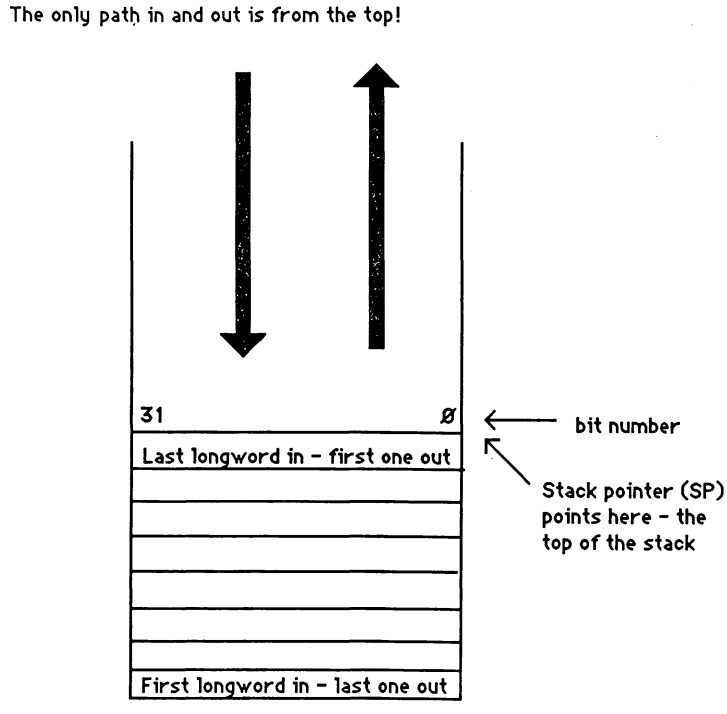


Figure 2.8 The Stack

Register A7 is used as the stack pointer. It contains the address of the last item stored on the stack (called the "top" of the stack) so that you don't need to keep track of where the stack is physically or how many items are stored there. When writing programs, the stack pointer can be referred to as A7 or SP.

What is the stack used for? Often, the stack is used as an extra register for quick, temporary storage. (You *push* something onto the stack and *pull* it off, which sometimes leads to the image of the stack as a spring-loaded tube.) The stack is also the place where the microprocessor stores subroutine return addresses.

Have you ever wondered how a Pascal program knows where to return to when a procedure ends? Every time the program encounters a statement that calls a procedure, it pushes the address of the statement just after the call onto the top of the stack. Everytime it finds the **END** that finishes a procedure, it pulls the top address of the stack and resumes execution at that address. The last in, first out access to the stack ensures that nested procedures will return properly.

Assembly language subroutines affect the stack in exactly the same way. Whenever you issue a **JSR** (jump to subroutine) instruction, the address of the next program instruction is pushed onto the stack. The **RTS** (return from subroutine) instruction causes the address to be pulled from the stack and lets the system know where to resume the main program.

The Program Counter

The final register that an application uses is the program counter. The program counter contains the main memory address of the beginning of the statement following the one currently being executed. In other words, it is a 32-bit register that contains the address of the next program instruction. In fact, it is the contents of the program counter, often abbreviated to "PC," that gets pushed onto the stack when you jump to a subroutine.

How Macintosh's RAM is Used

It may sound like a lot—128K RAM—but only a portion of that space is actually available to a program. Figure 2.9a shows how the Macintosh's RAM is divided between the user and the system in a 128K machine.

The bottom of RAM ($00-$FF) is used by the 68000 microprocessor for hardware exception vectors. These are rarely of concern to assembly language programmers. The next $300 bytes ($100-$3FF) are used by the operating system to store global variables that are shared by various parts of the system. (This is called the "system communication area.") There are more system globals in $800-$AFF.

The $400 bytes spanning $400-$7FF contain the System Dispatch Table. This table is the entry way to the ROM ToolBox routines. As a programmer, you don't need to know the exact address in ROM of any ToolBox routine you want to use. Instead, the assembler translates your call into a reference to the Dispatch Table (a "trap"), where the actual ROM addresses are stored. The table itself is stored in ROM and loaded into RAM when you start up the system.

At first this may seem like an extra, unnecessary step. Why look up the address in a table when a program could go to it directly just as easily? Because this arrangement gives added flexibility. If at some time in the future you upgrade your Macintosh and change the ROM, you won't have to modify any programs that use ToolBox routines. Using the Dispatch Table will also let you substitute a program of your own for any ToolBox routine. All you have to do is replace the address in the Dispatch Table with the starting address of your program (this is known as applying a *patch*). Since ROM can't be patched, it is essential that the Dispatch Table be in RAM in order to have the ability to change it.

The top of RAM (i.e., the high addresses $1FD00-$1FFE3) is used as a buffer for the Sound Driver. The Sound Driver is the part of the operating system that controls the sounds that come from the Macintosh's speaker. Just below the sound buffer ($1A700-$1FC7F) lies the main screen buffer. This areas is used to map out what will be displayed on the screen.

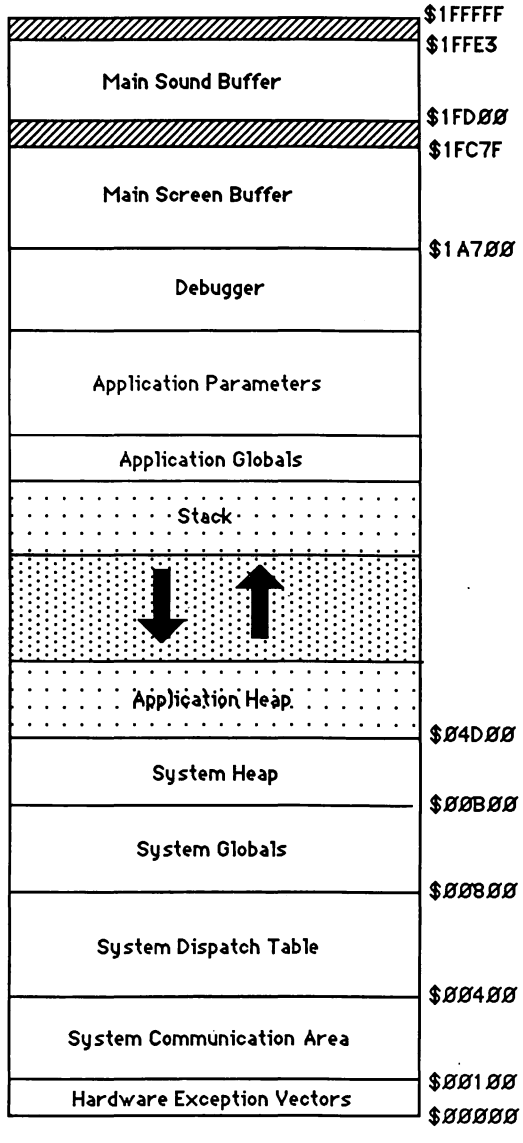


Figure 2.9(a) 128K Macintosh RAM

When you use a debugger to help develop assembly language programs, it installs just below the screen buffer. (See Chapter 3 for a definition of a debugger and how to use one.) The region just below the debugger is set aside to hold data (called *application globals*) for an application program. The size of the area is not fixed; it is initialized when the program is loaded to allow only as much space as the program actually requires.

The remaining space, from $B00 to the beginning of the application globals, is under programmer control. At system startup, the area $B00 to $4CFF is initialized as the *system heap*. This area is used by the operating system when a program is running.

Under most circumstances, programs running on a 128K machine begin at $4D00, the start of the *applications heap*, and grow up in memory; the stack begins at the top of the application heap (below the application globals) and grows down in memory. If the program and the stack meet, then application has run out of memory. Program execution will stop, for example, if the program attempts to add anything else to the stack.

One of the most important things to understand from the preceding discussion is that there is nowhere near 128K for an application program. There are $15A00 bytes between the bottom of the application heap and the bottom of the screen buffer (about 71K), but part of this is lost to application globals and the stack. The space for source code is therefore rather limited, especially if a program needs tables of text stored in RAM.

Memory use in a 512K Macintosh is very similar to that in the 128K machine. If you look at Figure 9.2b, you'll see that the extra memory is concentrated in the application areas and the system heap. Instead of a 16.5K system heap like the 128K machine, the 512K Mac has a 46K system heap. Programs therefore generally begin at $C000 rather than at $4D00 as they do on a 128K machine. The remainder of the extra RAM is allocated to the application heap, the stack, and the various parameters and global values.

Addressing RAM

When programming in Pascal, you don't have to worry about where data are stored in RAM. You use variable names as labels on storage locations; the loading/linking process assigns the actual addresses to the variable names, allowing a program to retrieve the data stored previously by simply specifying the particular variable wanted.

Assembly language, being closer to machine language, requires that the programmer keep track of where everything is stored in RAM. That includes not only the program itself but any data the program may need to use. Therefore, assembly languages provide a variety of ways of specifying where a data item is stored. The 68000 has thirteen different ways that fall into five general groups; these methods are known as *addressing modes*.

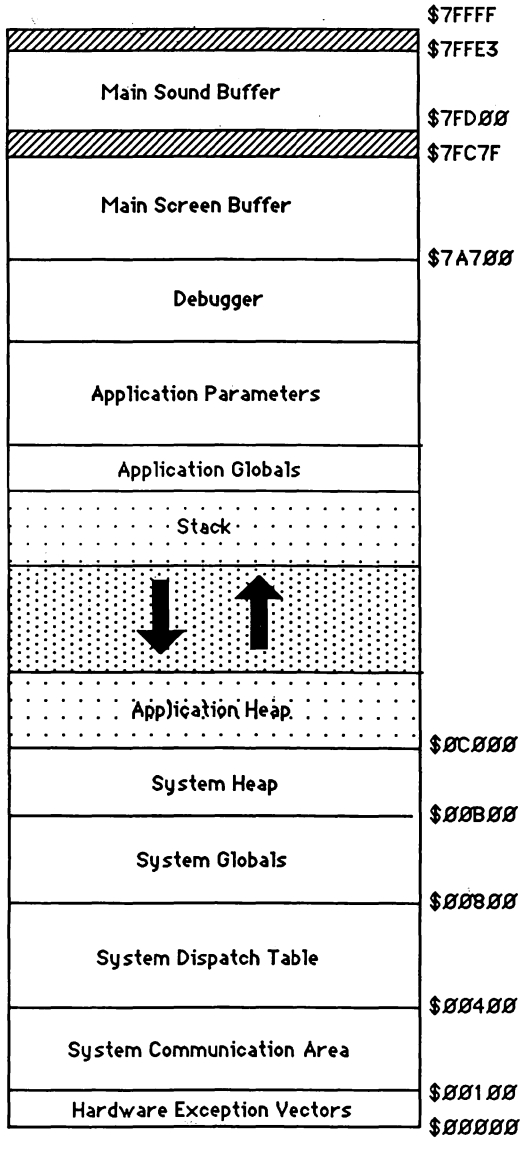
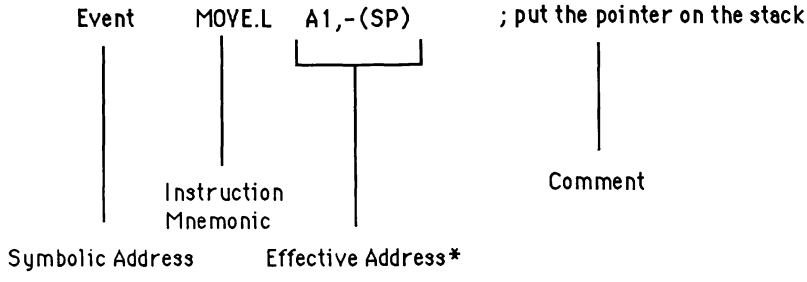


Figure 2.9(b) 512K Macintosh RAM

The purpose of the rest of this chapter is to introduce you to the 68000's addressing modes. Though, at this point, it may seem like overkill to have so many ways to indicate a main memory location, you will discover as you learn the instruction set and how to use the ToolBox and operating system routines that the flexibility that comes with these thirteen modes is essential to a well-written program.

To understand addressing, you must first know a little about the format of an assembly language statement. The format of assembly language statements is far more rigid than the format of high-level language statements. Statements are broken up into four fields. The first field, which may be left blank, is used for statement labels, known often as *symbolic addresses*. The second field contains the instruction mnemonic. The third field specifies either the data to be operated on or the address of where the data can be found. It often also indicates where the results of the operation should be placed. The data item itself is called the *operand*. The place where the operand can be found is its *effective address*. The fourth field is, like the label field, optional; it can be used for comments. Comment fields begin with a semicolon. Figure 2.10 shows a 68000 assembly language statement and its fields.



*This effective address field has two operands. The first, A1, is the effective address of the source operand. The second, -(SP), is the effective address of the destination operand.

Figure 2.10 Format of a 68000 Assembly Language Instruction

The instruction in Figure 2.10 takes the contents of register A1 and moves it onto the stack. The instruction therefore has two operands, one specifying the source of the data, and the other the destination. The two operands are separated by a comma. The comment ("put the pointer on the stack") is preceded by a semicolon.

To make addressing easier to understand, let's create a very simple computer—the "Extremely-Micro Computer"—to use in some of the examples. This computer has only two registers: a data register called **D** and an address register called **A**. It also has ten RAM locations, numbered in base 10 from 0 to 9.

Register Direct Modes

In register direct modes, the operand itself is loaded into either a data register or an address register.

Mode #1: Data Register Direct

Figure 2.11 shows the state of the Extremely-Micro Computer just before an operation using Data Register Direct addressing. The value 224, which is stored in RAM location 7, has been copied into the data register **D**. The effective address of that value is specified by simply coding:

```
D
```

Whatever operation is indicated by the assembly language instruction will act on the value that has been stored in register **D**.

To do Data Register Direct addressing using the 68000 microprocessor, replace **D** in the Extremely-Micro Computer statement with **Dn**, where **n** is the number of the data register.

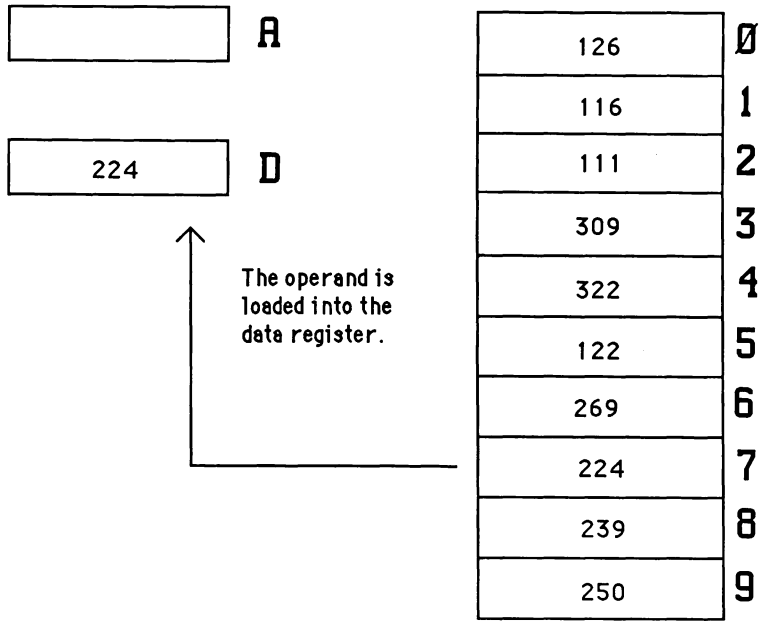


Figure 2.11 Using Data Register Direct Addressing

Mode #2: Address Register Direct

Address Register Direct addressing works exactly like Data Register Direct addressing. The only difference is that the operand is contained in one of the address registers rather than in a data register. The assembly language format for an address register direct effective address is:

An

where **n** is the number of the address register.

Never use register A7 for direct addressing or for any sort of addressing that requires changing the value in a register, since it is used as the stack pointer. Register A5 always contains the address of the top of the applications globals area. It too should never be used for any sort of addressing that requires a change in the quantity stored in the register.

Register Indirect Addressing

The basic principle behind register indirect addressing is that instead of putting the operand itself into a register, a program loads the register with the address where the operand can be found. Register Indirect addressing can be done only with the address registers.

Mode #3: Address Register Indirect

To perform Address Register Indirect addressing, store the *location* of the operand in an address register. For example, Figure 2.12 shows the Extremely-Micro Computer just before execution of a statement using Address Register Indirect addressing.

The operand is still the quantity 224, but the contents of the address register A is 7. The 7 is a *pointer* to the RAM location where 224 is stored. The effective address would appear as:

(A)

The parentheses are required. They can be read as "the contents of." Therefore, (A) translates to "the effective address is the contents of register A."

For the 68000, add the number of the address register to the Extremely-Micro format:

(An)

Be sure to replace the **n** with the number of the specific address register being used.

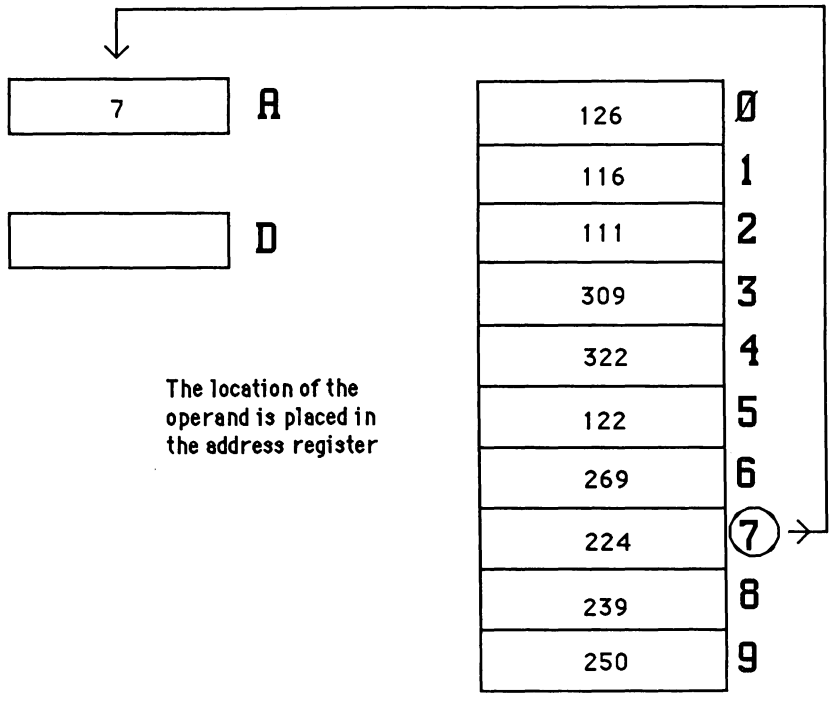


Figure 2.12 Using Address Register Indirect Addressing

Mode #4: Address Register Indirect with Postincrement

When a program needs to process a series of data items, such as when data are stored in an array, Pascal makes life easy by allowing the program to step through the array by using a variable as a subscript. Since you can't use variable names in assembly language, you might have to process the series of data values as follows:

1. Store the address of the first data value in an address register.
2. Process the value.
3. Increment the address so that it now reflects the location of the next data value.
4. Repeat steps 3 and 4 until all data values have been processed.

Address Register Indirect with Postincrement addressing, more simply called "Postincrement" addressing, is one way to do steps 2 and 3 with only one assembly

language statement. The format for the Extremely-Micro Computer will be:

(A)+

Prior to executing this statement, load the location of the first data value into register A. Suppose, for example, we want to process the values in RAM locations 0–4. Figure 2.13 shows the state of the Extremely-Micro Computer just before beginning that processing; 0 has been stored in register A, since it is the lowest address in the series we want to process.

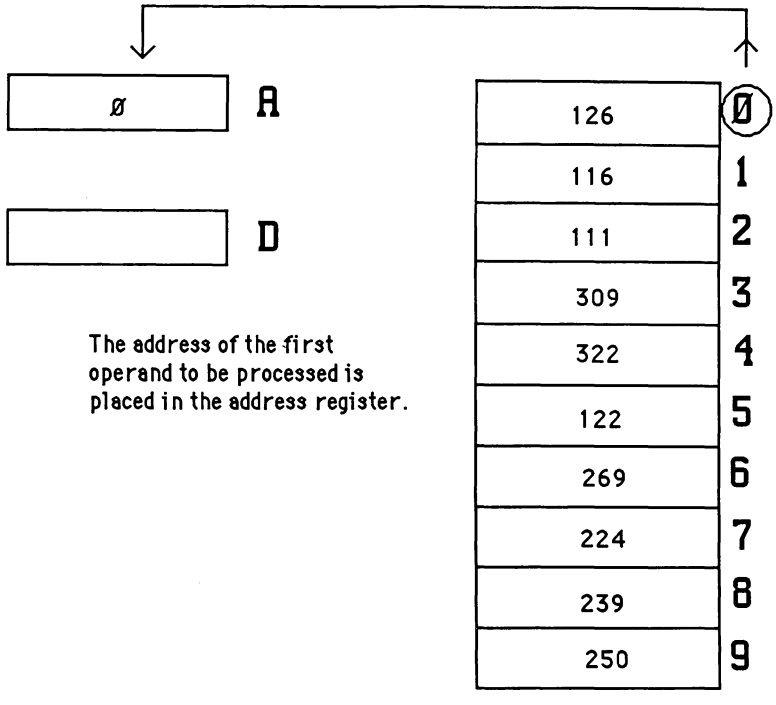


Figure 2.13 Using Address Register Indirect with Postincrement Addressing

When the computer executes the statement that processes the data, not only will the operation specified by the instruction be performed, but the address in register A will be increased by one, so that register A will then contain the address of the next value. First the operation is performed, then the address is incremented (thus the word "postincrement" in the name of this addressing mode).

While we've been using the Extremely-Micro Computer, we haven't worried about the size of the operands. The precise operation of Postincrement addressing, though, does depend on operand size. When the instruction specifies an

operation on one byte, the increment will be only one byte. For word operations, the increment will be two bytes; for longword operations, the increment will be four bytes.

InstructionMnemonic.B (An)+

describes an operation on a byte. (As always, the **n** should be replaced by the number of the address register being used.) Note that this is not a complete assembly language statement; many statements include not only the effective address of an input (source) operand, but the destination location for the results of the operation.

InstructionMnemonic.W (An)+ = operation on a word
InstructionMnemonic.L (An)+ = operation on a longword

We will discuss when to use which extension (**.B, .W,** or **.L**) as we discuss the individual 68000 instructions.

Mode #5: Address Register Indirect with Predecrement

Address Register Indirect with Predecrement addressing ("Predecrement" for short) is very similar to Postincrement addressing. When you use Predecrement addressing, the address found in the address register is decremented (decreased) *prior* to performing the operation specified by the assembly language instruction. The size of the decrement (byte, word, or longword) depends on the extension you put on the instruction mnemonic, just like it does with Postincrement addressing.

Predecrement addressing is specified by:

–(An) where **n** = address register number.

Mode #6: Address Register Indirect with Displacement

The two types of Displacement addressing available on the 68000 are additional ways to easily address data in a series of memory locations. Suppose (for whatever reason) your data are placed in every other location, as they are in the Extremely-Micro Computer example in Figure 2.14. Predecrement and Postincrement addressing will only let a program move one location at a time, but in this case you want to move two. What can you do?

Address Register Indirect with Displacement addressing allows you to specify a quantity (the displacement) which will be added to the contents of the address register. In a general form, we would use:

d(A) where d = the displacement.

In Figure 2.14, we want to move two memory locations. Therefore, the displacement is 2 and the general form becomes:

2(A)

When the computer executes a statement using the effective address specification, the displacement (2) will be added to the contents of register A (0) to give us the effective address (2). This statement will process the operand in location 2.

When Address Register Indirect with Displacement addressing is used with the 68000, there are two restrictions on the value of the displacement. First, it must be an integer, though it can be either positive or negative. Secondly, it must occupy no more than 16 binary digits, which translates to a value of $7FFF. (That means that bit 15 is not used as a part of the quantity; it is reserved to indicate the sign of the displacement.) The 68000 format is:

d(An) where d = 16-bit displacement
n = address register number

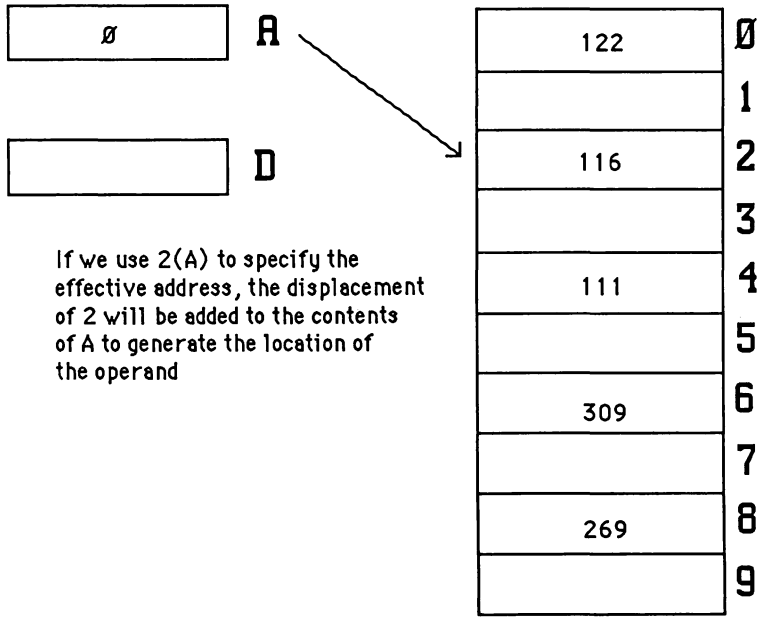


Figure 2.14 Using Address Register Indirect with Displacement Addressing

Really, then, what good is Address Register Indirect with Displacement addressing? It comes in handy when you want to access data in file structures.

Assume, for example, that you are working with a direct access file. The file will have a fixed number of bytes allocated for each field. (Without fixed field lengths you can't do direct access.) The file might have the following fields:

Name 25 bytes
Age 1 byte
Sex 1 byte

You want to read an entire 27-byte record at one time from the disk into main memory. How, then, can you retrieve one particular field? If you know how many bytes any given field is offset from the beginning of the record, you can use Address Register Indirect with Displacement addressing to locate the field you want.

To locate the **Age** field, first load the starting address of the record into address register **A2**. Then specify the effective address of the **Age** field by using:

25(A2)

Note that while **Age** is the 26th byte of the record, it is offset only *25* bytes from the first byte in the record.

We'll see much more of this technique when we talk about the File Manager in Chapter 11.

Mode #7: Address Register Indirect with Index

Address Register Indirect with Index addressing (the other form of displacement addressing) adds an additional wrinkle. The effective address will not only be the sum of the contents of an address register and a displacement, but the contents of an index register will also be needed. An index register is any data or address register that you decide to use to hold an index value. That, by the way, isn't as much a circular definition as it might seem at first glance.

Consider the Extremely-Micro Computer example in Figure 2.15. Suppose we want to process the values in locations 3–6. We load the address 3 into register A. We load a starting index value of 0 into register D. (In this case, we don't have any choice of what register to use as an index register since we only have two and we must use the address register to hold the memory address.) The effective address is computed as shown in 2.15(a). The address in register A (3) is added to the displacement (in this example, 0) which is added to the value in register D (also 0). This instruction will therefore process the value stored in memory location 3.

In order to process the next memory location, all we need to do is increment the value in register D. (As you'll see in Chapter 4, the incrementing can be done with a single 68000 statement.) In 2.15(b) register D contains a value of 1. When we repeat the same instruction, the effective address becomes 4. Note that though this example used a displacement of zero; in practice you may use other values.

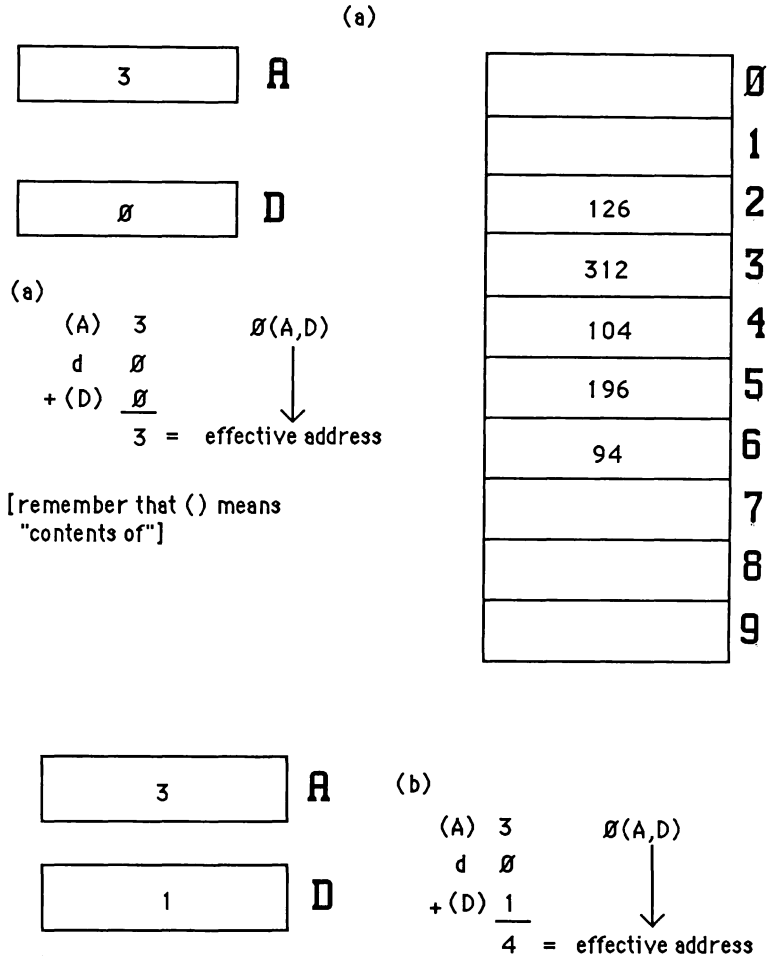


Figure 2.15 Using Address Register Indirect with Index Indexing

The 68000 form of Address Register Indirect with Index addressing is:

d(An,Rn) d = displacement
n = register number
R = either "A" or "D"

When using this addressing mode, you are limited to an 8-bit displacement (a range of −128 to +127). The R above should be replaced by either an A if you are using an address register, or D if you are using a data register for the index register.

We'll see this mode in action at the end of Chapter 5 when we discuss the handling of arrays.

Absolute Data Addressing

Absolute Data addressing allows you to follow the instruction mnemonic with the actual address of the operand. No registers are needed.

Mode #8: Absolute Short Address

To use Absolute Short addressing, follow an instruction mnemonic with 16-bit address:

InstructionMnemonic.W **16-bit address** (Remember that there may also be a destination specified in the 68000 statement along with the address of the operand)

The assembler "extends" this address to a 24-bit effective address by copying bit 15 into bits 16–31 of the next word. (Though the extension is to a full 32 bits, only 24 can be used for an address since the 68000 has that 24-bit address bus.)

The extension means that when a program uses absolute short addresses of $0000 to $7FFF, the effective address will be in the range $000000 to $007FFF. To understand why, we need to look at the binary equivalent of these addresses.

$7FFF = %0111 1111 1111 1111

Bit 15 is 0. When we extend that value, we get an effective address of:

%0000 0000 0111 1111 1111 1111 or $007FFF.

But look at what happens if we specify an address of $8000:

$8000 = %1000 0000 0000 0000.

After the extension we get:

%1111 1111 1000 0000 0000 0000 or $FF8000.

In other words, when a program uses Absolute Short addressing on an address in the range $8000 to $FFFF, the assembler generates an effective address of $FF8000 to $FFFFFF. But the 128K Macintosh has a maximum RAM address of $1FFFFF and the 512K Mac a maximum of $7FFFFF. For all practical purposes, then, this addressing mode is only good for addresses in the lower portion of memory — $0000 to $7FFFF.

Mode #9: Absolute Long Address

You can still use absolute addressing, even though Absolute Short addressing won't access the entire address range, by using Absolute Long addressing.

Absolute Long addressing has the form:

InstructionMnemonic.L 32-bit address

The **.L** following the instruction mnemonic tells the assembler not to extend whatever address follows. Therefore, the address specified will be used as the effective address without any changes.

Symbolic Addresses

In most applications, you will never use either absolute addressing mode. In fact, it is not only possible, but desirable to write programs without reference to absolute addresses. Instead, you will use what are known as *symbolic addresses*.

A symbolic address is a name (or label) assigned to either a program instruction or a main memory location where some data are sorted. Through the assembly and linking processes, the symbolic addresses are translated into absolute addresses in object code. But when writing the program, you need not worrry about specific RAM locations. You can refer to the address of any instruction in the program by simply using its label; you can refer to the storage location of a piece of data by using the name you assigned to it. You can also assign symbolic addresses to data structures. There is much, much more about this in Chapters 4 and 5.

For example, suppose a program has just performed a comparison operation to determine if two quantities are equal. If they are not equal, the program should branch to another portion of the program. The mnemonic for an unconditional branch is **BRA**. You could write the instruction using an absolute address:

BRA $A123

This statement assumes that you know exactly what program instruction begins at memory location **$A123**. If you change your program (perhaps you had an error to correct), it's likely that many of the instructions will shift their places in RAM. What you originally expected to find at **$A123** will no longer be there.

If however, you write the statement as:

BRA Label1

then the program will branch to whatever instruction has **Label1** in its label field. **Label1** is a symbolic address. It will be replaced by an absolute address in the object code when the program is assembled and linked.

Symbolic addresses can be used anywhere an absolute address is required. There are rules for constructing legal symbolic addresses:

1. If the symbolic address does not begin in column 1 (at the far left of the Editor's input window), you must follow it with a colon.

2. There is no limit to the number of characters in a symbolic address, but for practical considerations, attempt to keep them to under 15 characters. All characters are significant.
3. The first character must be a letter, period (.), or under bar (_).
4. All other characters must be selected from among letters, numbers, periods, underbars, and dollar signs. Blanks are not allowed.
5. Symbolic addresses must not be the same as 68000 instructions, nor can they duplicate the names of ToolBox or operating systems routines.

Program Counter Relative Addressing

As you remember, the program counter is a special register that holds the main memory address of the start of the next program instruction to be executed. The 68000 microprocessor has two addressing modes that let you specify effective addresses as relative to the current contents of the program counter.

Mode #10: Program Counter with Displacement

Program Counter with Displacement addressing works very much like Address Register Indirect with Displacement addressing (mode #6). The 68000 format for specifying an effective address is:

d(PC) d = displacement

The assembler computes the effective address by adding the displacement to the current contents of the program counter.

As with displacement addressing using an address register, the displacement must be a 16-bit integer. You should also note that the expression **(PC)** is used exactly as shown. (Remember that the parentheses mean "the contents of," so **(PC)** means "the contents of the program counter.)

Mode #11: Program Counter with Index

This second program counter mode is also analogous to an address register mode — Address Register Indirect with Index addressing (mode #7). The effective s is the sum of the contents of the program counter, a 16-bit displacement, ɜ contents of an index register. (You may use either a data or an address r.)

e effective address specification must indicate whether the index value is 16 ɔits. Therefore, the 68000 format has two possible forms:

(PC,Rn.W) or
(PC,Rn.L) d = displacement
R = either **A** or **D**
n = register number.

Just like other addressing modes that use a displacement, the displacement may be a positive or negative integer.

The Macintosh has a variation on Program Counter with Index addressing that is not standard for the 68000 microprocessor. If you specify an effective address as:

d(Dn) d = displacement

it will assemble as if you had written:

d(PC,Dn)

Though this shorthand for Program Counter with Index addressing looks like a Data Register Indirect with Displacement mode, it is not. There is no Data Register Indirect with Displacement addressing available with the MC68000 chip; that form of addressing can be performed only with an address register.

Immediate Data

Using immediate data doesn't qualify as addressing RAM, though it's usually discussed along with the other address modes. When you use immediate data, the operand itself is part of the assembly language statement.

Mode #12: Immediate

The major problem when using immediate data is finding a way to indicate the difference between immediate data and absolute addressing. In other words, how will the assembler know the difference between:

$FF

when the **$FF** refers to RAM location **$0000FF** and:

$FF

when the **$FF** refers to the quantity 255? To avoid the confusion, all immediate data is preceded by a #. Therefore, the quantity 255 should be written:

#$FF

If you have assigned symbolic addresses to data, you can use those symbolic addresses instead of the actual values. For example, to set the output type font you need to give the **TextFont** routine a code number that represents the font you want. Remembering the codes is difficult, so each one is assigned a symbolic address. The font called Geneva is coded as **3**. We could specify that font as **#3**.

But if we assign the value **3** to the symbolic address **geneva**, then we can use **#geneva** to represent the actual quantity associated with that address.

Immediate data can be character (or string) data as well as quantities. Strings are surrounded by paired single or double quotes. For example:

#'AB' or **#"AB"**

will assemble as the ASCII codes of the characters A and B. Strings occupy one byte of space per character.

Mode #13: Quick Immediate

The expression "quick immediate" refers to a special type of immediate data. Some of the 68000 instructions have a variation that embeds the operand into the machine language instruction code (the *op code*) itself upon assembly, though the specification of the operation in the source code is the same as standard immediate data.

Because the operand becomes a part of the op code, quick immediate data is limited to very small operands. Just how small depends on the individual instruction.

Why are quick immediate instructions of any use? They save space. A statement using immediate data takes a minimum of two words when assembled (one for the op code and one for the data); if there is a destination for the result specified in the instruction then at least three words will be needed. Quick immediate instructions use one less word of space, since op code and data assemble into a single word rather than two.

Questions and Problems

1. Convert the following decimal numbers to binary. Then convert the binary to octal and hexadecimal.

   a. 8
   b. 19
   c. 67
   d. 136
   e. 506
   f. 695
   g. 1023
   h. 1028

2. Convert the following hexadecimal numbers to binary.

   a. 00FC
   b. 0A03
   c. E216
   d. FFAD
   e. CC12
   f. 2390
   g. 01AE
   h. D333

3. A. Consider the user byte of the 68000's status register. Assuming that the unused bits (5–7) are always cleared, show the contents of the user byte when the execution of a word-sized instruction produces a result of:

   a. −6
   b. 28
   c. 0
   d. 40,000
   e. −65,000

   B. It's difficult to determine the value of one of the five flags without knowing exactly what kind of instruction was executed. Which flag is it?

4. A. If a microcomputer has a 16-bit address bus, what is the maximum address that bus can carry? Express your answer in hexadecimal.

   B. What is the maximum address that a 32-bit address bus can carry?

Problems 5 and 6 refer to the Extremely-Micro Computer. As you will remember, it has an address register, A, and a data register, D. Main memory consists of storage locations numbered 0 through 9.

5. Assume that A contains 6 and D contains 2.

   A. What location is indicated by each of the address specifications below?

   a. 6
   b. #6
   c. A
   d. (A)
   e. 2(A)
   f. 1(A,D)
   g. D
   h. −(A)

   B. Which of the 68000's addressing modes is being used?

6. Assume now that A contains A, D contains 3, and the program counter (PC) contains 2. Repeat questions A and B from problem 5 for the following effective address specifications.

   a. 2
   b. (A)
   c. −(A)
   d. 2(PC)
   e. 2(PC,D)
   f. (D)
   g. 2(PC,A)
   h. #2

7. A. What effect will the effective address specification (SP)+ have on the 68000 register A7?

   B. What effect will −(SP) have on register A7?

8. Indicate whether the following are legal or illegal 68000 effective address specifications. For each illegal specification, state why it is illegal.

a. D6	d. A0	g. (A4)–	j. –8(A4)
b. D8	e. (A)+	h. (D0)	k. –256(A4)
c. (D3)+	f. (A4)+	i. 6(A4)	l. –256(A4,D3)

9. Assuming that a program is performing word-sized operations, what address will be generated by the assembler from the following absolute short addresses?

a. 0023	c. FF39
b. A100	d. EE9B

C H A P T E R T H R E E

USING THE MACINTOSH 68000 DEVELOPMENT SYSTEM

Chapter Objectives

1. To learn the steps needed to create a Macintosh Assembly language application
2. To acquire proficiency in using the Macintosh 68000 Development System
3. To understand the purpose of a debugger and how it is used to aid program development

Introduction

This chapter is designed to familiarize you with the software that supports assembly language programming on the Macintosh. Though you can work with this software with only the internal disk drive, you will find that adding the external drive will save a great deal of disk-swapping and file-moving frustration. The figures in this chapter assume that you are using a two-disk system, though you will find instructions for shuffling files for operating with only one.

The software will run quite acceptably on a 128K Macintosh with one exception (see the discussion on debugging toward the end of this chapter). The 128K will, however, severely limit the size of application that can be developed. If you intend to pursue Macintosh program development beyond the course you are now taking, you should seriously consider upgrading a 128K.

Regardless of what size machine you are using, you should install the programmer's switch. That's the mysterious little piece of plastic that came with your Mac but without instructions. The programmer's switch snaps into place through the slots on the left hand side of the machine, all the way back and down. Place it so that the switch labeled RESET is toward the front of the machine. Pressing the RESET button will allow you to restart the system after a system error or when it is "hung" without having to turn the power off and on again. The other button, INTERRUPT, can be used to invoke the debugger.

To get the most out of the rest of this book, practice using the software now, before you become concerned with the 68000 instruction set. A sample program to be entered, assembled, linked and run appears in Listing 3.1. This program opens a window, prints a line of text, and then waits for the user to hit any key or click the mouse button before returning to the Finder.

Listing 3.1 Sample Assembly Language Program

```
Include MacTraps.D      ;Includes addresses of ToolBox routines
Include ToolEqu.D       ;Includes the ToolBox equates
Include SysEqu.D        ;Includes the System equates

PEA -4(A5)
_InitGraf               ;Initializes QuickDraw
_InitWindows            ;Initializes the Window Manager
_InitMenus              ;Initializes the Menu Manager
_InitFonts              ;Initializes the Font Manager


CLR.L  -(SP)            ;Clear space for WindowPtr result
PEA    StoragePointer ;Window Storage pointer
PEA    BoundsRect     ;Exterior coordinates of window
PEA    'MAL Output Window'   ;Title
ST     -(SP)           ;Make the window visible
MOVE  #documentProc,-(SP)  ;Make it a standard document window
MOVE.L        #-1,-(SP)       ;Put the window in front
ST     -(SP)           ;Draw a go-away box
CLR.L  -(SP)           ;Place for window's reference value
_NewWindow             ;Draw a standard document window

LEA    WindowPtr,AØ ;load destination address for pointer
MOVE.L        (SP)+,(AØ)      ;retrieve pointer

MOVE.L        WindowPtr,-(SP)
_SelectWindow

MOVE.L        WindowPtr,-(SP)       ;put pointer back on the stack
_SetPort               ;make this window the current grafport

_InitCursor            ;set the cursor to the arrow                    (continued)
```

```
MOVE.W      #7,-(SP)        ;7 = athens
_TextFont               ;Set the text font

MOVE.W      #18,-(SP)       ;18 for 18-point type
_TextSize               ;Set the text size

MOVE.W      #65,-(SP)       ;Horizontal coordinate
MOVE.W      #1ØØ,-(SP)      ;Vertical coordinate
_MoveTo                     ;Move the pen

PEA    'HOORAY!!! You did it!'
_DrawString

MOVE.L      everyEvent,DØ ;Mask to select all events

_FlushEvents            ;Clear the event queue


Event  CLR    -(SP)             ;Space for boolean result
       MOVE   #%ØØØØØØØØØØ11111Ø,-(SP)    ;Mask for keyboard and mouse
       PEA    EventRecord       ;Place to receive event info
       _GetNextEvent            ;Get next event from queue

       MOVE   (SP)+,DØ          ;Has a keyboard or mouse event occurred?
       CMP    #Ø,DØ
       BEQ    Event             ;If no event, branch to look again

       RTS                      ;Return to the Finder


WindowPtr      DC.L   Ø
BoundsRect     DC.W   4Ø,2Ø,3ØØ,35Ø
everyEvent     DC.L   $ØØØØFFFF
EventRecord                   ;where GetNextEvent Puts its result
What   DC      Ø
Message        DC.L   Ø
When   DC.L    Ø
Point  DC.L    Ø
Modify DC      Ø

StoragePointer DCB.W windowSize,Ø

       END
```

The *Macintosh 68000 Development System* (the MDS) is the formal name for the set of programs that enable a programmer to enter, assemble, link, and run assembly language programs. It also includes a family of debuggers, programs that, among other things, display what's happening in the Macintosh's registers while a program is running.

On the disk named MDS1 (Figure 3.1) you will find:

1. the Editor (Edit) – allows you to enter assembly language source programs.
2. the Executive (Exec) – automates the assembling and linking process
3. the Assembler (Asm) – translates source code created by the Editor into binary object code
4. the Linker (Link) – links separately assembled modules of source code into an executable application
5. the Resource Compiler (RMaker) – creates files that define windows, menus, etc.
6. Debug Nubs – files used by some of the debuggers
7. Assembler Support Files (in the folder **ASM Stuff**)

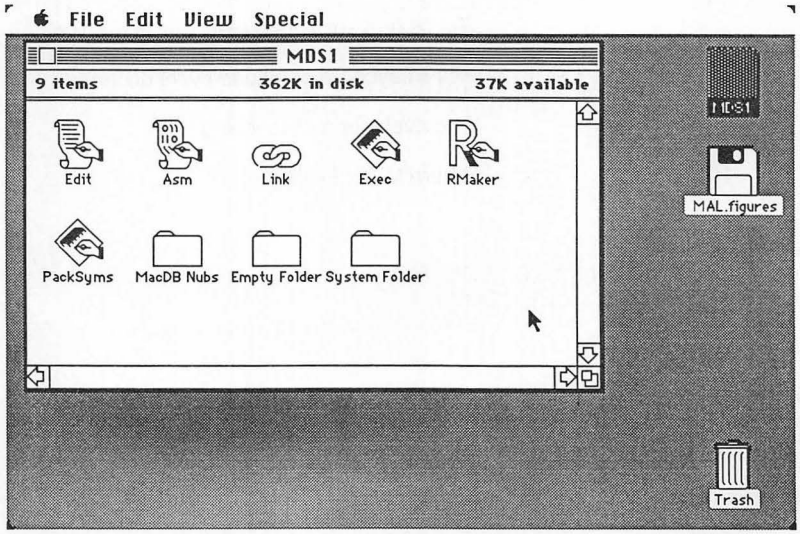


Figure 3.1 The Disk MDS 1

The disk named MDS2 (Figure 3.2) contains:

1. the Macintosh Debuggers (in the folder **Debuggers**)
2. the Equates Files (in the **Equ Files** folder) – handy definitions that the ToolBox uses
3. the Symbol Packer (PackSyms) – a program that compacts Equates Files so they will take up less room in your source files

4. Packed Symbol Files (in the **.D Files** folder) — what you get when you put Equates Files through the Symbol Packer
5. Trap Files (in the **Trap Files** folder) — files that assign names to the instruction words that reference the ToolBox Dispatch Table
6. some Sample Programs

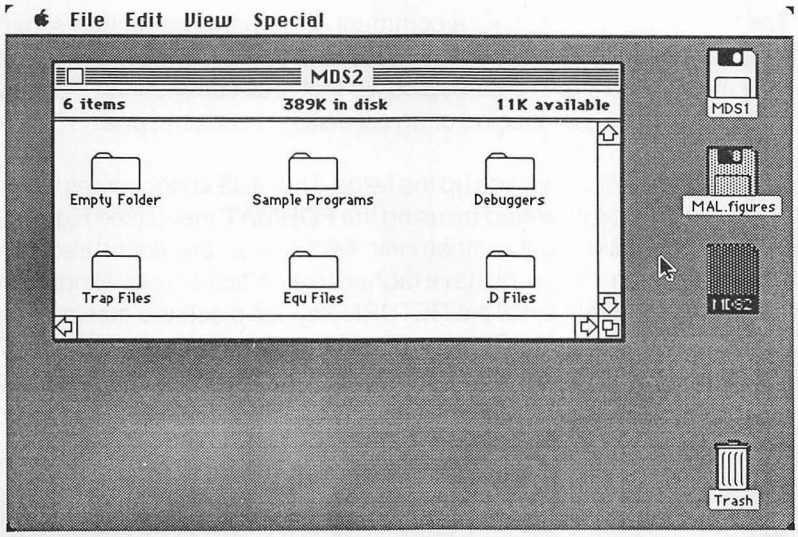


Figure 3.2 The Disk MDS 2

Using the Editor

The Macintosh 68000 Development System comes with its own text editor for creating program source files. You may also use MacWrite, but save the document as text only, without any formatting information. The MDS editor is "disk based." That means you can edit files much larger than what will fit in RAM; the editor shuffles bits and pieces of text between the disk and RAM as needed.

Invoke the editor by double-clicking on its icon. (There are two other ways to get into the editor, but this will do for now.)

Assembly language source files are more or less free form (i.e., there are no set columns in which particular parts of the statements must appear). The only rules are:

1. The first field is reserved for symbolic addresses. If a statement doesn't have a symbolic address, then it must begin with at least one blank. Symbolic

addresses don't necessarily have to start in column one (the far left-hand position on the screen), but if they don't, they must be followed by a colon (:).

2. The second field is reserved for the instruction mnemonic. It must be separated from the symbolic address (if one is present) by at least one space.

3. The third field holds one or more operands (either the operands themselves or their effective addresses). The operand field must be separated from the mnemonic by at least one space.

4. The fourth field may contain a comment. Comments begin with semicolons (;) and must be separated from the operand field by at least one space. You may also have a line in your source file that is all comment. In that case you must either have a semicolon or an asterisk (*) in column one.

For readability, we usually line up the fields. The MDS editor comes with preset tab stops which can be changed by using the **FORMAT** menu (see Figure 3.3).

To make indentation to the mnemonic field easier, the editor also provides automatic indentation. Once you have tabbed to a particular spot without entering text in any preceding tab zone, the RETURN key will place the cursor at that tab stop instead of in column one. To type something to the left, hit the BACKSPACE key. Automatic indentation can be turned off from the **FORMAT** menu (Figure 3.3).

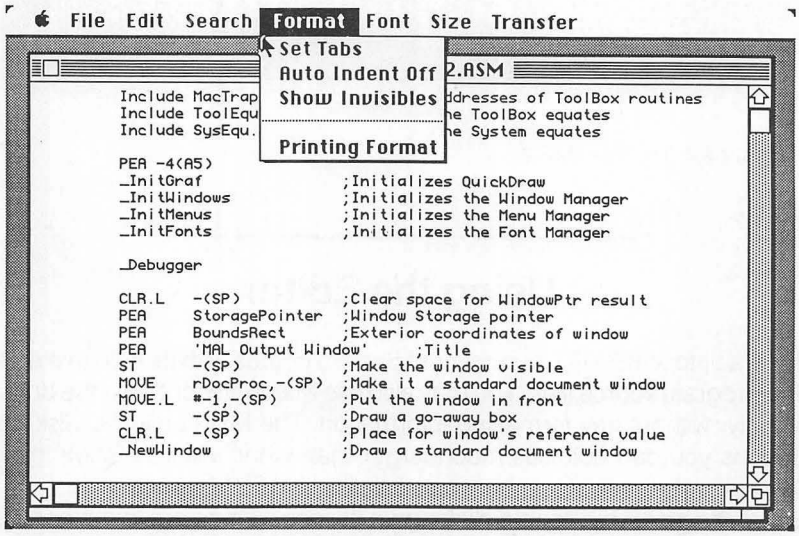


Figure 3.3 The MDS Editor's Format Menu

The editor provides some basic features for changing source code. Cut, copy, and paste work just as they do in MacWrite. You can also align all the text in a selected block (select with the mouse as when using MacWrite) with options

available from the **EDIT** menu (see Figure 3.4). The **SEARCH** menu (Figure 3.5) provides standard find and change capabilities.

When you have finished entering the sample program, save it to disk. The **FILE** menu (Figure 3.6), just like the MacWrite **FILE** menu, allows you to name the file before you save it.

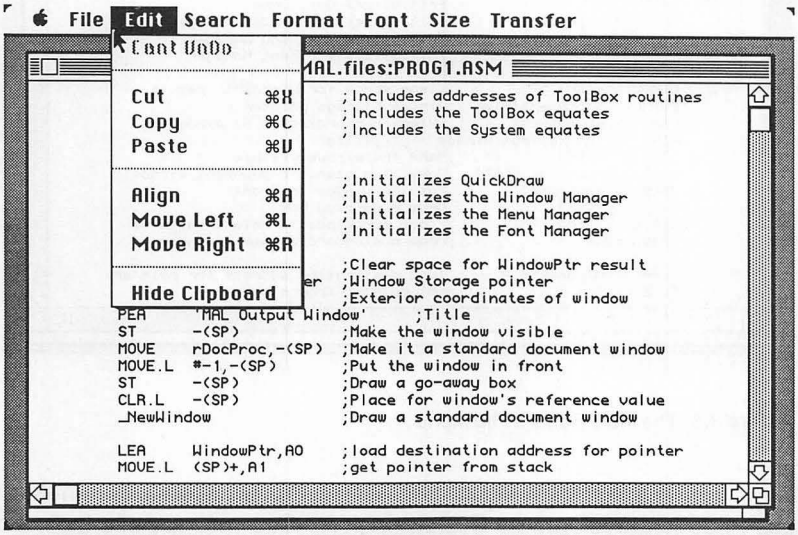


Figure 3.4 The MDS Editor's Edit Menu

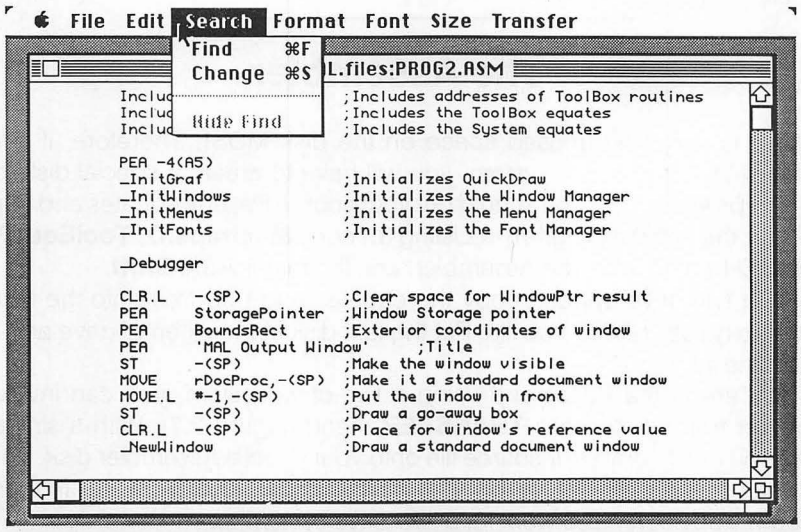


Figure 3.5 The MDS Editor's Search Menu

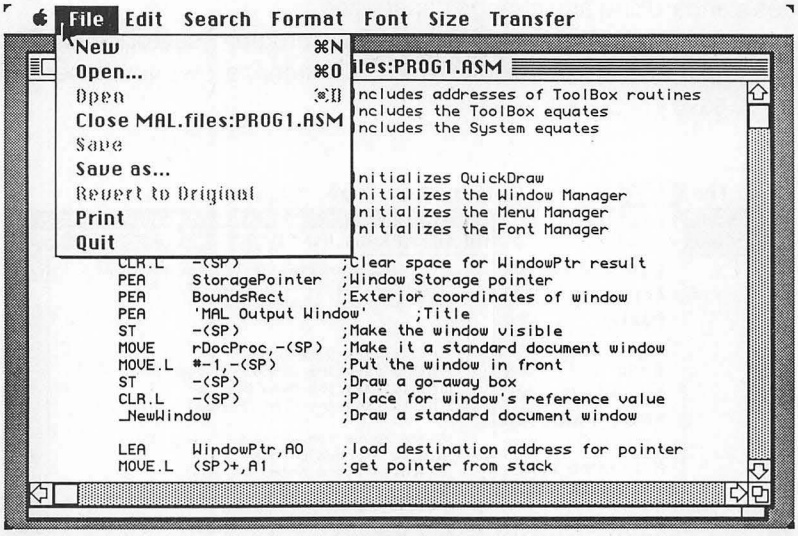


Figure 3.6 The MDS Editor's File Menu

How you name your file is important. The various programs that make up the Macintosh 68000 Development System look for files with specific extensions to their names. Assembly language source files should have the extension **.ASM**. You could, for example, name the sample program **Sample.Asm**.

The Assembler

There is very little unused space on the disk MDS1. Therefore, if you are working with a single disk system, you will have to create a special disk for the assembly process. On it you should put your source file, any equates and trap files it uses (for the sample program in Listing 3.1 copy **Mactraps.D, ToolEqu.D,** and **SysEqu.D** from MDS2), the Assembler, and the folder **ASM Stuff**.

With a two-drive system, copy the equates and trap files onto the text disk which also holds your source file. Put the text disk in the external drive and leave MDS1 in the internal drive.

If you are in the Editor and using a two-drive system, you can invoke the Assembler from the Editor's **TRANSFER** menu (Figure 3.7). With a single-disk system you must copy your source file onto your special Assembler disk. You can then enter the Assembler by double-clicking on its icon from the Finder (this method will obviously also work for a two-drive system).

The Assembler will present a list of the files which it can identify as possible candidates for assembly (Figure 3.8). If you have a large number of source files on

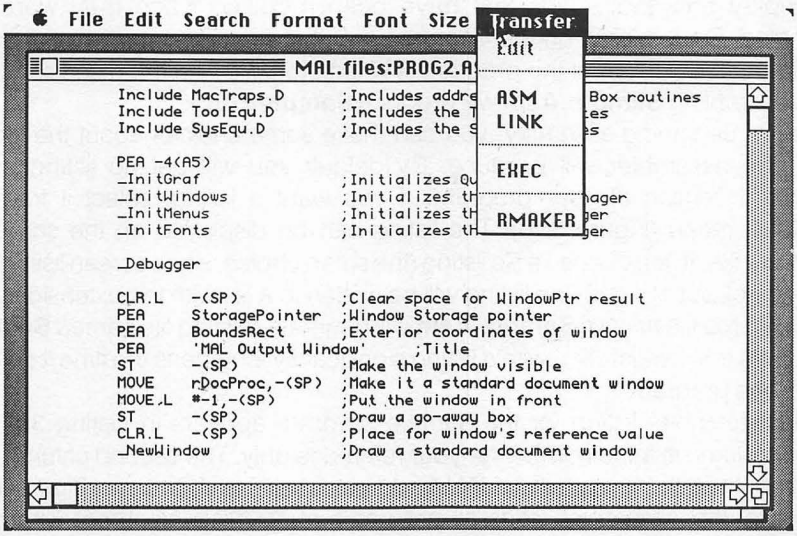


Figure 3.7 The MDS Editor's Transfer Menu

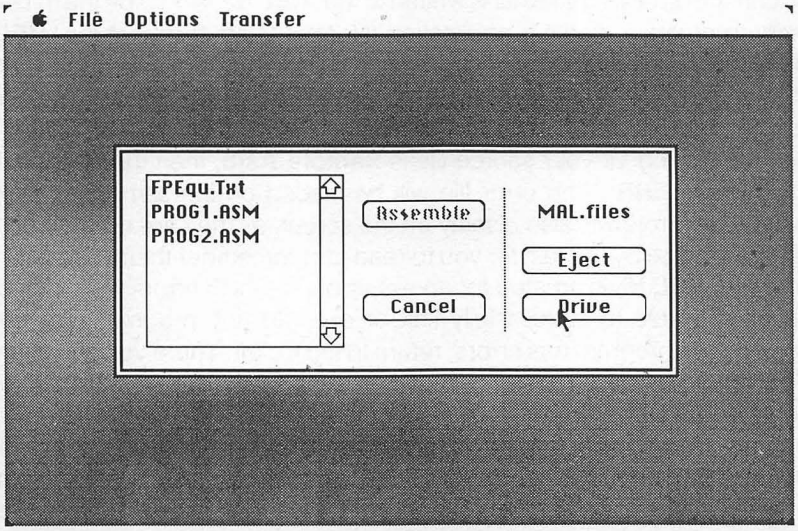


Figure 3.8 Assembler File Select Screen

your disk, select the **Filter by Time** option from the **FILE** menu (Figure 3.9). This will display only those files that have been modified since they were last assembled. Double-click on the file name and the assembly process will begin. The assembled version of the program is written to a file with the extension **.REL** (e.g., assembling **Sample.Asm** will produce **Sample.REL**).

Before beginning assembly, you can make some choices about the kind of output the assembler will produce. By default you will get no listing of the assembled version of your program. If you want a listing, select it from the **OPTIONS** menu (Figure 3.10). The listing can be displayed on the screen or written to a file. If you choose a file listing (the smart choice, since screen listings will rapidly scroll out of sight), the listing will be written to a file with the extension **.LST** (e.g., a source file named **Sample.Asm** will generate a listing file named **Sample.LST**). Note that assembling with a listing significantly lengthens the time it takes to assemble a program.

The Assembler listing for the Sample program appears in Listing 3.2. The leftmost column is a line number for your reference only. The second column from the left contains the hexadecimal RAM address where each program line begins. By default, the Assembler starts all programs at $0000. This is not where the program will end up in RAM when the program is run. The operating system will add all the program locations to a fixed base address at run time.

The remaining numbers are the hexadecimal equivalents of the instruction mnemonics and their operands. You will have noticed that there are x's in some places rather than hexadecimal numbers. The x's fill in places for absolute addresses which the assembler was unable to identify. They will be replaced with addresses by the Linker when space for storage locations the applications globals area is allocated.

You can also specify that what is written to the **.REL** file should be the minimum necessary to create a working application (Normal Output) or that the **.REL** file should include extra information to permit creation of a Linker listing (Verbose Output). Verbose Output will lengthen both the assembly and linking processes.

If any errors are detected during assembly, they will be stored in a file with extension **.ERR** (e.g., if your source file is **Sample.Asm**, then the errors will be listed in **Sample.ERR**). The error file will be placed on the same disk as your source file. The errors will also display on the screen as they are discovered, but they generally scroll by too fast for you to read and remember them.

Though a **.REL** file is created for an assembly in which errors were detected, you will not be able to successfully link or execute any program with errors. Therefore, if your program has errors, return to the Editor. There you can examine the **.ERR** file at your leisure (printing it out if necessary) and then make the needed changes to your source file.

If you are using a two-disk system, you can return to the Editor through the Assembler's **TRANSFER** menu (Figure 3.11). With a single-disk system, you must transfer the **.ERR** file back to the disk that contains the Editor and then enter the Editor from the Finder.

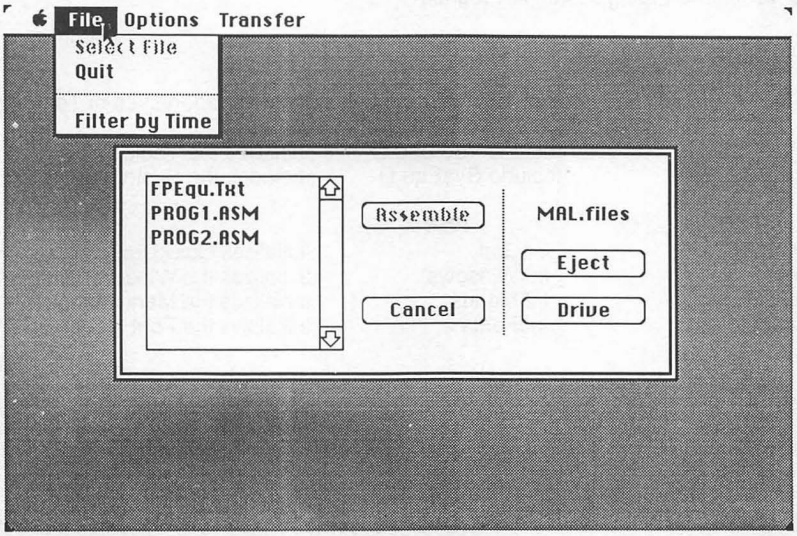


Figure 3.9 Assembler File Menu

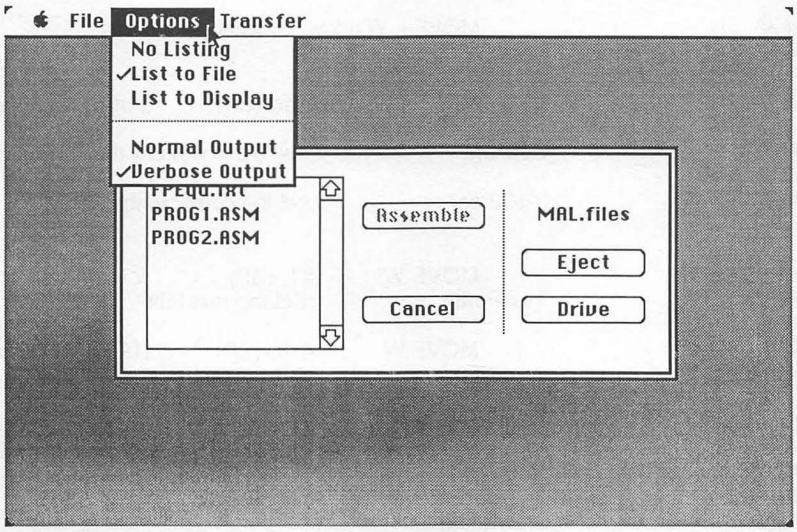


Figure 3.10 Assembler Options Menu

Listing 3.2 Assembler Listing of Sample Program

```
ØØØØ                        Include MacTraps.D      ;Includes addresses of ToolBox
                                                    routines
ØØØØ                        Include ToolEqu.D       ;Includes the ToolBox equates
ØØØØ                        Include SysEqu.D        ;Includes the System equates
ØØØØ
ØØØØ   486D FFFC                   PEA -4(A5)
ØØØ4   A86E                 _InitGraf               ;Initializes QuickDraw
ØØØ6   A912                 _InitWindows            ;Initializes the Window Manager
ØØØ8   A93Ø                 _InitMenus              ;Initializes the Menu Manager
ØØØA   A8FE                 _InitFonts              ;Initializes the Font Manager
ØØØC
ØØØC
ØØØC   42A7                 CLR.L  -(SP)            ;Clear space for WindowPtr result
ØØØE   484Ø xxxx      (PX)   PEA    StoragePointer ;Window Storage pointer
ØØ12   484Ø xxxx      (PX)   PEA    BoundsRect     ;Exterior coordinates of window
ØØ16   484Ø xxxx      (PX)          PEA   'MAL Output Window'   ;Title
ØØ1A   5ØE7                 ST     -(SP)           ;Make the window visible
ØØ1C   3F3C ØØØØ            MOVE  #documentProc,-(SP)   ;Make it a standard
document window
ØØ2Ø   2F3C FFFF FFFF       MOVE.L  #-1,-(SP)       ;Put the window in front
ØØ26   5ØE7                 ST     -(SP)            ;Draw a go-away box
ØØ28   42A7                 CLR.L  -(SP)            ;Place for window's reference value
ØØ2A   A913                 _NewWindow              ;Draw a standard document window
ØØ2C
ØØ2C   41CØ xxxx      (PX)   LEA    WindowPtr,AØ ;load destination address for
pointer
ØØ3Ø   2Ø9F                 MOVE.L (SP)+,(AØ)       ;retrieve pointer
ØØ32
ØØ32   2F3A xxxx      (R)          MOVE.L WindowPtr,-(SP)
ØØ36   A91F                 _SelectWindow
ØØ38
ØØ38   2F3A xxxx      (R)          MOVE.L WindowPtr,-(SP)      ;put pointer back on the
stack
ØØ3C   A873                 _SetPort                ;make this window the current grafport
ØØ3E
ØØ3E   A85Ø                 _InitCursor             ;set the cursor to the arrow
ØØ4Ø
ØØ4Ø
ØØ4Ø   3F3C ØØØ7            MOVE.W  #7,-(SP)        ;7 = athens
ØØ44   A887                 _TextFont               ;Set the text font
ØØ46
ØØ46   3F3C ØØ12            MOVE.W  #18,-(SP)       ;18 for 18-point type
ØØ4A   A88A                 _TextSize               ;Set the text size
ØØ4C
ØØ4C   3F3C ØØ41            MOVE.W  #65,-(SP)       ;Horizontal coordinate
ØØ5Ø   3F3C ØØ64            MOVE.W  #1ØØ,-(SP)      ;Vertical coordinate
ØØ54   A893                 _MoveTo                 ;Move the pen
ØØ56   484Ø xxxx      (PX)   PEA    'HOORAY!!! You did it!'
ØØ5A   A884                 _DrawString
ØØ5C
ØØ5C   2Ø3A xxxx      (R)          MOVE.L everyEvent,DØ   ;Mask to select all events
```

(continued)

```
ØØ6Ø    AØ32                    _FlushEvents'          ;Clear the event queue
ØØ62
ØØ62    4267                    Event  CLR    -(SP)          ;Space for boolean result
ØØ64    3F3C ØØ3E               MOVE  #%ØØØØØØØØØØ111110,-(SP)      ;Mask for
keyboard and mouse
ØØ68    484Ø xxxx          (PX)       PEA    EventRecord    ;Place to receive event info
ØØ6C    A97Ø                    _GetNextEvent          ;Get next event from queue
ØØ6E
ØØ6E    3Ø1F                    MOVE  (SP)+,DØ         ;Has a keyboard or mouse event
occurred?
ØØ7Ø    ØC4Ø ØØØØ                      CMP    #Ø,DØ
ØØ74    67 EC          (P)             BEQ    Event          ;If no event, branch to look again
ØØ76
ØØ76    4E75                    RTS                    ;Return to the Finder
ØØ78
ØØ78
ØØ78    ØØØØ ØØØØ              WindowPtr      DC.L   Ø
ØØ7C     ØØ28 ØØ14 Ø12C Ø15E        BoundsRect     DC.W   4Ø,2Ø,3ØØ,35Ø
ØØ84    ØØØØ FFFF              everyEvent     DC.L   $ØØØØFFFF
ØØ88                          EventRecord                   ;where GetNextEvent Puts its result
ØØ88    ØØØØ                  What           DC     Ø
ØØ8A    ØØØØ ØØØØ              Message        DC.L   Ø
ØØ8E    ØØØØ ØØØØ              When DC.L      Ø
ØØ92    ØØØØ ØØØØ              Point  DC.L    Ø
ØØ96    ØØØØ                  Modify         DC     Ø
ØØ98
ØØ98    xxxx xxxx xxxx     (R)    StoragePointer DCB.W windowSize,Ø
Ø1DØ
Ø1DØ     11 4D 41 4C 2Ø 4F 75 74 7Ø 75 74 2Ø 57 69 6E 64 6F 77 ;
                  'MAL Output Window'
Ø1E2     16 48 4F 4F 52 41 59 21 21 21 2Ø 2Ø 59 6F 75 2Ø 64 69 64 2Ø 69 74 21 ;
                  'HOORAY!!! You did it!'
Ø1F9    ØØ
```

The Linker

A **.REL** file contains an object code that is *relocatable* (capable of being moved around in main memory). Though it is in the binary, machine language form that the computer will understand, it is not an executable application since many of the absolute addresses are missing. The Linker provides the final step in the process.

The Linker generates two types of output. Assuming that no errors are detected during the linking process, you will get an executable application (appears on the desktop as a diamond with a hand holding a pen) and a file with a **.MAP** extension. A **.MAP** file contains a symbol table (exactly where everything is when your program is in RAM) and also the Linker listing, if you requested one.

The operation of the Linker is determined by a Linker control file. A control file contains the names of the **.REL** files to be linked (you can assemble a large program in small parts and then have the Linker combine them into a single application) and, optionally, a symbolic address that indicates which instruction in your source code is the start of your program; instructions on how the program can be segmented (it is possible to break a program which is too large to fit into memory into segments which are then loaded as needed); and options that control the contents of the Linker output file.

Linker control files are text files that are created with the Editor. They must be given the extension **.LINK** (e.g., the Linker control file for the Sample program should be called **Sample.LINK**). At a minimum, a Linker control file must contain the name of the program to be linked and a **$** that marks the end of the file.

For the Sample program, create a text file that contains:

```
[
Sample
$
```

The **[** will turn on the listing to the **.MAP** file and is therefore optional.

If you are working with a two-drive system, save the Linker control file on your text disk. With a single-drive system, put the **.REL** file, the Linker control file, and the Linker on one disk before beginning the linking process.

You can enter the Linker from the Finder, or from the Assembler's **TRANSFER** menu (Figure 3.11). The Linker displays a list of Linker control files on the current disk (Figure 3.12). Double-clicking on the file name will then begin the linking process.

If the Linker encounters any errors, they will be stored in a file with a **.LERR** extension (e.g., for the Sample program, Linker errors will be written to **Sample.LERR**). A **.LERR** file can be examined from the Editor, just like **.ERR** files.

If you include a **[** in a Linker Control file, the **.MAP** file will include a program listing like the one in Listing 3.3. This listing differs from an Assembler listing in one important way: the x's in the Assembler listing have been replaced with absolute addresses. This is the version of the program that will actually run.

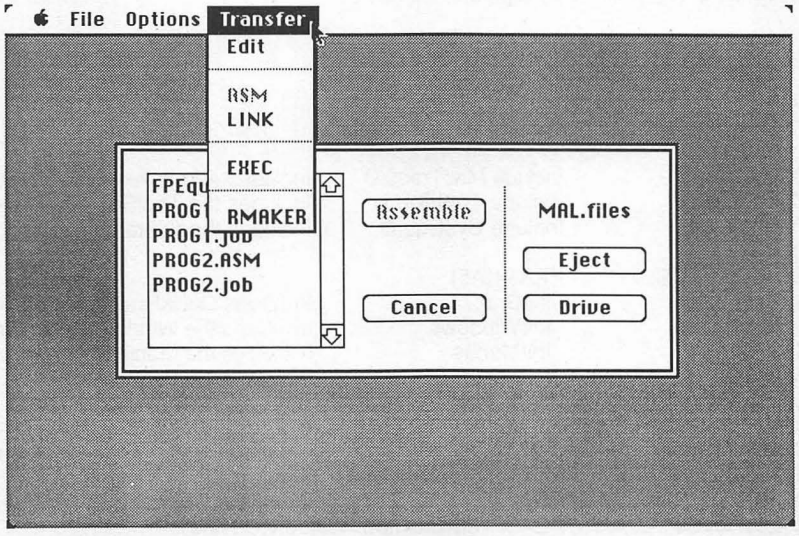


Figure 3.11 Assembler Transfer Menu

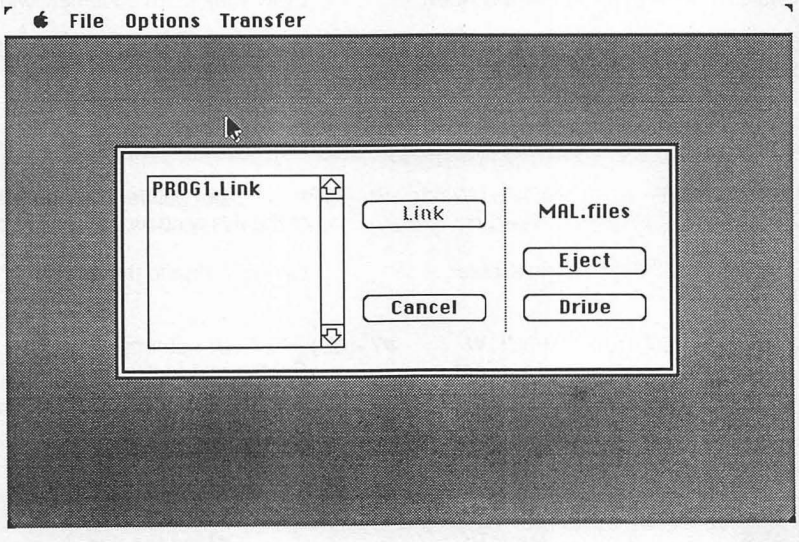


Figure 3.12 Linker File Select Screen

Listing 3.3 Linker Listing of Sample Program

Sample.Rel

```
ØØØØØØ:                    Include MacTraps.D     ;Includes addresses of ToolBox routines
ØØØØØØ:                    Include ToolEqu.D      ;Includes the ToolBox equates
ØØØØØØ:                    Include SysEqu.D       ;Includes the System equates
ØØØØØØ:
ØØØØØØ: 48 6D FF FC        PEA -4(A5)
ØØØØØ4: A8 6E              _InitGraf              ;Initializes QuickDraw
ØØØØØ6: A9 12              _InitWindows           ;Initializes the Window Manager
ØØØØØ8: A9 3Ø              _InitMenus             ;Initializes the Menu Manager
ØØØØØA: A8 FE              _InitFonts             ;Initializes the Font Manager
ØØØØØC:
ØØØØØC:
ØØØØØC: 42 A7              CLR.L  -(SP)           ;Clear space for WindowPtr result
ØØØØØE: 487A ØØ88          PEA    StoragePointer ;Window Storage pointer
ØØØØ12: 487A ØØ68          PEA    BoundsRect     ;Exterior coordinates of window
ØØØØ16: 487A Ø1B8          PEA    'MAL Output Window'  ;Title
ØØØØ1A: 5Ø E7              ST     -(SP)          ;Make the window visible
ØØØØ1C: 3F 3C ØØ ØØ        MOVE  #documentProc,-(SP)  ;Make it a standard document
window
ØØØØ2Ø: 2F 3C FF FF FF FF   MOVE.L#-1,-(SP)       ;Put the window in front
ØØØØ26: 5Ø E7              ST     -(SP)          ;Draw a go-away box
ØØØØ28: 42 A7              CLR.L  -(SP)          ;Place for window's reference value
ØØØØ2A: A9 13              _NewWindow            ;Draw a standard document window
ØØØØ2C:
ØØØØ2C: 41FA ØØ4A          LEA    WindowPtr,AØ   ;load destination address for pointer
ØØØØ3Ø: 2Ø 9F              MOVE.L(SP)+,(AØ)      ;retrieve pointer
ØØØØ32:
ØØØØ32: 2F 3A ØØ 44        MOVE.LWindowPtr,-(SP)
ØØØØ36: A9 1F              _SelectWindow
ØØØØ38:
ØØØØ38: 2F 3A ØØ 3E        MOVE.LWindowPtr,-(SP)      ;put pointer back on the stack
ØØØØ3C: A8 73              _SetPort               ;make this window the current grafport
ØØØØ3E:
ØØØØ3E: A8 5Ø              _InitCursor            ;set the cursor to the arrow
ØØØØ4Ø:
ØØØØ4Ø:
ØØØØ4Ø: 3F 3C ØØ Ø7        MOVE.W     #7,-(SP)    ;7 = athens
ØØØØ44: A8 87              _TextFont              ;Set the text font
ØØØØ46:
ØØØØ46: 3F 3C ØØ 12        MOVE.W     #18,-(SP)   ;18 for 18-point type
ØØØØ4A: A8 8A              _TextSize              ;Set the text size
ØØØØ4C:
ØØØØ4C: 3F 3C ØØ 41        MOVE.W     #65,-(SP)   ;Horizontal coordinate
ØØØØ5Ø: 3F 3C ØØ 64        MOVE.W     #1ØØ,-(SP)  ;Vertical coordinate
ØØØØ54: A8 93              _MoveTo                ;Move the pen
ØØØØ56:
ØØØØ56: 487A Ø18A          PEA    'HOORAY!!! You did it!'
ØØØØ5A: A8 84              _DrawString
ØØØØ5C:
ØØØØ5C: 2Ø 3A ØØ 26        MOVE.LeveryEvent,DØ;Mask to select all events
```

(continued)

```
000060: A0 32               _FlushEvents              ;Clear the event queue
000062:
000062: 42 67         Event          CLR    -(SP)           ;Space for boolean result
000064: 3F 3C 00 3E         MOVE  #%0000000000111110,-(SP)     ;Mask for
keyboard and mouse
000068: 487A 001E           PEA    EventRecord   ;Place to receive event info
00006C: A9 70               _GetNextEvent             ;Get next event from queue
00006E:
00006E: 30 1F               MOVE  (SP)+,D0         ;Has a keyboard or mouse event
occurred?
000070: 0C 40 00 00         CMP    #0,D0
000074: 67 EC               BEQ    Event              ;If no event, branch to look again
000076:
000076: 4E 75               RTS                       ;Return to the Finder
000078:
000078:
000078: 00 00 00 00         WindowPtr     DC.L   0
00007C: 00 28
00007E: 00 14
000080: 01 2C
000082: 01 5E          BoundsRect  DC.W  40,20,300,350
000084: 00 00 FF FF       everyEvent        DC.L   $0000FFFF
000088:             EventRecord                       ;where GetNextEvent Puts its result
000088: 00 00          What DC     0
00008A: 00 00 00 00         Message       DC.L   0
00008E: 00 00 00 00         When   DC.L   0
000092: 00 00 00 00         Point  DC.L   0
000096: 00 00          Modify       DC     0
000098:
000098: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00
         StoragePointer   DCB.W windowSize,0
0001D0:
0001D0: 11 4D 41 4C 20 4F 75 74 70 75 74 20 57 69 6E 64 6F 77

0001E2: 16 48 4F 4F 52 41 59 21 21 21 20 20 59 6F 75 20 64 69 64 20 69 74 21

0001F9: 00
```

A caveat is in order with regard to the Linker. If your attempt at linking gives system error #28, then the Finder has run out of memory (the stack has run into the heap) and cannot place your application file in the disk directory. A disk should theoretically hold somewhere near one hundred files, but if you are working with a 128K Mac you may see this error with less than 20 files on your disk. If this occurs, delete some files or transfer just the few files you absolutely need to another disk to successfully complete the linking. (**.MAP, .ERR, .LST** and **.LERR** files are good candidates for deletion.)

Running an Application

After a successful linking, there are two ways to execute an application. The successful linking will add an extra option to the Linker's **TRANSFER** menu (Figure 3.13). You can run the program by selecting that option. You can also run any application at any time by double-clicking its icon from the Finder.

Assuming that you have successfully entered, assembled, and linked the Sample program, your output will appear as in Figure 3.14

Run-Time System Errors

There are some errors that the Assembler's error-checking capabilities will not catch. These often don't show up until an application is running and appear as system errors that require resetting the system to recover (such as error #28 mentioned above).

For example, assume that you wanted to specify an operand as immediate data. To correct, you should have used:

```
InstructionMnemonic  #SomeQuantity,D0
```

Unfortunately, you left off the # which means that your source code contained:

```
InstructionMnemonic  SomeQuantity,D0
```

The Assembler interpreted the quantity as an absolute address; what was in the source file was a totally correct use of Absolute addressing. The problem, though, is that you don't want what is stored at whatever address the quantity represents; you want the quantity itself. Nonetheless, since the syntax of the statement is correct, the Assembler won't pick up the error.

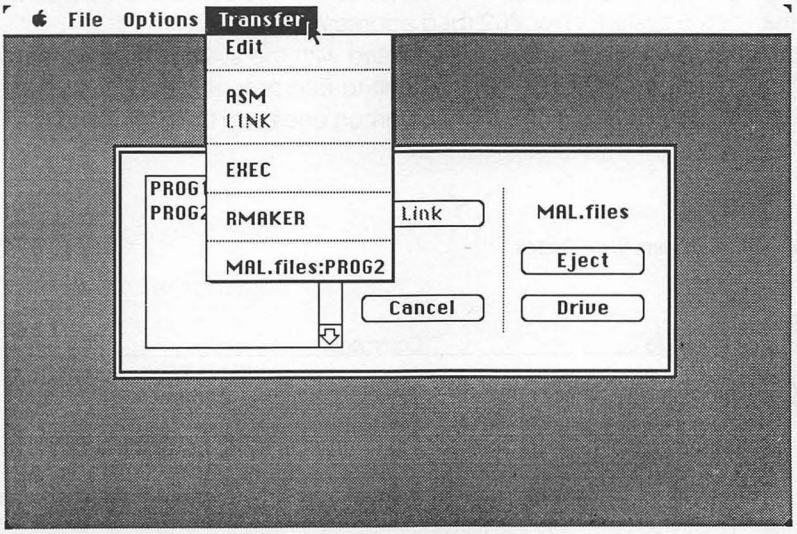


Figure 3.13 Linker Transfer Menu after a Program has been Successfully Linked

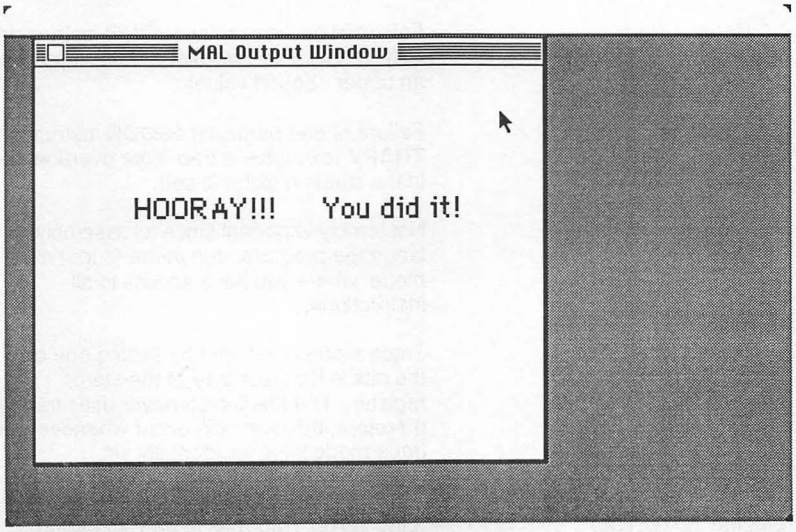


Figure 3.14 Output From Sample Program

When you run the application, all sorts of strange things can happen. More often than not, a system error #02 (bad address) will occur.

You'll find the error messages associated with the system errors in Table 3.1. Though such errors are extremely difficult to interpret, the table includes some suggestions as to causes of the more common ones and their solutions.

Table 3.1 Macintosh's System Error Codes

Error Code	Error Message	Comments
01	Bus Error	Not applicable on the Macintosh
02	Address Error	Your program has attempted to use an address which makes no sense to the operating system (a word or longword reference has been made to an odd address). Can be caused when an immediate operand is missing its #.
03	Illegal Instruction	The code in an instruction field does not represent any instruction in the 68ØØØ's instruction set. Check immediate addressing for missing #.
04	Zero divide	Just what is says -- your program has attempted to do a division by zero.
05	Range Check Error	Failure of one particular 68ØØØ instruction -- **CHK** (checks one word of a data register against an upper - bound value).
06	Overflow	Failure of one particular 68ØØØ instruction -- **TRAPV** (executes a trap if the overflow flag in the status register is set).
07	Privilege violation	Not terribly important since all assembly language programs run in the "supervisor" mode, where you have access to all instructions.
08	Trace Mode Error	Trace mode is initiated by setting one of the bits in the user byte of the status register. The Macintosh never uses trace mode; therefore, this error will occur whenever the trace-mode bit is accidentally set.
09	Line 1Ø1Ø Trap	"Line 1Ø1Ø Trap" has to do with calling ToolBox routines (see Chapter 6).

(continued)

Error Code	Error Message	Comments
10	Line 1111 Trap	Another trap not used on the Macintosh. Line 1111 traps are reserved for further expansion of the instruction set (details are in Chapter 6).
11	Hardware Exception Error	The system thinks some other sort of trap has occurred. This usually means that the machine is seeing some sort of illegal binary instruction code. If you get this, check for addresses and/or operands that are the wrong size.
12	Unimplemented Core Routine	Can occur when a program invokes the debugger when the debugger isn't present in memory.
13	Uninstalled Interrupt	Can occur when a program invokes the debugger when the debugger isn't present in memory.
14	I/O Core Error	Problem with file access.
15	Segment Loader Error	Caused by failure of an attempt to load a program segment into main memory.
16	Floating Point Error	The problem lies in whatever part of the program calls FP68K, the Macintosh's floating point arithmetic package.
17-24	Packages Ø-7 missing	Packages are self- contained routines present in the system (see Chapters 6, 11 and 12 for more information).
25	Memory Full	You have two options -- upgrade to 512K or segment your program into portions that don't need to be memory co-resident.
26	Bad Program Launch	Usually caused by an attempt to launch a file that isn't an executable application.
27	File System Map Trashed	Something is wrong with a disk's directory.
28	Stack Ran Into Heap	Another sort of out-of-memory error.
29	not used	
30	Disk Insertion Error	Generates the "Please insert the disk:" alert.

(continued)

Table 3.1 (continued)

Error Code	Error Message	Comments
31	not used	
32-56	Memory Manager Errors	Indicate problems with the routines that manage the use of Macintosh RAM.
41	No Finder	The Finder isn't on any disk currently in the system's drives.
100	Bad startup disk	System can't boot because something is wrong with the startup disk. Causes a blank screen with a disk icon in the center. The disk icon contains a question mark.

The Executive

If you have been working along with this chapter, you may have decided that transferring from the Editor to the Assembler to the Linker and back again is a giant pain. There is a way, though, to "automate" most of the tedious steps in the process by using the Executive.

The actions of the Executive are controlled by a file created with the Editor and given the extension **.JOB**. A **.JOB** file has four fields, separated by tabs. The first field contains the names of the application to be executed (e.g., **ASM** or **LINK**). The second field contains what input the application requires (usually a file name). The third field is the application to which the Executive should return if the execution of the application in the first field is successful (usually the Executive). The fourth field is the application that should be executed if the execution of the application in the first field is not successful (usually the Editor).

An Executive control file for the Sample program might appear as:

```
ASM     Sample.Asm      Exec                Edit
LINK    Sample.Link     text.Disk:Sample    Edit
```

When setting up Executive control files, you need to pay attention to what disk your files are on. All applications should be on the startup disk (i.e., the internal drive). Source files (source code and Linker control files) should be on the same disk as the **.JOB** file (preferably on a text disk in the external drive). Because of disk space considerations, it will be very difficult to use the Executive with a single-drive system.

If you want the Executive to automatically run your program after it finishes linking (assuming your source files and the completed application are on a text disk in the external drive), precede the program's name with the name of the disk. For

example, if your text disk is named **Text.Disk** as in the sample **.JOB** file above, specify the name of the application to be created by the Linker as:

Text.Disk:Sample

The name of the application is separated from the name of the disk by a colon.

To initiate the actions specified in an Executive control file, enter the Executive. Usually, you will do so by either double-clicking on its icon from the Finder or transferring to it from the Editor.

The Executive's file select screen (Figure 3.15) lets you select the **.JOB** file to execute. Once you double-click on the file name, the process becomes automatic.

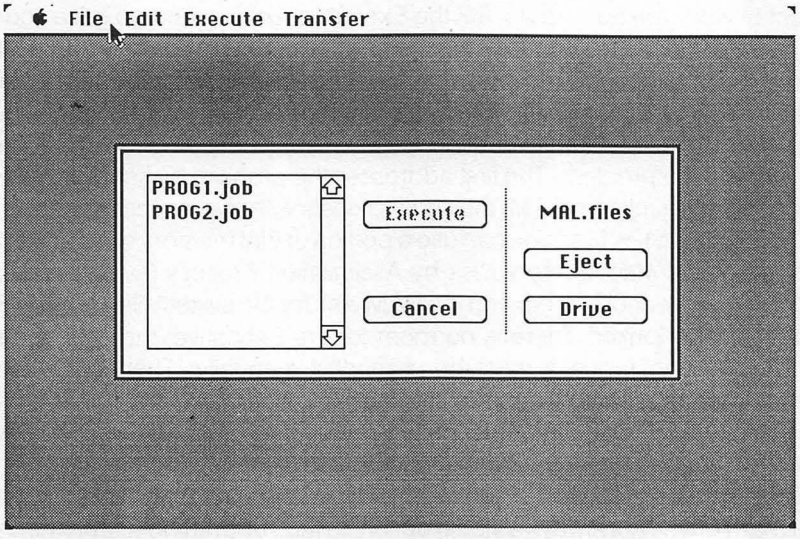


Figure 3.15 The Executive's File Select Screen

The two-line **.JOB** file above will perform the following actions:

1. Assemble the file **Sample.Asm**
2. If the Assembler detects errors, execute the Editor
   a. Make the file **Sample.ERR** the active window
   b. When **Sample.ERR** is closed, make **Sample.Asm** the active window

3. After a successful assembly, link the file **Sample.REL**, using **Sample.LINK** as the Linker control file
4. If the Linker detects errors, execute the Editor
   a. Make the file **Sample.LERR** the active window
   b. When **Sample.LERR** is closed, make **Sample.LINK** the active window
5. If the linking is successful, execute the completed application, **Sample**

Though using the Executive does not speed up the processes required to prepare an assembly language program (the Editor, Assembler and Linker still have to be loaded into memory every time you need them), it will decrease the amount of work *you* have to do. Set the Executive running and go get a soda. . .

The time it takes to prepare an assembly language program for execution is severely constrained by the Macintosh's disk access speed. When using the 68000 Development System as it is distributed by Apple there is no way to keep the Editor, Assembler, and Linker continuously in RAM. There are, however, two ways to get around the problem. The first addresses the problem by keeping the Editor, Assembler, and Linker in RAM; the second deals with disk access speed.

If you have a 512K Mac you can use a portion of that memory as a RAM disk. To do so, purchase *Mac Memory Disk* by Assimilation Process (available for about $30). There is just enough room on the RAM disk for the system files and the Editor, Assembler, and Linker. There is no room for the Executive; the editing, assembling, and linking process must be managed manually. That is far less of a disadvantage than it might seem. Since all three programs are in RAM, transfer between them is almost instantaneous. The major drawback to using the RAM disk is that it doesn't leave enough room in memory for a debugger.

The only way to speed up disk access time is to use a hard disk. In terms of cost, a hard disk is not always a viable option. In fact, upgrading a 128K machine to 512K and purchasing the RAM disk software will cost far less than purchasing a hard disk.

When you use the Executive, you no longer have access to the Assembler and Linker **OPTIONS** menus (e.g., to control listings). You must therefore specify the options you want in your source file (see the section on Assembler Directives in Chapter 4).

Debugging

An assembler, like an interpreter or compiler, checks for syntax errors as it translates source code to object code. None of the three translation programs, however, can catch logic errors; they simply aren't capable of "understanding"

what a programmer intended. Finding logic errors is therefore the toughest part of the programming. A *debugger* is a program designed to help the assembly language programmer with that task.

When debugging a Pascal program you may have placed **writeln** statements at strategic places in the code to display the contents of important variables. This allowed you to monitor the contents of the variables as they changed and helped you pin-point the exact spot in a program where something went wrong. The same strategy isn't sufficient, however, when you are working in assembly language.

Assembly language programs have much greater control over the computer than high-level language programs in the sense that as well as manipulating data storage locations (i.e., variables) they have direct access to the CPU's registers. Therefore, in order to find the source of an error it is usually necessary to see what is happening within the registers while the program is running.

A debugger is a program that, among other things, will do the following:

1. Run an assembly language program one instruction at a time
2. Display the contents of the CPU's registers after each instruction is executed
3. Display the contents of main memory locations
4. Disassemble program instructions from either RAM or ROM.

It is generally very difficult to successfully complete an assembly language program without at some point employing a debugger.

If you open the **Debuggers** folder on MDS2, you will find not one, but six debuggers. The best one is MacDB. Unfortunately, you need two Macintosh's hooked together to use it (one runs the program and the other runs the debugger). Of the other five, two require external terminals (TermBugA and TermBugB) and one runs on the Lisa (LisaBug). Both MidiBug and MaxBug, though, will run on a single, free-standing Macintosh.

MaxBug will run only on a 512K machine. MidiBug will run with 128K, but (and this is a very big "but") once MidiBug is installed, there is no room in memory for any other application (the Editor, Linker, etc.). Why is this such a problem? Debuggers can't be executed like other applications (i.e., by clicking an icon from the Finder). Instead, whenever you boot a disk containing a file called **MacsBug** (regardless of whether that file was originally MidiBug or MaxBug), that debugger will be automatically placed in memory. It will sit in memory until invoked by an "exception" in your program.

This means that whenever you want to run a program and use MidiBug with a 128K machine, you must:

1. Create a special debugging disk with a file named **MacsBug** on it. (Be sure the file is a renamed MidiBug since MaxBug won't fit, no matter how hard you try.)

2. Use MDS1 to boot your Macintosh and complete the assembly and linking process
3. Copy the completed application to the debugging disk
4. Reboot the system with the debugging disk as the startup disk

This long procedure would appear to be the only way to use a debugger with a 128K machine.

The presence of a debugger in memory does not necessarily mean that the debugger will be activated when you run an application. The debugger must be "invoked." Though there are several ways to do so, the easiest is to include the instruction:

__Debugger

in your source code at the point you wish the debugger to take over.

MidiBug and MaxBug provide the same kind of display; with MaxBug you simply get more of it. Figure 3.16 shows the information you receive after the execution of a single instruction.

```
>
ØØCCFE:                                  PC MOVE.W #$ØØ3E,-(A7)
PC=ØØØØCCFE  SR=ØØØØAØ14
DØ=ØØØØØØØØ D1=ØØØØØØFF  D2=ØØ3FØØØØ  D3=ØØØØØØØØ
D4=ØØØØØØ18  D5=ØØØØØØØØ D6=ØØØØØØØØ  D7=ØØØØØØØØ
AØ=ØØØØ22CØ  A1=ØØØØØ21F  A2=ØØØ1437A  A3=ØØØ7Ø364
A4=ØØØ142AF  A5=ØØØ7ØE42  A6=ØØØ7Ø68Ø  A7=ØØØ7ØD3C
>
```

Figure 3.16 MidiBug and MaxBug Display

The debugger first prints the starting address of the instruction in main memory (in Figure 3.16, $00CCFE). It then disassembles and prints the instruction itself. It is important to remember that what is being disassembled is the object code that is stored in RAM. That means that the symbolic addresses that you used in your source code will not appear; instead you will see the absolute addresses that were substituted for the symbolic addresses during the assembly and linking process. All addresses and quantities are expressed in hexadecimal, regardless of the numbering system used in your source code. The stack pointer disassembles as A7, even though it may have been referred to as **SP** in the original program.

The remainder of the debugger's output displays the contents of the 68000's registers. **PC** refers to the program counter, **SR** to the status register, D0–D7 to the eight data registers, and A0–A7 to the eight address registers. All register contents are in hexadecimal.

Once a debugger is invoked, it will print its > prompt, display information about the current instruction, print another >, and wait for your command. Though there are many commands to control action of the debugger, two will be of the most use. **T** (for Trace) executes a single instruction. Traps (calls to ToolBox and operating system routines) are handled as if they were one instruction; the debugger will not trace the instructions that are part of the ToolBox or operating system routine.

S (for Step) when used alone, will also execute one instruction. Traps, though, are not treated as single instructions; the debugger will display each step in any ToolBox or operating system routines. You can also execute a series of instructions with Step by appending a quantity to the command that represents the number of commands to be executed. For example,

S 6

will execute six instructions, printing the debugging information about each one.

MidiBug replaces the very bottom of the screen with output for one instruction. The rest of the screen displays the output from the program being executed. As you execute successive instructions, the display for the previous instruction will scroll out of sight.

MaxBug replaces the entire screen with its own output and can therefore display information for up to five instructions at one time. If a program affects Macintosh's screen, then MaxBug will briefly show program output each time the screen changes and then return to the debugging display. The ` key (the key above and to the left of the TAB) will also toggle between the application's screen and the debugger's screen.

Using a debugger does present one problem. Since the debugger is monitoring the keyboard for your commands, it effectively prevents a program from getting input from either the keyboard or the mouse. If a program expects input to stop a loop, then when you run the program from within the debugger, you won't be able to stop the loop the same way you would if the program were running on its own. The situation can be somewhat distressing, since a disk drive may be spinning continually when you are using the debugger. (There is a process for stopping a drive while using a debugger; see the MDS manual.)

Ultimately, most loops stop by checking one of the flags in the status register. For example, the Sample program uses an instruction that checks the zero flag (bit 2). If the zero bit is set, the loop continues; if the bit is clear, the loop will end and the program stop. The solution, then, is to trick the program into thinking that it has required input by manually clearing the zero bit.

In Figure 3.16, the contents of the status register is $0000A014, which means that the zero bit is set. How in the world can you tell? Remember that each hexadecimal digit represents four binary digits. Therefore, the 4 in the right-most position actually represents $0100. The zero bit is bit 2 (the third bit from the right). What we need to do is replace the 4 with the hexadecimal representation of any of the following code groups: %0000, %0001, %0010, %0011, %1000, %1001, %1010, or %1011 (in hexadecimal: 0, 1, 2, 3, 8, 9, A, or B). The trick is that the third bit must be zero; the contents of the others is irrelevant.

The command:

SR 0000A010

will replace the contents of the status register with whatever follows **SR**. Give the debugger this command just before executing the instruction that tests the zero bit.

The debuggers allow you to change the contents of any register at any time.

Dn new contents

will replace the contents of data register **n**.

An new contents

will do the same for address register **n**.

To replace the contents of the program counter, use:

PC new contents

Be very careful when changing the program counter, since the instruction executed after a **T**race or **S**tep instruction will be whatever instruction begins at the address in the program counter.

To see the assembly language version of an application's instructions as they are stored in memory, use **ID** (instruction disassemble). Used alone, **ID** will disassemble the instruction at the current contents of the program counter. Follow **ID** with an address and it will disassemble the instruction at that address.

The debugger command **SM** (set memory) will change the contents of a memory location. It's general form is:

SM main memory address new contents

For example:

SM 1A2B 33

will place $33 in location $1A2B. Note that the debugger expects all addresses and quantities to be expressed in hexadecimal; no leading **$** is necessary.

In some cases, you may wish to trace a few steps of a program and then let it run on its own again. The command **G**, for GO, will resume normal program execution, sending the debugger back into the background. It is therefore possible to place the trap that invokes the debugger at several places in a program. This will allow you to trace a few steps at whatever parts of the program are of interest.

If a program is so full of bugs that it cannot terminate successfully on its own, there are two ways to exit the debugger. The debugger command **ES** (exit to shell) will generally return to the Finder (note that some program errors will cause this command to fail and your only recourse is to reboot). **RB** (reboot) will reset the machine.

The successful use of a debugger is something that cannot be directly taught; it's something that comes from practice. To begin to understand what a debugger does, insert **__debugger** in the Sample program just below the **__InitFonts** statement. Copy the appropriate debugger onto a disk that also contains a System Folder. For a single drive system, place the final version of the Sample program on this disk as well; in a two-drive system, the Sample program should be on a text disk in the external drive. Boot the system to install the debugger and then run the Sample program by double-clicking on its icon. The debugger screen will appear almost instanteously.

Monitor the progress of the program using the **T** command. Keeping a printed listing of the program handy will also aid in understanding what appears on the screen. Look primarily at how each instruction changes the contents of the CPU's registers. Experiment with the other debugger commands. When you are finished, type **G** to return control to Sample so that it can terminate with a click of the mouse button or a key press.

C H A P T E R F O U R

THE 68000 INSTRUCTION SET (PART 1)

Chapter Objectives

1. To create an I/O shell program that can be used to explore the 68000 instruction set
2. To understand the purpose and use of assembler directives
3. To understand data manipulation instructions (**MOVE, LEA, PEA**)
4. To understand instructions used to make comparisons in assembly language programs
5. To take a first look at creating a loop within an assembly language program, including instructions which execute unconditional branches

Creating an I/O Shell

Since all Macintosh I/O is done exclusively through the ToolBox, if you are going to see the result of executing even the simplest 68000 instruction, you'll need to be able to use the ToolBox right away. That would seem to mean that you must learn how to use the ToolBox at the same time you are learning the instruction set.

If, though, you modify the Sample program from Chapter 3 so that it appears as in Listing 4.1, you will have a ToolBox "shell" into which you can insert bits of 68000 code. The shell will display the results of executing those instructions. You can

then, for the most part, leave worrying about the ToolBox until you understand the instruction set. Therefore, many of the program listings in this chapter are designed to be inserted into the shell (as indicated in Listing 4.1) before they are run.

Listing 4.1 Sample Macintosh Assembly Language Program

```
Include MacTraps.D      ;Includes addresses of ToolBox routines
Include ToolEqu.D       ;Includes the ToolBox equates
Include SysEqu.D        ;Includes the System equates

PEA -4(A5)
_InitGraf               ;Initializes QuickDraw
_InitWindows            ;Initializes the Window Manager
_InitMenus              ;Initializes the Menu Manager
_InitFonts              ;Initializes the Font Manager


CLR.L  -(SP)            ;Clear space for WindowPtr result
PEA    StoragePointer   ;Window Storage pointer
PEA    BoundsRect       ;Exterior coordinates of window
PEA    'MAL Output Window'   ;Title
ST     -(SP)            ;Make the window visible
MOVE  #documentProc,-(SP)  ;Make it a standard document window
MOVE.L #-1,-(SP)        ;Put the window in front
ST     -(SP)            ;Draw a go-away box
CLR.L  -(SP)            ;Place for window's reference value
_NewWindow              ;Draw a standard document window

LEA    WindowPtr,AØ     ;load destination address for pointer
MOVE.L (SP)+,(AØ)       ;retrieve pointer

MOVE.L WindowPtr,-(SP)
_SelectWindow

MOVE.L WindowPtr,-(SP)      ;put pointer back on the stack
_SetPort                ;make this window the current grafport

_InitCursor             ;set the cursor to the arrow


MOVE.W #7,-(SP)         ;7 = athens
_TextFont               ;Set the text font

MOVE.W #18,-(SP)        ;18 for 18-point type
_TextSize               ;Set the text size

MOVE.W #65,-(SP)        ;Horizontal coordinate
MOVE.W #1ØØ,-(SP)       ;Vertical coordinate
_MoveTo                     ;Move the pen
```

(continued)

Listing 4.1 (continued)

```
;-------------------------------------------------------------------------

        PEA     'HOORAY!!! You did it!'     REMOVE THESE STATEMENTS
                                            TO CREATE THE TOOLBOX
                                            SHELL
        _DrawString

;-------------------------------------------------------------------------
        MOVE.L everyEvent,DØ;Mask to select all events
        _FlushEvents            ;Clear the event queue

Event   CLR     -(SP)           ;Space for boolean result
        MOVE    #%ØØØØØØØØØØ111111Ø,-(SP)    ;Mask for keyboard and mouse
        PEA     EventRecord     ;Place to receive event info
        _GetNextEvent           ;Get next event from queue

        MOVE    (SP)+,DØ        ;Has a keyboard or mouse event occurred?
        CMP     #Ø,DØ
        BEQ     Event           ;If no event, branch to look again

        RTS                     ;Return to the Finder

WindowPtr       DC.L    Ø
BoundsRect      DC.W    4Ø,2Ø,3ØØ,35Ø
everyEvent      DC.L    $ØØØØFFFF
EventRecord             ;where GetNextEvent Puts its result
What    DC      Ø
Message         DC.L    Ø
When    DC.L    Ø
Point   DC.L    Ø
Modify  DC      Ø
```

Assembler Directives

lacintosh assembly language source file may contain more than just 68000 ;ions. It can also include *assembler directives*. Assembler directives are l mnemonics that give the assembler directions that are to be followed the assembly process. Most of them involve setting aside space for storage. ;an also assign values to symbolic addresses and cause external source files ncluded as a part of the file being assembled.

EQU (Equate)

One of the most useful assembler directives is **EQU** (equate). **EQU** assigns a permanent value to a symbolic address. For example:

```
Name  EQU  0
```

assigns the value 0 to the symbolic address **Name**. Then, instead of using 0 in source code, use **Name**. When the program is assembled, the value 0 will be substituted for **Name** everywhere it appears.

An equate is directly equivalent to assigning a constant value to an identifier in the **const** block of a Pascal program. Like Pascal constants, the values assigned to symbolic addresses by **EQU** cannot be changed during program execution.

To handle equates and other symbolic addresses, the assembler builds a *symbol table*. Think of a symbol table as a two-dimensional array kept in RAM while the assembler is running. One column holds the symbolic addresses; there is therefore one row in the symbol table for each symbolic address. A second column in the table identifies the type of symbolic address (e.g., whether it is an equate or a statement label). The assembler enters a symbolic address into the symbol table when it is first encountered. For an equate, a third column in the array holds the value assigned to the symbolic address. For statement labels, the third column holds the address of the program statement to which the label refers.

Each time the assembler recognizes a reference to a symbolic address in the program being assembled, it checks the symbol table to see if it can find an entry for that symbolic address. If the symbolic address is an equate, then the assembler merely substitutes the value of the equate in the table for the symbolic address in the source code.

Because the assembler expects to find an entry for an equate in the symbol table, **EQU** statements must appear before their symbolic addresses are used in program instructions; otherwise, the program simply will not assemble. It is therefore good programming to group all **EQU** statements together (along with comments explaining what they reference) immediately after the **INCLUDE** directives (discussed directly below) at the very beginning of the program.

You can **EQU** addresses as well as constant numeric data. For example, if you include:

```
Address_1  EQU  $1A3B
```

in source code, you can use **Address_1** in any place where you need to reference the address $1A3B. It is acceptable in any of the Macintosh's addressing modes that accept absolute addressing.

What, then, is in those equates files (e.g., ToolEqu.D and SysEqu.D) that came with your Macintosh 68000 Development System? If you look at the source listings (ToolEqu.Txt and SysEqu.Txt) you'll see that both files are nothing more than a series of **EQU** statements. They set up constants that are useful when working with ToolBox and operating system routines.

INCLUDE

To make the symbolic addresses available in the equates file to any program you write, **INCLUDE** the equates files. **INCLUDE** is another assembler directive. It instructs the assembler to seek another source file which is to be inserted into a program. To use **INCLUDE**, specify:

```
INCLUDE   fname
```

where **fname** is the name of the source file to be included in the program being assembled.

Data Allocation

There are two assembler directives that fall into the classification "data allocation directives." These set up symbolic addresses for storage locations in either the program itself or the applications globals area of RAM. You can think of them as analogous to variable names (i.e., the symbolic address represents the *location* of one or more pieces of data). The contents of storage locations identified by such symbolic addresses can be changed while the program is running.

DC (define constant) assigns one or more values to a symbolic address. The statement:

```
Label   DC   0
```

will, for example, cause the following actions during assembly:

1. An address for **Label** will be selected at the end of the source code. (If you look at the bottom of the assembler listing for the Sample program, you will see the space that has been allocated for each **DC** directive.
2. **Label** will be associated with that address.
3. The address associated with **Label** will be given an initial value of 0.

There are four variations on the define constant directive: **DC, DC.B, DC.W, DC.L**. The extensions determine whether the data will be aligned on byte, word, or longword boundaries. If no extension is present, the data will be aligned on word boundaries by default.

At first glance, it might seem that **DC** isn't much different from **EQU**. Remember, though, that **EQU** assigns a permanent value to a symbolic address, whereas values assigned by **DC** are only initial values and can be changed by the instructions within a program.

The fact that **DC** allows changing the value associated with a symbolic address does not mean that you should necessarily do so. It is good practice to use **DC** only

to store constants and not as locations for data that will change (i.e., consider a location established by **DC** as if it were in ROM, useful for read-only operations). The major exception to this rule occurs when an application does printing (see Chapter 10 for details).

DC is also used to assign a series of storage locations, each with its own unique value, to a single symbolic address. The statement:

```
Label  DC  0,16,'A Sample Window'
```

reserves enough storage to store the values 0, 16, and the string "A Sample Window." Use of the symbolic address **Label** will reference the two numeric values and the string. This capability is important when preparing data for use with ToolBox routines.

DCB (define constant block) sets aside a block of memory locations, all of which will be initialized to the same value. (Notice that this is not the same as using **DC** to reference a series of values, since the **DC** values can be different from one another.) To use **DCB**, you must not only specify the initial value for the storage locations, but the length of the block of locations to be reserved. For example:

```
Label  DCB  12,0
```

will reserve twelve words of storage, beginning at the symbolic address **Label**. Each location will be given the initial value 0.

The general form of the **DCB** assembler directive is:

```
Symbolic address  DCB  length of block, initial value
```

The actual number of bytes reserved depends on the extension applied to the **DCB** directive. If there is no extension, or if you use an extension of **.W**, the "length of block" parameter will refer to the number of words to be set aside. An extension of **.B** indicates that the length is expressed in bytes; **.L** specifies a length in number of longwords.

DS (define storage) also reserves a block of storage locations. This storage does not become a part of an assembled program. Rather, it is allocated in the applications globals area at run time. This form of storage allocation should be used for all read/write operations (i.e., a program should avoid writing into its own code, as it would if you wrote to a **DC** location).

The applications globals area begins at $ – 100(A5) and grows *down* in memory. All storage locations allocated by **DS** must therefore always be referenced relative to A5 with what looks like Address Register Indirect with offset addressing. Since A5 always contains the starting location of the applications globals area, its contents should never be changed during program execution.

The general form of the statement is:

```
Symbolic address  DS  length of block
```

Therefore, the statement:

```
Label  DS  12
```

will set aside twelve words of storage. No initial value is given to the storage.

As with the **DCB** directive, how the length parameter is interpreted depends on the extension affixed to the mnemonic. No extension or an extension of **.W** refers to words, **.B** to bytes, and **.L** to longwords.

Access to the storage set aside by **Label** above appears as:

```
Label(A5)
```

The amount of space needed for **DS** locations appears on the Linker screen during the linking process beside the label "Data Size."

End of Source

Another essential assembler directive is **END**. **END** is the last statement in a source code file. Any statements after **END** will be ignored by the assembler. It is important to remember that **END** is the *physical* end of the source code. It has nothing to do with the *logical* end of a program.

Printing Control Directives

If you are using the Executive, you cannot control listing options from the **OPTIONS** menus in the Assembler and Linker. You can, though, specify the same choices in your source code.

.EJECT will cause the printer to start a new page. This directive will take effect when creating a hard copy of either an assembler or linker listing.

.Verbose, ListToFile, and **.ListToDisp** have the same effect as selecting those commands from the **OPTIONS** menus (see Chapter 3). To turn off verbose assembly or a listing use **.NoVerbose** or **.NoList** respectively.

Data Manipulation Instructions

An important part of any microprocessor's instruction set is concerned with moving data around in memory. Arithmetic instructions require that at least one operand be located in a data or address register. Even more importantly, the Macintosh's ToolBox routines look for parameters which have been placed on the

stack; operating system routines expect their parameters to be pointed to by addresses in registers.

The most frequently used 68000 data manipulation instructions used in Macintosh assembly language programs are **MOVE, PEA, LEA**.

MOVE

The **MOVE** instruction takes a piece of data and shifts it from one location to another. Like an assignment statement in a high-level language (e.g., C=A), the data in the source location is *copied* into the destination location; the contents of the source location are not altered.

The format of the **MOVE** instruction is:

MOVE source address, destination address

For example:

MOVE #12,D1

will put the decimal quantity 12 into data register D1. (Remember that when # precedes a number it will be interpreted as a quantity rather than as an address.)

The size of the operand transferred by a **MOVE** statement depends on the extension given the instruction. **MOVE** or **MOVE.W** will move one word of data. **WORD.B** will move a byte and **MOVE.L** will move a longword.

Source and destination addresses can be specified using most of the 68000's addressing modes. The examples which follow will show you the ones most commonly used.

In order to see the results of **MOVE** statements, let's use a ToolBox routine to display a single character on the screen. This routine is called **DrawChar** and it expects to find the ASCII code for the character to be printed on the top of the stack. Therefore, the step that immediately precedes the call to **DrawChar** must **MOVE** a character onto the stack.

All ToolBox routines are called by their names. To let the assembler know that the statement is a call, an underbar (_) is put in front of the routine name. Therefore, if you put the line:

_DrawChar

into your source code, it will execute the **DrawChar** routine. More detail on how such calls work appears beginning in Chapter 6.

The ASCII code for a character is placed on top of the stack using Address Register Indirect with Predecrement addressing. (In fact, putting things on the stack is a very common use of this addressing mode.) For example:

MOVE source address, – (SP)

This statement will cause the Mac to first decrement the contents of the stack pointer (SP or A7). The data pointed to by the source address will then be moved to the new address contained in the stack pointer.

Why is the address decremented rather than incremented? Remember that the stack starts high in memory and grows down (i.e., the bottom of the stack has a high address; the top of the stack will always have an address *lower* than the bottom). Therefore, each time we put something on the stack, the address of the top must first be decreased.

Insert these statements into the ToolBox shell:

```
MOVE   #$0040, – (SP)
_DrawChar
```

When you assemble, link, and run the program, the character "@" will print on the screen (see Figure 4.1). $0040 is the ASCII code for "@". Because $0040 is preceded by **#**, the quantity $0040 is moved to the stack. This is an example of using immediate data as the source address in a **MOVE** statement. (Note: The **DrawChar** routine expects to find an entire word of data on the stack. Though ASCII codes occupy only a single byte, you must nevertheless move a word onto the stack with the ASCII code in the low-order byte. Thus we move $0040 onto the stack, forcing the ASCII code into bits 0–7.)

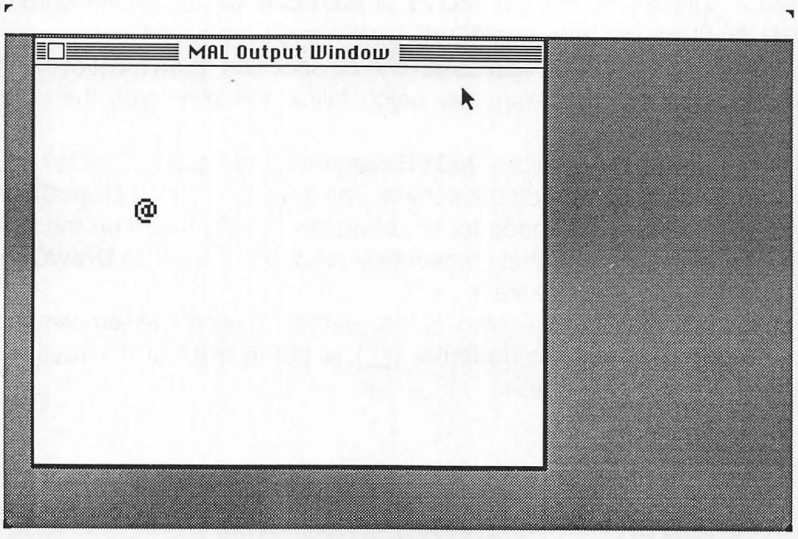


Figure 4.1 Output From a Single Call to DrawChar

It is also possible to use **MOVE** to take things off the stack. This is important because many of the ToolBox routines return information needed later in a program. That information is placed on the top of the stack. If you use the instruction:

```
MOVE  (SP)+,D1
```

the contents of the RAM location pointed to by the contents of the stack pointer will be moved to data register D1. Then the stack pointer will be incremented.

As we have previously discussed, when an operand or address is placed on the stack, the contents of the stack pointer must be decremented. Similarly, when something is taken off the stack and effectively "removed" from the stack, the stack pointer must be incremented. Therefore, the example above uses Address Register Indirect with Postincrement addressing. The contents of the stack pointer are incremented *after* the instruction is executed. This is probably the most common situation in which this particular addressing mode is used.

Other addressing modes are also commonly used with the **MOVE** statement. Remove the two statements you previously placed in the ToolBox shell and insert the following:

```
MOVE  #$0040,D1
MOVE  D1,-(SP)
_DrawChar
```

Running the program should still print that "@." (If you're getting tired of "@," substitute the hexadecimal equivalent of any other ASCII code Macintosh uses.)

The first **MOVE** uses Data Register Direct addressing to specify the destination address. The $0040 will be stored in data register D1.

The second **MOVE** uses the same addressing mode to specify the source address. The contents of data register D1 are moved onto the top of the stack (after, of course, the contents of the stack pointer [A7] are decremented).

You can also move data stored under symbolic addresses. For example, try this in the shell:

```
Data    EQU   $0040
        MOVE  #Data,-(SP)
_DrawChar
```

The **EQU** permanently associates the symbolic address **Data** with the value $0040. Using the symbolic address in the **MOVE** statement has the same effect as using $0040 as immediate data. Notice that just like the number $0040, the symbolic address was preceded by a **#** so that the assembler realized that the quantity stored as **Data** was to be used as immediate data rather than as an address.

Symbolic addresses assigned values by **EQU** can be used anywhere you would use data. For example:

```
Data    EQU     $0040
        MOVE    #Data,D1
        MOVE    D1,-(SP)
        _DrawChar
```

will put **$0040** into data register D1 and then move it onto the stack. If you put the above code into the ToolBox shell, you should still see "@" printed in the output window.

MOVE can also be used to transfer data between registers. The third line of the following code will move the contents of data register D1 to data register D2.

```
Data    EQU     $0040
        MOVE    #Data,D1
        MOVE    D1,D2
        MOVE    D2,-(SP)
        _DrawChar
```

The source address in a **MOVE** statement can be specified using any of the 68000's addressing modes. The destination address, however, cannot be specified with immediate addressing nor can it use either of the program counter addressing modes.

The reason immediate addressing cannot be used should be obvious. The destination must be a *location*, a place to put something. It's simply not possible to store something in a piece of data.

Why the program counter modes can't be used may not be so clear. But consider this: if you store a piece of data in the program counter, you will destroy the previous contents of the program counter. Since the program counter keeps track of which instruction is to be executed next, erasing that address will completely disrupt program execution.

The **MOVE** instruction, like most other instructions, affects the flags in the status register. The extend bit is unaffected. The carry and overflow bits always get a value of 0. (We say that they are *cleared*.)

What happens to the negative and zero bits depends on the value being moved. If the value is equal to zero, the zero flag will be set (given a value of 1) and the negative bit will be cleared. If the value is negative, the negative bit will be set and the zero bit cleared. If the value is positive, both bits will be cleared.

PEA

The letters **PEA** stand for Push Effective Address. This instruction is not commonly used in many 68000 machines, but because it pushes addresses onto

the stack and then automatically decrements the stack pointer, it is extremely useful for setting up parameters for ToolBox routines.

Take a look at the two statements you removed from the Sample program to create the shell:

```
PEA  'HOORAY!!!  You did it'
_DrawString
```

This use of the ToolBox routine **DrawString** displays the string that you see as the operand for the **PEA** instruction. Like **DrawChar, DrawString** looks for its operand on the stack. The string itself, though, is not placed on the stack; during assembly and linking it is placed at the end of the program code. Therefore, when you want to display a string, push a *pointer* to the start of the string.

What's a pointer? A pointer is an address that corresponds to the starting address of a series of storage locations. Usually, a pointer will be the starting address of a string or a data structure in main memory.

The general form of the instruction is:

PEA effective address of source data

PEA can use any addressing mode except immediate, simply because immediate data isn't an address. This instruction does not affect the codes in the status register.

LEA

LEA stands for Load Effective Address. It moves an address into an address register. The general form of the instruction is:

LEA source address, destination address register

LEA is most useful for retrieving the absolute address assigned to a symbolic address. To see how it works, let's look at the data structure used to pass parameters to the operating system routines that provide access to disk files.

```
paramBlock
        Link        DC.L  0
        Type        DC    5
        Trap        DC    0
        CmdAddr     DC.L  0
        Complete    DC.L  0
        Result      DC    0
        NamePtr     DC.L  0
        VRefNum     DC    2
```

These eight parameters are common to all file manager routines. (The complete parameter block contains 8 to 16 additional fields, depending on the specific routine.) The first four fields are used by the File Manager. The other four, though, are of concern to the programmer.

For example, **NamePtr** must contain the address of the location where the name of a file is stored. The pointer must be loaded into **NamePtr** before calling the File Manager routine. Assume that the file name is stored under a symbolic address:

```
Fname  DC  'SampleFile.Text'
```

The instruction:

```
LEA  Fname,A1
```

will store the starting address of the string **SampleFile.Text** in **A1**. This is an example of absolute addressing, since **Fname** represents a specific RAM location.

To put that address into **NamePtr**, the address of **NamePtr** must also be available in an address register:

```
LEA  NamePtr,A2
```

Then, a program can execute:

```
MOVE.L  A1,(A2)
```

This statement takes whatever is stored in A1 (the address of **Fname**) and stores it at the address stored in A2 (the address of **NamePtr**).

There are some things that are important to remember about **LEA**. The destination of the instruction is always an address register. The mnemonic does not take any extensions; **LEA** always transfers a full longword (even though the addresses are only 24 bits).

The source address can be either in an address register, the program counter, or can be an absolute address. Three address register indirect addressing modes are acceptable: Address Register Indirect, Address Register Indirect with Displacement, and Address Register Indirect with Displacement and Index. Both of the program counter modes can also be used for the source address.

LEA does not affect any of the flags in the status register.

LOOPING

Executing a series of statements repeatedly is rather easy in a high-level language. In Pascal for example, you can use WHILE/DO,REPEAT/UNTIL, and

FOR to implement iteration. With 68000 assembly language, though, there are no built-in looping instructions. To understand the sequence of instructions necessary to create a loop, consider the steps required to repeat a set of instructions a fixed number of times.

1. Initialize the counter to 1.
2. Compare the counter with the quantity that represents the number of times the loop is to be executed.
3. If the counter equals the ending value, then terminate the loop.
4. Otherwise, execute the instructions that form the body of the loop.
5. Increment the counter.
6. Return to step 2.

To program a loop in assembly language, you must execute each step above.

To see a loop in action, insert the following instructions into your I/O shell:

```
        MOVE    #1,D1           ;counter
        MOVE    #5,D2           ;number of times to execute loop
Again   CMP     D1,D2           ;check the counter
        BMI     Done            ;end the loop
        MOVE    #$0040,-(SP)
        _DrawChar
        Add     #1,D1           ;increment the counter
        BRA     Again           ;continue the loop
```

In order to get this code to work (it should print a series of six "@"s as in Figure 4.2), place the symbolic address **Done** in the label field of the statement:

```
MOVE.L  everyEvent,D0
```

so that the statement appears as:

```
Done    MOVE.L  everyEvent,D0
```

This sequence introduces four new instructions: **CMP** (used to make decisions), **BMI** (one way to check the flags in the status register), **ADD** (integer addition), and **BRA** (one way to do an unconditional branch). Once you are familiar with these instructions and their variations you will, believe it or not, know most of the instructions used in Macintosh assembly language programs.

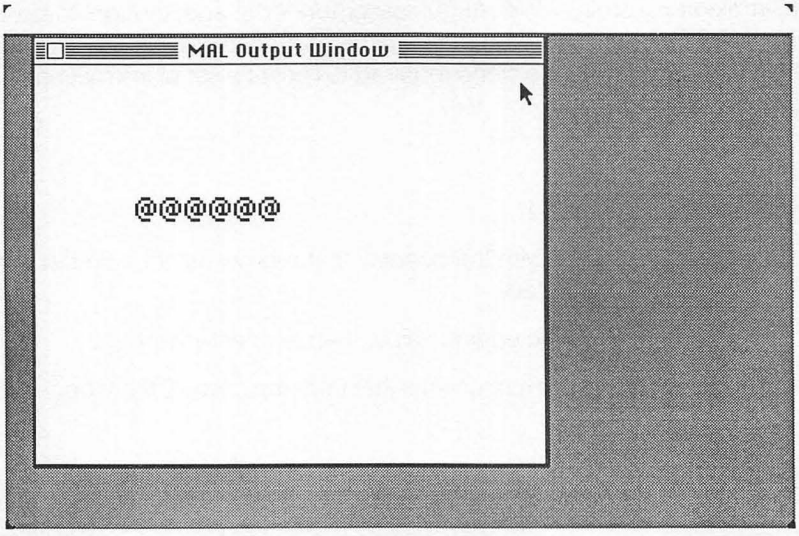


Figure 4.2 Output From Multiple Calls to DrawChar

Making Comparisons

The 68000 instruction set has one generalized instruction for making comparisons – **CMP**. (There are others, but they are more specialized and less commonly used.) The general form of the instruction is:

CMP address of source operand, destination data register

CMP *subtracts* the source operand from the quantity in the destination data register. The result of the subtraction isn't stored anywhere. The instruction does, though, set the codes in the status register according to that result.

For example, consider this series of instructions:

```
MOVE    #6,D1
MOVE    #10,D2
CMP     D1,D2
```

The **CMP** instruction will perform the subtraction "10 – 6." The result (4) is not stored anywhere. The negative bit in the status register is cleared (the result was positive). The zero bit is also cleared (the result was non-zero). Since no overflow occurred and no borrow was required, both the overflow and carry bits are cleared. **CMP** does not affect the extend bit.

Now, look at these instructions:

```
MOVE    #12,D1
MOVE    #10,D2
CMP     D1,D2
```

The result of the subtraction is −2. Therefore, the negative and carry bits will be set and the others cleared.

After executing:

```
MOVE    #5,D1
MOVE    #5,D2
CMP     D1,D2
```

only the zero bit will be set; all the others will be cleared.

CMP will work with characters as well as quantities. If you think about ASCII codes for a moment, you'll notice that letters that come alphabetically first have numerically lower codes than those that come later (e.g., A = $41, B = $42, C = $43, etc.). Therefore, when **CMP** performs a subtraction using ASCII codes, a program is actually testing for alphabetical order.

For example:

```
MOVE    #$0043,D1
MOVE    #$0046,D2
CMP     D1,D2
```

tests whether **C** comes before **F** in an alphabetical sequence. Remember that lower-case letters have different codes from upper-case letters so, for example, **h** will be greater than **H**.

You can specify the source operand using any addressing mode.

Testing the Condition Codes

CMP is conceptually only part of an **IF/THEN** statement. It compares the operands in question and sets the status register so you can actually test the condition. Testing the condition requires a separate instruction.

In Pascal, any executable statement, including a compound statement, can follow **THEN** for execution if the condition is true. In assembly language, you are much more limited. Though you can test for a variety of relationships between the quantities being compared (e.g., equal to, not equal to, greater than, less than,

plus, etc.), there are only two possible actions: you can branch to another instruction (the branch will take place if the condition is true; otherwise program execution continues with the next statement); or you can set or clear a destination byte (the byte will be set if the tested condition is true, cleared if the condition is false).

Using Pascal, you would write:

IF condition is true THEN GOTO symbolic address

or

IF condition is true THEN destination byte = $FF
ELSE destination byte = $00;

Regardless of whether you decide to branch or set a byte, you will still be testing the condition codes that were set during a previous operation.

Bcc

Bcc stands for Branch on Condition Code. It is a *conditional* branch, since the branch occurs only if the condition being tested is true. The **cc** is replaced by two letters which stand for the specific condition you want to test. The most commonly used forms are:

BEQ Branch if Equal (true if the zero bit is set)
BNE Branch if Not Equal (true if the zero bit is clear)
BMI Branch if Minus (true if the negative bit is set)
BPL Branch if Plus (true if the negative bit is clear)

The following conditions, also often used, are tested using logical combinations of the bits in the status register:

BGE Branch if Greater Than or Equal To
BGT Branch if Greater Than
BLE Branch if Less Than or Equal To
BLT Branch if Less Than

The full set of condition codes can be found in the *68000 Programmer's Reference Manual* that came with your Macintosh 68000 Development System.

To use a **Bcc**, code a statement like:

Bcc symbolic address of destination

How does a branch work? During assembly, the assembler computes the number of bytes between the **Bcc** instruction and the destination statement. This quantity, know as an offset, becomes a part of the instruction in the object code.

When the statement is executed, the appropriate condition codes are tested. If the condition is true, the offset is added to the contents of the program counter. The program continues at the program counter's new contents. The offset is limited to the quantity that will fit in one word.

To explore how **Bcc** works, insert the following code into your ToolBox shell:

```
            MOVE    #0,D1
            MOVE    #5,D2
            CMP     D1,D2
            BMI     LessThan
            PEA     'The source operand is smaller than the destination
                    operand'
            __DrawString
            JMP     Ending
LessThan    PEA     'The source operand is larger than the destination
                    operand'
            __DrawString
Ending              PEA '!!!'
            __Drawstring
```

Vary the mnemonic in the fourth line (**BMI**) to see how the different conditions work. You can also put different values in D1 and D2. Try, for example, using equal quantities.

Unconditional Branching without Tests

There is one instruction in the above example that we haven't discussed — **JMP**. **JMP** is one of two instructions that does an *unconditional* branch. ("Jump directly to a symbolic address; Do not pass Go, Do not collect $200. . .") The general form is:

JMP symbolic address of destination

During assembly, the symbolic address of the destination is replaced by the actual address of the destination instruction.

The other instruction that causes an unconditional branch is **BRA**. Like **Bcc**, during assembly the assembler computes the number of bytes between the **BRA** instruction and the destination instruction and turns that quantity into an offset. The offset is limited to the quantity that will fit one word.

The general form is:

BRA symbolic address of destination

When a program executes an unconditional branch, the contents of the program counter are changed. If branch is initiated by a **JMP** instruction, the address in the operand field will *replace* whatever was in the program counter. With **BRA**, the offset in the operand is *added* to the current contents of the program counter. In either case, program execution continues at the new address indicated by the modified program counter.

In most cases, choosing whether to use **JMP** or **BRA** is a toss up. If, though, you have a very long program and are concerned about space, **BRA** can save at least one word of space over **JMP**. In cases where the offset will fit within a byte, it is assembled in the same word as the **BRA** instruction. If the offset is more than 255, it will be assembled into the word after the instruction. A **JMP** always occupies two or three bytes, one for the instruction and one or two for the address, depending on its size. Therefore, if an unconditional branch spans less than 255 bytes, you will save one or two words of space in your object code every time you use **BRA** rather than **JMP**. On the other hand, if you want to shift program control more than 32,767 bytes (the maximum offset), you must use the **JMP**.

More on Testing Condition Codes (Scc)

The second option for action after testing a condition code—setting or clearing a byte—is specified by the various forms of **Scc** (Set on Condition Code). The **cc** is replaced by two characters representing the condition to be tested.

A **Scc** statement is written:

Scc address of byte to be set or cleared

The destination byte can be specified by any addressing mode except: 1) Address Register Direct; 2) Program Counter with Displacement; 3) Program Counter with Index; 4) Immediate; and 5) Quick Immediate.

For example, consider these instructions:

```
MOVE   #2,D1
MOVE   #6,D2
CMP    D1,D2
SEQ    D3
```

The **SEQ** (Set if Equal) instruction checks the zero bit in the status register. In this case, the zero bit has been cleared because the result of the comparison was non-zero. Therefore, the **SEQ** instruction will clear D3 (fill it will all zeros).

If, though, you execute:

```
MOVE   #2,D1
MOVE   #6,D2
CMP    D1,D2
SNE    D3
```

D3 will be set (filled with all 1's [$FF]). **SNE** (Set if Not Equal) is true if the zero bit in the status register has been cleared.

As with **Bcc**, you can test a wide variety of conditions:

SGE Set if Greater Than or Equal To
SGT Set if Greater Than
SLE Set if Less Than or Equal To
SLT Set if Less Than
SMI Set if Minus
SPL Set if Plus

(Other, less frequently used codes are in the *Programmer's Reference Manual*).

It is also possible to set or clear a byte without testing the condition codes.

ST destination address

will fill the byte specified by the destination address with all 1's. By the same token,

SF destination address

clears the byte at the destination address.

To clear either a word or longword, use the **CLR** instruction:

CLR destination address

with no extension or a **.W** extension will clear two bytes beginning at the destination address; an extension of **.L** will clear four bytes. **CLR.B** will clear one byte. The address to be cleared can be specified using any addressing mode except: 1) Address Register Direct; 2) Program Counter with Displacement; 3) Program Counter with Index; 4) Immediate; and 5) Quick Immediate.

There is no instruction to simply set all the bits in a word or longword.

Questions and Problems

For problems 1 through 5, assume the contents of the following selected 68000 registers and memory locations (the latter are identified by symbolic and absolute addresses):

D0 . . [0000AB12] D1 . . [00000002]
D2 . . [FF00FFAA] D3 . . [FF000000]
A0 . . [00000001] A1 . . [00000002]

$0001 . . [003A] LOC1	$0002 . . [0001] LOC2	$0003 . . [0010] LOC3
$0004 . . [0002] LOC4	$0005 . . [0020] LOC5	$0006 . . [0011] LOC6

1. What will be stored in register D3 after each of the instructions below are executed?

a.	MOVE.B	D0,D3	d.	MOVE.B	D2,D3
b.	MOVE	D0,D3	e.	MOVE	D2,D3
c.	MOVE.L	D0,D3	f.	MOVE.L	D2,D3

2. A. What will be stored in the destination register after each of the instructions below are executed?

   B. Identify the addressing mode used in each case.

a.	MOVE	LOC1,D0	j.	SF	D0
b.	LEA	LOC1,A0	k.	CLR	D2
c.	MOVE.L	A0,D0	l.	CLR.L	D2
d.	MOVE	(A0),D0	m.	MOVE	#'C',D0
e.	MOVE	4(A0,D1),D0	n.	MOVE	#'AB',D0
f.	MOVE	2(A0),D0	o.	MOVE.B	#'AB',D0
g.	CMP	D1,D0	p.	MOVE.L	#'ABCD',D0
h.	ST	D0	q.	MOVE.L	#'ABC',D0
i.	CLR.B	D0	r.	MOVE	#'ABC',D0

3. Identify the contents of each register and memory location that changes when the following blocks of code are executed:

a.
```
MOVE    LOC2,D0
MOVE    #0006,A0
MOVE    D0,A0
```

b.
```
LEA     LOC2,A0
MOVE    #0006,(A0)
```

c.
```
MOVE    #0004,A0
MOVE    (A0)+,D0
```

d.
```
Offset  EQU     3
        LEA     LOC2,A0
        MOVE    Offset(A0),D0
```

e.
```
        MOVE    #6,D0
        MOVE    #10,D1
        CMP     D0,D1
        BGT     Greater
        MOVE    D1,D2
        JMP     Done
Greater MOVE    D0,D2
Done    ...
```

f.
```
        MOVE    LOC5,D0
        MOVE    LOC6,D1
        LEA     LOC1,A0
        CMP     D0,D1
        BLT     Store
        MOVE    D1,(A0)
        JMP     Done
Store   MOVE    D0,(A0)
Done    ...
```

g.
```
        MOVE    LOC6,D0
        MOVE    LOC5,D1
        LEA     LOC1,A0
        CMP     D0,D1
        BLT     Store
        MOVE    D1,(A0)
        JMP     Done
Store   MOVE    D0,(A0)
Done    ...
```

4. Problems (f) and (g) in 3 above are essentially the same; their difference lies only in the quantities being compared. Looking at both blocks of code, what do they do?

5. For each block of code below, indicate the state of the flags in the status register after the code has been executed.

a.
```
MOVE    LOC1,D0
CMP     LOC2,D0
```

b.
```
MOVE    LOC6,D0
CMP     LOC1,D0
```

c.
```
MOVE    LOC3,D1
CMP     #10,D1
```

d.
```
LEA     LOC5,A0
MOVE    LOC4,D0
CMP     (A0),D0
```

6. Write a block of code that will load an operand into a data register from a main memory location called **Spot** and then push that same operand onto the stack:

   a. Write the code assuming that **Spot** has been defined as:

      Spot DC 0

   b. Write the code assuming that **Spot** has been defined as:

      Spot DS 1

7. Write a block of code that pulls a longword from the stack and stores it in a main memory location called **NextPlace**:

   a. Write the code assuming that **NextPlace** has been defined as:

      NextPlace DC.L 0

   b. Write the code assuming that **NextPlace** has been defined as:

      NextPlace DS.L 1

8. Write a block of code that:

   a. loads an operand from **Place1** into a data register.
   b. loads a second operand from **Place2** into another data register.
   c. compares the operands.
   d. If the operands are equal, branches to a statement labeled **Done**.

      i. if **Place 1** > **Place 2**, writes the first operand in **Largest** and the second in **Smallest**
      ii. if **Place 2** < = **Place 2**, writes the first operand in **Smallest** and the second in **Largest**

   All operands are word-sized. Be sure to set aside storage space for **Place1, Place2, Smallest,** and **Largest** with the **DC** or **DS** directive. (Remember: storage locations defined by **DS** must be referenced relative to register A5.) Use additional statement labels as necessary.

9. Write two versions of a block of code that creates a string — 'Some silly text' — and pushes its addresses onto the stack:

   a. Allocate the string as a literal within the code itself.
   b. Allocate the string with a **DC** directive.

10. Write a block of code that loads an operand from main memory into a data register. If the operand is positive, set D7; if it is negative, clear D7. Allocate any necessary storage locations. Something to think about: is a **CMP** instruction required as part of your code?

C H A P T E R F I V E

THE 68000 INSTRUCTION SET (PART 2)

Chapter Objectives

1. To understand the two's complement system of integer representation
2. To review the process of constructing an assembly language loop
3. To learn the integer arithmetic instructions
4. To learn the logical instructions
5. To understand the use of assembly language subroutines

Integer Arithmetic

Microprocessor instruction sets contain instructions for doing arithmetic with integers. To manipulate them, you need to know how integers are stored.

Two's Complement

The Macintosh stores integers using a *two's complement system*. Complementing is easier to understand if we look first at base 10 (decimal). The complement of a base 10 number is the quantity which, when added to the original number, produces a sum of 10. For example, the 10's complement of 6 is 4; the 10's

complement of 4 is 6. By the same token, the two's complement of a binary number is the quantity which, when added to that number, will produce a result of 2.

There is a simple procedure for obtaining a binary number's two's complement:

1. Invert the bits in a number (for every 0 write a 1, for every 1 write a 0)
2. Add 1 to the least significant bit

For example, to convert %100011 to its two's complement:

1. Invert: %100011 becomes %011100
2. Add 1: %011100 + 1 becomes %011101

To convert a number back to its true-magnitude binary form, take the two's complement of the two's complement.

The Macintosh has two sizes of integer — 16 bits and 32 bits (integer and longinteger). In each case, the high-order bit is used as a sign bit — bit 15 of an integer and bit 31 of a longinteger. (Remember that the bits are numbered beginning with 0.) If the high-order bit is clear, the number is positive; if it is set, the number is negative. That means that the high-order bit does not participate in the magnitude of the number. An integer therefore has only 15 bits available for the number itself, producing a range of −32,768 to +32,767. A longinteger has 31 bits available for the number, giving it a range of −2,147,483,648 to +2,147,483,647.

Negative numbers are stored in their two's complement form. Positive numbers are stored in their *true magnitude form* (i.e., they are not translated to two's complement). This means that if you look at positive numbers in registers or in main memory, they can be directly converted to decimal. Negative numbers, on the other hand, must first be converted back to their true magnitude form before you can determine their value.

As an example, consider the number −5. In binary, 5 is %0101. If the number were positive, it would be stored in a word-sized location as %0000 0000 0000 0101 ($0005). To store a −5, however, two things must happen: the binary must be converted to two's complement form, and a 1 must be placed in bit 15 as the sign bit:

1. Convert to two's complement
   a. Invert the digits (%000 0000 0000 0101) to get %111 1111 1111 1010. Note that we are working with only 15 bits; the 16th will be added later to serve as a sign bit.
   b. Add 1 to get %111 1111 1111 1011. This is the two's complement form.
2. Insert a sign bit to get the final number %1111 1111 1111 1011

In hexadecimal, −5 appears as $FFFB. That is the quantity you will see displayed by the debugger if you examine a register or memory location that contains −5. In hex, −1 is $FFFF, −2 is $FFFE, −3 is $FFFD, −4 is $FFFC, and so on.

The Integer Arithmetic Instructions

Before going on, let's recapitulate the code that creates a loop like the one first introduced in Chapter 4:

```
TopOfLoop   MOVE   #1,D1                    Step 1
            MOVE   #TargetValue,D2            2
            CMP    D1,D2                      3
            BMI    Outside Loop               4
            {body of the loop goes here}      5
            ADD    #1,D1                      6
            BRA    TopOfLoop                  7
Outside Loop .....
```

The steps in this loop are:

1. Initialize a counter
2. Set a location equal to the target value
3. Compare the counter to the target value
4. If the counter equals the target value, end the loop
5. Execute the body of the loop (any executable statements go here)
6. Increment the counter
7. Transfer control to the top of the loop

The instruction in statement 6 is an example of integer arithmetic. Integer arithmetic adds and subtracts numbers up to 32 bits in length. The highest-order bit (regardless of the size of the operands) is maintained as a sign bit (0 = a positive number, 1 = a negative number).

Integer arithmetic also multiplies and divides signed or unsigned whole numbers up to 16 bits in length: the result can fill up to 32 bits. If you indicate that you want to do a signed operation, the highest-order bit in each operand will be used as a sign bit. Otherwise, all bits participate in the magnitude of the number.

To do arithmetic with larger or smaller numbers or numbers that have a fractional portion, you must use the Macintosh floating point arithmetic package (see Chapter 12).

ADD

The **ADD** instruction adds a source operand and a destination operand and stores the result in the destination location. One of the two operands must be a data register; therefore, the instruction can take two forms:

ADD effective address of source operand, destination data register

or

ADD source data register, effective address of destination operand

The statement:

```
ADD   #16,D1
```

will add the quantity 16 to the contents of D1 and store the result in D1. The second operand, which had previously been in D1, will be lost when the result is stored. The **ADD** statement has the same effect as the Pascal statement:

```
D1 := D1 + 16
```

In this form of **ADD**, you may use any addressing mode to specify the source operand.

When you specify the destination operand as a RAM address (the source operand will be in a data register), you may only use "alterable" addressing modes: all the address register direct modes and absolute addressing. For example, assume the symbolic address **Label1** has been assigned to a location in the applications globals area. Then:

```
MOVE   #22,D1
ADD    D1,Label1
```

will 1) put the quantity 22 into D1, 2) add the quantity in D1 to the quantity in the RAM location associated with the symbolic address **Label1**, and 3) store the result in **Label1**. (The Pascal equivalent is **Label1 := Label1 + D1.)**

If you want to use an address register as the destination for the result of an addition, you need to use a variation of the **ADD** instruction: **ADDA**. The instruction is written as:

ADDA effective address of source operand, destination address register

For example:

```
ADDA   #22,A1
```

will add the quantity 22 to the contents of A1 and store the result back in A1. (In Pascal, **A1 := A1 + 22**.) You may use any addressing mode to specify the source operand.

It is also possible to add immediate data to an operand stored in RAM without moving the operand into a data register. **ADDI** (Add Immediate) and **ADDQ** (Add Quick) will both do the job. **ADDI** has the form:

ADDI #quantity, effective address of destination operand

An **ADDQ** instruction is written exactly like an **ADDI**, but the immediate data is restricted to the range 1 to 8. The quantity is assembled as a part of the instruction and therefore can save space in your source code.

Any variation of the **ADD** instruction can be specified as operating on a byte (**ADD.B**), a word (**ADD** or **ADD.W**), or a longword (**ADD.L**).

This family of instructions affects all the condition codes. As you might expect, the negative bit will be set if the result is negative, cleared if positive. The zero bit will be set if the result is zero, cleared if non-zero. The carry and extend bits are both set if a carry occurs and cleared if there has been no carry. An overflow will set the overflow bit; otherwise, it will be cleared.

SUB

SUB (Subtract) is exactly analogous to **ADD**. The instruction subtracts the quantity in a source location from the quantity in a destination location and stores the result in the destination location. As with **ADD**, there are two forms:

SUB effective address of source operand, destination data register

or

SUB source data register, effective address of destination operand

The instruction:

```
SUB   #12,D1
```

has the same effect as the Pascal statement:

```
D1 := D1 - 12
```

The instructions:

```
MOVE  #12,D1
SUB   D1,Label1
```

perform the same actions as:

Label1 = Label1 – D1

(assuming that **Label1** has been previously assigned as a symbolic address).

SUB has the same restrictions on addressing modes as **ADD**. If the source operand is specified by its effective address (as opposed to being in a data register), then you may use any addressing mode. But if the destination address is identified by an effective address, only the register indirect and absolute modes are acceptable.

SUB, as does **ADD**, has three variations:

1. **SUBA** – the destination address is an address register, as in:

   SUB #333,A1

2. **SUBI** – the source address is an immediate quantity and the destination is identified by its effective address; i.e.:

   SUB #54,Label3

   where **Label3** has been previously defined as a symbolic address.

3. **SUBQ** – the source address is an immediate quantity in the range 1 through 8 and the destination location is specified with any addressing mode but the program counter modes. For example:

   SUBQ #2,(A2)

With each variation you may specify the size of the operands as byte (e.g., **SUB.B**), word (e.g., **SUB** or **SUB.W**), or longword (e.g., **SUB.L**).

SUB also affects the condition codes in the same way as **ADD**: the negative bit is set if the result is negative (cleared if positive); the zero bit is set if the result is zero (cleared if non-zero); carry and extend bits are set if a borrow occurred (cleared if no borrow occurred); and the overflow bit is set if an overflow occurred (cleared if no overflow).

Integer Multiplication

Integer multiplication comes in two forms – **MULS** and **MULU**. **MULS** (for Signed Multiply) computes the product of two 16-bit signed numbers and returns a signed 32-bit result. **MULU** (Unsigned Multiply) does the same but returns an unsigned result.

The general form for these instructions is:

MULS effective address of source operand, destination data register

or

MULU effective address of source operand, destination data register

You may use any addressing mode except Address Register Direct to specify the effective address of the source operand. For example:

```
MULU  #62,D1
```

will multiply whatever quantity is stored in D1 by the quantity 62 and store the result in D1. When using **MULU** or **MULS**, remember that you must use a data register as the destination in a multiplication operation.

The source operand can only be a word in length; therefore, **MULU** and **MULS** do not take extensions.

With either instruction, the overflow and carry bits of the status register are always cleared; the extend bit is not affected. **MULS** will cause the negative bit to be set if the result is negative; **MULU** will set the negative bit if the most significant bit of the result is set. (In both cases the negative bit will be cleared if the condition for setting the bit has not occurred.) The zero bit will be set when either **MULU** or **MULS** produces a zero result and cleared for a non-zero result.

Integer Division

DIVS and **DIVU** perform division on signed and unsigned numbers, respectively. The general form of the instructions is:

DIVS effective address of source operand, destination data register

or

DIVU effective address of source operand, destination data register

The destination operand (up to 32 bits in length and contained in a data register) is divided by the source operand. The source operand can be specified using any addressing mode except Address Register Indirect and is 16 bits in length.

The result is stored in the destination data register. The lower-order half of the longword (bits 0–15) will contain the quotient. The upper half (bits 16–31) will contain the remainder. For example:

```
MOVE  #33,D1
DIVS  #4,D1
```

will cause D1 to receive the following contents:

%0000 0000 0000 0001 0000 0000 0000 1000

The quotient (8) is, as explained above, in the lower-order half of the 32-bit longword; the remainder (1) begins in bit 16, the first bit of the higher-order half of the longword.

Since the source operand is restricted to 16 bits, neither **DIVU** or **DIVS** take an extension. The size of the operation is always a word.

Overflows can be nasty when doing integer division. An overflow condition arises when the quotient is larger than 16 bits. If the condition is detected before the operation finishes, it is possible that the overflow bit in the status register will be set and the destination data register left unchanged. Therefore, if a division could generate an overflow, a program should check the overflow bit before assuming that the operation was completed successfully. If no overflow has occurred, the bit will be cleared.

The carry bit will always be cleared by a division. The extend bit is unaffected. The zero and negative bits are set or cleared, depending on the result of the operation.

Logical Operations

The way the integer division instructions return their results presents an interesting problem — what can you do if you are interested in the quotient, but not in the remainder? Conversely, what if you need just the remainder? To isolate the quotient, you will need to fill the high-order half of the destination data register with zeros. To isolate the remainder, you'll need to first fill the low-order half of the destination register with zeros and then swap the two halves so that your remainder is in the low-order half.

There is more than one way to selectively set the bits in a byte, word, or longword, but a commonly employed strategy is to use a logical operator and an immediate operand called a "mask." The logical operations available in the 68000 instruction set are **AND, OR, EOR,** and **NOT**.

AND

Logical instructions work differently than any other kind of instruction — they operate separately on each bit in the operands. **AND** compares the state of the pair of bits that occupy the same location in each operand. If the two bits are both 1, then that bit will have a result of 1. If either or both are 0, the result will be zero. Table 5.1 summarizes the effect of **AND**ing two bits together. In essence, **AND** has the same effect as multiplying the two bits.

The **AND** instruction takes two forms:

AND effective address of source operand, destination data register

or

AND source data register, effective address of destination

If the effective address field is the source operand (the first form above), then you may use any addressing mode but Address Register Direct. If the effective address field is the destination of the operation, there are further restrictions; Data Register Direct, both program counter modes, and Immediate are also not allowed. The size of an **AND** operation can be specified as byte (**.B**), word (no extension or **.W**), or longword (**.L**).

AND	1	0
1	1	0
0	0	0

Table 5.1 AND Truth Table

To see how **AND** works, consider the following example:

```
MOVE.B  #%00110101,D0
AND.B   #%11110000,D0
```

Can you predict what the result (stored in D0) will be? Remember that **AND**ing two 1's produces a 1, but **AND**ing anything else produces a 0. The result will therefore be %00110000.

How then, can this help us when we want to isolate one part of the result of a division operation? There's another way to look at how an **AND** works – **AND**ing something with a 1 preserves the value of the source bit. **AND**ing something with a 0 will always return a 0. To retrieve the quotient of a division, we need to zero out the high-order bits and leave the low-order bits alone. To get only the remainder, we need to first zero out the low-order bits, leaving the high-order bits untouched, and

then swap the low- and high-order halves of the register. The strategy, then, is to create a "mask" so that when we **AND** the mask with the data register holding the result of the division, the part we want to retain will be unaltered, but the half we don't want will be filled with 0s. Let's look at an example:

```
MOVE #88,D1   (D1) = $00000058
DIVU  #3,D1   (D1) = $0001001D (quotient=29; remainder =1)
AND   #$0000FFFF,D1
```

The mask in the example is $0000FFFF (in binary: %0000 0000 0000 0000 1111 1111 1111 1111). Therefore, the contents of D1 after the **AND** instruction is executed will be $0000001D. The remainder has been "masked" off and we can now use the quotient in D1 as a quantity somewhere else in the program.

To isolate the remainder, we'll need to reverse the mask:

```
AND   #$FFFF0000,D1
```

The contents of D1 will be $00010000. The problem with this result is that though the remainder is actually 1, the quantity D1 is 65,536. What we need now is some way to make the high-order bits the low-order bits, and make the low-order bits the high-order bits. The instruction **SWAP** does exactly that for the contents of any data register:

```
SWAP  D1
```

will leave us with $00000001 in D1, which is exactly what we need to work with the remainder as a quantity. Note that **SWAP** only works with data registers. It sets the negative flag if the most significant bit of the result is set and sets the zero flag if the entire result is zero (otherwise, both are cleared). The overflow and carry bits are always cleared; the extend bit is not affected.

OR

Like, **AND, OR** has two general forms:

```
OR   effective address of source operand, destination data register
```

and

```
OR   source data register, effective address of destination operand
```

OR is also exactly like **AND** with regard to restrictions on addressing modes, operand size specification, and effect of the condition codes.

OR is not like **AND**, though, when it comes to producing results. If you **OR** together two bits, the result will be 1 if *either* of the two bits is 1; the result will be 0 only if both input bits are 0 (see Table 5.2).

OR	1	0
1	1	1
0	1	0

Table 5.2 OR Truth Table

What do you think the final contents of D1 will be after we execute these instructions?

```
MOVE.B    #%00001111,D1
OR.B      #%10101010,D1
```

The final contents of D1 will be %10101111. The only places where the result will have 0s are those bit positions in which there were 0s in the **OR** instruction operands.

NOT

The general form of the **NOT** instruction is:

NOT effective address of destination operand

The instruction *inverts* the bits in the destination operand, which can be specified using any addressing mode but: 1) Address Register Direct; 2) Program Counter with Displacement; 3) Program Counter with Index; 4) Immediate; and 5) Quick Immediate. In other words, it replaces each 0 with a 1, and each 1 with a 0. For example, if D1 contains %0000 0001 1111 1010 0000 1111 1000 1011, then:

```
NOT.L  D1
```

will place %1111 1110 0000 0101 1111 0000 0111 0100 in D1. Note that **NOT** takes an extension (**.B, .W,** or **.L**) to specify the size of the operand.

NOT, like the other logical operators, does affect the condition codes in the status register. The negative and zero bits are set or cleared according to the result of the operations, overflow and carry are always cleared, and extend is not affected.

EOR

You may remember that **AND** does a multiplication of two bits and returns the result. **EOR** (Exclusive OR) adds two bits and returns the results. (In the case of 1 + 1, it returns 0 and throws away the carry.) Therefore, **EOR** will produce a result of 0 when both input bits are the same (either two 1s or two 0s); the result will be 1 when the two inputs are different (0 and 1). See Table 5.3 for the truth table.

For example:

```
MOVE.B    #%00001111,D2
EOR.B     #%11001100,D2
```

will place %11000011 in D2.

EOR functions exactly like **AND** and **OR** in terms of operand size specification, address mode restrictions, and effect on the condition codes.

EOR	1	0
1	0	1
0	1	0

Table 5.3 EOR Truth Table

Subroutines

Assembly language programs are never famous for their elegant structure, but you can achieve some semblance of order if you break your program into modules by placing blocks of code that perform a single function into subroutines.

Assembly language subroutines are much like Pascal procedures used in a program where all variables are defined in the program's **var** block (i.e., all variables are global). All storage locations defined by data allocation directives are available to all subroutines (i.e., they are also *global*). You must take care that you place your subroutines so that the main program will not drop into them, since

assembly language programs execute sequentially unless they encounter a branch instruction. Generally, that means that subroutines will be placed toward the end of the source code, after the statement that forms the *logical* end to the main program.

To call a subroutine, you may **JSR** (jump to subroutine) or **BSR** (branch to subroutine):

JSR symbolic address of first statement of subroutine

or

BSR symbolic address of first statement of subroutine

The difference between the two is the same as the difference between **JMP** and **BRA**. During assembly, the symbolic address following **JSR** is turned into an absolute address. When the **JSR** is encountered during program execution, the absolute address replaces the contents of the program counter, and program execution continues with the instruction at that address.

On the other hand, assembling a **BSR** instruction creates an offset equal to the number of bytes between the **BSR** instruction and the start of the subroutine. The Macintosh will add the offset to the contents of the program counter to determine the absolute address for the first instruction of the subroutine.

Even before changing the contents of the program counter, both instructions cause the address of the following instruction to be pushed onto the stack. This is the address where program execution will continue when the subroutine is finished. Subroutines end with **RTS** (return from subroutine). **RTS** pulls the address that **JSR** or **BSR** pushed onto it from the top of the stack and puts it in the program counter.

Remember that because the stack is a last in, first out device, nested subroutines will always return to whatever routine called them. There may be situations, though, where you don't need to thread your way up through nested subroutines but would like to return directly to, for example, a main program. You can do this by pulling one longword off the stack for each level of subroutine nesting you want to skip. An example of this technique appears in the following section.

NOTE: RTS has a special use in Macintosh assembly language. While most assembly language programs signal the logical end of the program with something akin to an END statement, a Macintosh assembly language program does not. (Remember that **END** is an assembler directive that signals the *physical* end of your source code.) Whenever your program should return to the Finder (i.e., a *logical* ending place), use **RTS**. It has the same effect as **END.** in a Pascal program. It is an executable statement that stops the assembly language program and returns control of the system to the Finder. Obviously, this will only work if there are no subroutine return addresses on the stack. (If there are, the **RTS** will simply return you to the statement below the last encountered **JSR** or **BSR**.)

Putting the Instruction Set to Work — Sorting and Searching Arrays

Among the things that assembly language does exceptionally well are sorting and searching. When the data to be sorted and searched are kept in an array in main memory, the processes execute at breakneck speed. Let's look, then, at how the video tape index program maintains its master file as a sorted RAM array which can be searched using an efficient binary search technique. You will see that understanding the individual instructions is really a very minor part of the task; it's figuring out which instructions to use when that's the challenge.

Introduction to the Video Tape Index Program

The video tape index program actually uses two files. The first — TAPE.MASTER — is a sequential file that is read into a main memory array at the start of program execution. All changes to TAPE.MASTER are made while it is in main memory. It is rewritten to disk just before the program ends (when the user selects **QUIT** from the **OPTIONS** menu). The second file — ANNOTATIONS — is a direct access file that is kept on disk. Since the annotations can be rather long (up to 256 characters each), they are brought into memory only as needed.

Though TAPE.MASTER is a sequential file, it nonetheless has fixed field lengths, and therefore fixed record lengths. Why? To locate a particular field in a particular record in main memory, you must know exactly where each piece of data will begin relative to the starting address of the array. This is not possible if the ends of fields depend only on the number of characters in each individual piece of data.

NOTE TO PURISTS: There is a way to manage this data with variable field and record lengths by preceding the records with a look-up table that gives the relative starting location of each record; the programming required to maintain and especially to search such a structure is far more complex than that required by the video tape index program.

The structure of TAPE.MASTER is:

TapeName	30 characters
Producer	20 characters
ReleaseDate	4 characters
Rating	4 characters
TapeNumber	4 characters
AnnotNum	1 word (2 bytes)

Total record length = 64 bytes

To allocate space in main memory to hold the array, we need a very large block of storage set aside in the applications globals area:

```
TapeArray   DS.B   6400
```

This statement allocates enough storage for 100 records (one byte for each of the 64 characters in each record). Note that because this statement uses a **DS** directive, there is no way to automatically assign a starting value to each byte in the storage block when the program is assembled.

New records are entered into a temporary area called **NewRecord**. **NewRecord** is a data structure (we'll talk more about data structures in Chapter 6) defined as follows:

```
NewRecord   DS.B   64
```

Offsets into the record are defined as equates at the top of the program:

```
oTapeName     EQU   0
oProducer     EQU   30
oReleaseDate  EQU   50
oRating       EQU   54
oTapeNumber   EQU   58
oAnnotNum     EQU   62
```

The symbolic address **NewRecord** refers to the starting address of this data structure in memory. A program can, however, get to any field within the structure by using Address Register Indirect With Offset Addressing. For example, to specify the starting location of the ReleaseDate field, use:

```
NewRecord+oReleaseDate(A5)
```

Remember that because space for **NewRecord** is allocated with **DS**, its address is relative to (A5), the start of the applications globals area.

Inserting New Records into a Sorted Array

In order to do a binary search, the array you are searching must be in some order. TAPE.MASTER is kept in alphabetical order by the name of the tape. Though there are many ways of sorting an array, one simple technique for inserting a new record into an array that is already in order is the straight-insertion method. To understand the process, take a look at Listing 5.1, pseudocode that describes the video tape index's straight-insertion sort.

Listing 5.1 Pseudocode for Straight Insertion Sort

```
Get number of records in TapeArray.

Subtract 1 from number to records to get record number of last record (the record pointer).

Initialize two character pointers to the first character, one for TapeArray and one for NewRecord.

If record to be inserted is not the first record then

    Repeat

        Get next character from TapeArray record indicated by record pointer;

        Get next character from NewRecord;

        If character from TapeArray is greater than character from NewRecord then

            Move entire TapeArray down one record position;

            Decrement record pointer;

            Reset character pointers to first character

    Until entire name field has been compared OR character from NewRecord is greater
          than character from TapeArray OR record pointer is -1.

Add 1 to record pointer to obtain record number where NewRecord will be inserted into
      TapeArray.

Move characters from NewRecord to TapeArray.

Increment the total number of records in TapeArray.
```

The strategy involves comparing the data to be inserted with the bottom record in the array. If the new record should be placed "above" the last record, the last record is moved down, in effect creating a hole in the array. The new record is then compared to the last record but one. If the new record should be placed above the last record but one, the last record but one is moved into the hole created when the last record was moved. This process is repeated, making comparisons between the new record and records already in the array from the bottom up, until such time as the new record is equal to or less than a record in the array. Once that condition is encountered, the new record is inserted into the hole in the array (thus the name, straight-insertion sort).

Locating Data Stored in Arrays

Before examining the subroutine that performs the straight-insertion sort in detail, let's look at accessing data stored in arrays. How do we do it? We use Address

Register Indirect with Index addressing.

The starting address of the TAPE.MASTER array in main memory is given by the symbolic address **TapeArray(A5)**. (There is no need for us to know its absolute address.) The starting address of any given record will therefore be equal to:

[(Record Number) * 64] + TapeArray(A5)

where 64 is the number of bytes in a record. (In this case the characters are packed into adjoining bytes.) The expression in brackets above is an offset into the TAPE.MASTER array. If this expression seems a bit confusing at first, remember that in a computer, numbering systems generally begin with 0 rather than 1 (i.e., the second record will have a record number of 1). We might use that quantity as the displacement in Address Register Indirect with Index addressing.

Using the displacement locates the start of one particular record. It does not, though, locate a particular field or character that is a part of the record. (The displacement is an offset with the *array*.) To do that, we need an additional offset within the *record*. The index register portion of the effective address could be used for that purpose. The same equates that hold offsets into **NewRecord** can be used as offset into a **TapeArray** record since both have the same structure. To locate, for example, the first character in the **Rating** field, **oRating** might first be placed in a data register:

```
MOVE   #oRating,D0
```

Then, an effective address for the first character in the **Rating** field would appear as:

```
Offset(A0,D0)
```

where **Offset** is computed by the method described above, and the address of **TapeArray(A5)** has previously been stored in **A0**.

There is a major problem with using the offset as a displacement, however, in an array the size of the one used by the video tape index program. With Address Register Indirect with Index addressing, the displacement is limited to a range of −128 to +127. As soon as there are more than three records in the array, the offset will exceed that range. It is therefore easier to manually compute an address into **TapeArray**.

For example, to locate the beginning of the **Rating** field:

1. Get the starting address of **TapeArray**:

```
LEA   TapeArray(A5),A0
```

2. Compute the record offset (assume the record number is in D0):

```
MULU   #64,D0
```

3. Add the record offset to the start of the array:

```
ADD    D0,A0
```

4. Add the field offset:

```
ADD    #oRating,A0
```

It may also be necessary to step through a record, character by character. In that case, the strategy is to initialize the index register with the offset into the array and then increment it by 1 to move to each successive character.

Assuming that D0 is used as the index register and that A0 contains the starting address of **TapeArray**, an entire 64-character record could be handled using the following code:

```
        MOVE      RecordNumber,D0
        MULU      #64,D0          ;compute offset
        MOVE      #0,D7           ;initialize character counter
Loop    MOVE.B    (A0,D0),D1      ;get one character
        {process the character in some way}
        ADDQ      #1,D0           ;increment index register
        ADDQ      #1,D7           ;increment character counter
        CMP       #64,D7          ;have 64 char. been handled?
        BNE       Loop            ;return to get another
        RTS
```

This technique is used to compare the name of the tape in the record to be inserted with tape names already in the file.

The Straight-Insertion Sort

The assembly language version of the straight-insertion sort appears in Listing 5.2. This is part of the subroutine that handles the entry of new records. It assumes that the data to be inserted into **TapeArray** has been collected in **NewRecord**.

Since the sort starts by looking at the last record in the array, the record number of the first record to be considered will be equal to the total number of records in the file. Therefore, the sort first loads that quantity into D1 [(a) in Listing 5.2]. When computing offsets, though, the quantity should be one less than the number of records. (Remember that the records are numbered beginning with 0.) The routine therefore subtracts 1 from the number of records. The program statement at (b) initializes D2 as a character counter and index register.

Listing 5.2 Straight-Insertion Sort (Version 1)

```
(a)     Sort    MOVE    TotalRecords,D1
                SUBQ    #1,D1                   ;adjust for record #'s beginning with Ø
                MOVE    #Ø,D2                   ;index register/character counter
(b)             LEA     TapeArray(A5),A1        ;start of array
(c)             LEA     NewRecord(A5),A2        ;start of new record
                CMP     #Ø,D1                   ;first record?
(d)             BEQ     InsertNew               ;if so, insert immediately

        Checking
(e)             JSR     ComputeOffset1
        NextChar
(f)             MOVE.B      (A1,D6),D3          ;character from array
(g)             MOVE.B      (A2,D2),D4          ;character from new record
(h)             CMP     D3,D4                   ;new - old
                BGT     InsertNew               ;found place to insert record
                BLT     MoveOld                         ;move existing record down
(i)             ADDQ    #1,D2                   ;increment character counter/index
                ADDQ    #1,D6
                CMP     #3Ø,D2                  ;are two fields exactly equal? (3Ø bytes
processed?)
                BEQ     InsertNew               ;if equal, insert new record
                BRA     NextChar                ;look at next character

(j)     MoveOld
                MOVE    D1,D5
                ADDQ    #1,D5                   ;record # to move to
                JSR     ComputeOffset1
                JSR     ComputeOffset2

(k)     Another         MOVE.B      (A1,D6),(A1,D7)             ;move one character
                ADDQ    #1,D6                   ;increment index
                ADDQ    #1,D7
(l)             CMP     #64,D6                  ;has an entire record been moved?
                BNE     Another
(m)             SUBQ    #1,D1                   ;move back a record
                CMP     #-1,D1                  ;does new record go in first position?
                BEQ     InsertNew
                BRA     Checking

(n)     InsertNew
                MOVE    D1,D5
                ADDQ    #1,D1                   ;record number to insert at

                MOVE    #Ø,D2                   ;initialize index
(o)             JSR     ComputeOffset2

(p)     Again   MOVE.B      (A2,D2),(A1,D7)             ;move one character
                ADDQ    #1,D2
                ADDQ    #1,D7
                CMP     #64,D2                  ;entire record moved?
                BNE     Again

(q)             LEA     TotalRecords,AØ
                ADDQ    #1,(AØ)
                BRA     AllDone                 ;return - sort is complete
```

(continued)

Listing 5.2 (continued)

```
        ComputeOffset1
(r)             MOVE  D1,D6             ;offset = record # * 124
                MULU  #64,D6
                RTS

        ComputeOffset2
                MOVE  D5,D7
                MULU  #64,D7
                RTS
```

We also need to place the starting addresses of **TapeArray** and **NewRecord** in address registers so they can be used as part of Address Register Indirect with Index addressing. That happens at (c); A1 will hold the address for **TapeArray** and A2 will hold **NewRecord**'s address. If the record being inserted is the first record (e.g., the array is empty), the record is simply moved to **TapeArray** without further processing (d). If **TapeArray** already has some records, the sort needs to begin comparing characters.

The first task is to compute the offset for the record indicated by D1. If you look at (e), you'll see that offsets are computed in subroutines. The subroutine ComputeOffset1 (r) uses the contents of D1 as the record number; ComputeOffset2 bases its computations on D5. To compute an offset, the program:

1. Moves the record number into a temporary storage register (D6) and then
2. Multiplies the record number by the record length (64 bytes).

Once the offset is computed, one character from the tape array can be loaded into D3 (f). A character from the new record is loaded into D4 (g). The characters are compared to each other (h). If the character from the new record is greater (comes later in an alphabetical sequence) than the character from the array, then the place to insert the new record has been found. The program branches to do the insertion (n). If the character from the new record is less than the character from the array, then the record in the array must be moved "down" one position (j). On the other hand, if the two characters are equal, there are two possibilities.

If 30 bytes (the total length of the field) have been examined, then the names of the two tapes are equal. The program checks for this condition by incrementing the index register/character counter in D2 and then comparing the new value with 30 (i). The video tape index program inserts records with duplicate tape names without further ordering. Therefore, if the two fields are equal, the new record can be inserted directly after the old one.

If all 30 characters have not been checked, then it is not possible to make a judgment about whether to insert a record or move an existing one. The only

recourse is to check the next character in the field. Therefore, the program branches back to (f) to begin the comparison process again.

Moving an existing record down (j) is done character by character. The first task is to compute two offsets: one to the beginning of the record (Offset1 in D6) which will be moved; and the other to the beginning of the location to which it will be moved (Offset2 in D7). Then, statement (k) moves a single character. The index registers are incremented and then checked against the number of bytes in the record (64) to determine if all of the characters have been moved. If not, the program branches to move another character.

Once an entire record has been moved, the contents of D1 are decremented (m). Why decrement the record number? Simply because a straight insertion sort starts at the bottom of the array and moves toward the beginning. If, after the decrement, D1 contains −1, then the new record comes before all others already in the file and should be inserted. In that case, the program branches to insert the new record (n). Otherwise, the program branches to begin a new comparison (e).

Inserting a new record (n) involves moving characters one by one from **NewRecord** into the array. The insertion position is one record beyond the one pointed to by D1. Therefore, D1 is incremented. The offset into **TapeArray** is computed (o) and a single character is moved (p). The index registers (D2 and D7) must then be incremented to count the characters just transferred. Just as with the procedure for moving an existing record down, the number of characters moved is compared against the total number of characters which must be moved (64) to determine if the process is complete. If not, the program branches to move another (p).

Once the new record is inserted into the array, only one task remains — incrementing the total number of records. The absolute address associated with the symbolic address **NumRecords** is loaded into address register A1 (q). The quantity stored at the address in A0 can then be incremented with a single instruction. Now **NumRecords** reflects the number of records in the array after the new record has been inserted. This action completes the straight-insertion sort.

Locating Records in a Sorted Array

One of the fastest ways to search an ordered list is to use a binary search. The binary search strategy involves looking at the middle record in the list, deciding whether the record you want is above or below the middle, and then looking only in the half of the list where the record could occur. The file is repeatedly cut in half, always looking at the middle record, until either the desired record is located or it is apparent that the record wanted isn't present in the array.

Pseudocode for a binary search appears in Listing 5.3. **TapeArray** refers to the array in RAM while **SearchString** contains the tape name to be found. A pointer to the top record being considered is initialized to 0. (When we talk about the top and bottom of the array, we think of the array as if it were written on a sheet a paper, with record number 0 at the top.) The pointer to the bottom of the array is

initialized to the total number of records minus one. Then we compute the number of the middle record by adding top to bottom and dividing by 2.

If the record we are looking for is above the middle record, then we move the bottom pointer *up* to the middle; if it is below the middle record, we move to top pointer *down* to the middle. We know that a search has been unsuccessful (the record we want isn't present in the array) if the two pointers cross (i.e., bottom becomes greater than top).

We must handle the top two records and the two bottom records in the array separately. Therefore, if the computation of the middle record number generates a result equal to 1 or 2, the program does a sequential search of the first two records; if the computation generates a record number equal to the total number of records −1 or the total number of records, the program searches the last two records sequentially. Note that these two "special case" searches occupy more than 1/2 of the pseudocode listing.

A binary search also falls apart if there are less than four records in the array. If you wish to handle such a possibility in a program, check the number of records in the array before beginning the search. If there are less than four records, search the array sequentially. The video tape index program assumes that there will never be less than four records—a fairly realistic assumption considering the nature of the application—and therefore does not handle that situation.

Listing 5.3 Pseudocode for Binary Search

```
Set bottom record pointer equal to total number of records - 1.

Set top record pointer equal to Ø.

Initialize character pointers for TapeArray and SearchString.

Repeat

        Compute number of middle record;

        If middle record is not one of the first two records or last two records then

                Get next character from TapeArray;

                Get next character from SearchString;

                Compare the characters;

                If character from name field of TapeArray record is greater than character from
                        SearchString then

                        Make bottom pointer equal to the middle record number;

                        Reset character pointers to beginning of records
```

(continued)

Else

Make top pointer equal to the middle record number;

Reset character pointers to beginning of records

Until all characters in name field have been compared and are equal **OR** top pointer is greater than bottom pointer **OR** middle record is one of first two records or last two records.

If top pointer is greater than bottom pointer **then**

Report "No Find"

Else

If all characters in name field have been compared and are equal **then**

Location of record with SearchString is middle record number.

Else {must be first two or last two records}

If middle record is one of first two records **then**

Set middle record to Ø for first record;

While character from name filed of TapeArray record is equal to character from SearchString **do**

Get next character from TapeArray;

Get next character from SearchString:

If all characters in name field of TapeArray record are equal to all characters in SearchString **then**

Location of SearchString is record Ø

Else

Set middle record to 1 for second record;

While character from name filed of TapeArray record is equal to character from SearchString **do**

Get character form TapeArray;

Get character from SearchString;

If all characters in name field of TapeArray record are equal to all characters in Search String **then**

Location of SearchString is record 1

(continued)

Listing 5.3 (continued)

```
        Else

                Report "No Find";

    Else

        Set middle record number equal to last record - 1;

        While character from name filed of TapeArray record is equal to
                character from SearchString do

                Get next character from TapeArray;

                Get next character from SearchString;

        If all characters in name field of  TapeArray record are equal to all
                characters in SearchString then

                Location of search string is last record -1

        Else

                Set middle record number equal to last record;

                While character from name field TapeArray record is equal to
                        characters in SearchString do

                        Get next character from TapeArray record;

                        Get next character from SearchString;

                If all characters in name field of TapeArray record are equal to
                        all characters in SearchString then

                        Location of SearchString is last record

                Else

                        Report "NoFind".
```

The assembly language version of the binary search is a subroutine called by three modules in the video tape index program (Select, Change, and Delete). The code appears in Listing 5.4.

The name of the tape for which the routine is searching is stored in the first field of **NewRecord**. When a search is successful, the record number of the record in the array whose **TapeName** matches the tape name in **NewRecord** is returned in D5 (this assumes that the records are numbered beginning with 0). If a search is unsuccessful, then the routine returns a −1 in D5.

Listing 5.4 Binary Search

```
        NameSearch                  ;result appears in D5 (-1 = no find)
(a)         LEA     TapeArray(A5),A2
            LEA     NewRecord(A5),A2
            MOVE    TotalRecords,D1
(b)         SUBQ    #1,D1           ;bottom pointer
            MOVE    D1,D3
(c)         SUB     #1,D3   ;save total number of records-1 for later reference
(d)         MOVE    #Ø,D2           ;top pointer

        MidPoint
(e)         MOVE    D2,D5           ;find middle record #
            ADD     D1,D5
            DIVU    #2,D5
(f)         AND.L   #$ØØØØFFFF,D5;mask off remainder
(g)         CMP     #1,D5
(h)         BLE     TopRec          ;handle first two records
            CMP     D5,D3
(i)         BLE     BottomRec       ;handle last two records
            MOVE    #Ø,D4           ;initialize index

            JSR     ComputeOffset2
        CheckChar
            MOVE.B (A2,D7),DØ       ;character from array
            MOVE.B (A1,D4),D6       ;character from search string
(j)         CMP     DØ,D6
(k)         BPL     BottomHalf
(l)         BMI     TopHalf
            ADDQ    #1,D4
            ADDQ    #1,D7
(m)         CMP     #3Ø,D4          ;are two fields exactly alike?
            BNE     CheckChar
            RTS

(n)     BottomHalf
            MOVE    D5,D2           ;move top pointer down
            BRA     NoFindCheck
(o)     TopHalf
            MOVE    D5,D1           ;move bottom pointer up
(p)     NoFindCheck
            CMP     D2,D1
            BMI     NoFind          ;pointers have crossed
            MOVE    #Ø,D4           ;reset index
            BRA     MidPoint        ;find new middle record and go again

(q)     NoFind
            MOVE    #-1,D5          ;-1 = no find
            RTS

(r)     TopRec      MOVE  #Ø,D5
            JSR     OneCheck
            MOVE    #1,D5
            JSR     OneCheck
            MOVE    #-1,D5          ;no find
            RTS
```

(continued)

Listing 5.4 (continued)

```
(s)     BottomRec
                MOVE  D3,D5
                JSR   OneCheck
                ADDQ  #1,D3
                MOVE  D3,D5
                JSR   OneCheck
                MOVE  #-1,D5          ;no find
                RTS

(t)     OneCheck
                MOVE  #Ø,D4
                JSR   ComputeOffset2

        OneMore
                MOVE.B (A1,D7),DØ     ;character from array
                MOVE.B (A2,D4),D6     ;character from search string
                CMP   D6,DØ
                BNE   WrongOne
                ADDQ  #1,D4
                ADDQ  #1,D7
                CMP   #3Ø,D4
                BNE   OneMore
(u)             MOVE.L (SP)+,D7       ;pop two subroutine return addresses off stack
                RTS                   ;return directly to "Select" routine
(v)     WrongOne
                RTS                   ;return to Top or Bottom
```

Conducting a Binary Search

To begin the binary search, we load the addresses of the two data structures and the value of the one constant that the search will need to reference (**TapeArray, NewRecord,** and **TotalRecords**) into registers [(a) in Listing 5.4]. The record number of the last record in the array (equal to the total number of records minus one, since the records are numbered beginning with zero) is saved in D1 (b) as the bottom pointer. The number of the last record but one is moved to D3 for future reference (c), and the top pointer—held in D2—is initialized to 0 (d).

To compute the middle record (e), we sum the contents of the top and bottom pointers and then divide by 2. Then the remainder portion of the result is removed by **AND**ing the destination location (D5) with the appropriate mask (f). If you can't remember how this works, refer back to the section in this chapter that deals with **AND**.

The next step in the search is to determine whether the middle record is either the first or second record (h) or one of the last two records (i). If it is, then the program must branch to examine those records separately.

Otherwise, the routine must compare the name of the tape in the middle record with the name of the tape for which we are searching. The comparison (j) is performed in the same way as the comparisons in the straight-insertion sort.

There are three possible results of the comparison. The character from the name of the tape for which we are searching may be greater than the name of the tape in the middle record (k). If so, the top pointer is moved down to equal the middle record (n). If the character from the name of the tape for which we are searching is less than the character from the name of the tape in the middle record (l), the bottom pointer must be replaced by the number of the middle record (o). In either case, before proceeding to compute another midpoint, the program needs to determine if the two pointers have crossed (p).

A top pointer greater than a bottom pointer indicates that the record for which we are searching is not in the array (q). The search routine loads the "no find" flag (a −1) into D5 and returns to the calling program. If the pointers have not crossed, then the search must continue by computing another midpoint (e) and repeating the entire comparison procedure.

On the other hand, if the two characters being compared are equal, then it is not possible to decide immediately whether the correct record has been found or whether the character checking must continue. The deciding factor is the total number of characters that have been checked. If all 30 characters are alike (m), the name of the tape for which we are searching is exactly the same as the name of the tape in the middle record. The search therefore ends successfully (the number of the middle record remains in D5) and the subroutine returns to the calling program.

The top and bottom two records are searched sequentially (r,s). For example, if the middle record was computed to equal either 0 or 1, then 0 is loaded into D5. The comparison between the name of the tape for which we are searching and the name of the tape in record 0 is performed by the subroutine OneCheck (t). The procedure is exactly the same as that used earlier in the program beginning at the symbolic address CheckChar.

Assuming that the search of record 0 is successful, there is no need for the routine to return to Top (r), where it was called; it can return directly to the part of the program that called the entire search. To "skip" one subroutine level, we need to pull one subroutine return address off the stack. At (u) the top of the stack is moved into D7 and, since Postincrement addressing is used, the stack pointer is also incremented. Remember that incrementing the stack pointer has the effect of removing the top item from the stack. The **RTS** that follows will therefore transfer program control back to the original calling program.

If the search of record 0 is unsuccessful (u), then the search continues with record 1. An unsuccessful search of record 1 indicates a "no find." The two bottom records are handled in exactly the same manner.

This binary search technique can be used with any ordered file or array that contains more than three records. Since TAPE.MASTER is ordered by tape name, that is the only field on that will support a binary search. If we need to retrieve tapes by something other than the name of the tape, there are two alternatives: reorder the array on the field to be searched, or do a sequential search. The video tape index program uses the latter approach.

Questions and Problems

1. Show how the decimal numbers below would be stored as 16-bit binary integers in a 2's complement system.

   a. 12
   b. −12
   c. 84
   d. −84
   e. 603
   f. −603
   g. 2006
   h. −2006

2. Convert your answers from problem 1 to their hexadecimal representation.

3. Convert the 2's complement integers below from hexadecimal to binary and then to their true magnitude in decimal. Remember to consider the high-order bit as a sign bit.

   a. 0016
   b. EA14
   c. 1183
   d. FF00
   e. 010A
   f. 4100
   g. 88BC
   h. 0333

4. Indicate whether each of the following represent legal 68000 instructions. For each illegal instruction, describe what is wrong with it.

   a. ADD SomePlace, D0
   b. ADD.L D0, SomePlace
   c. ADD D0, Locate(A5)
   d. SUB D0,#8
   e. SUB #8,D0
   f. SUB #10,A0
   g. SUB (SP)+,D0
   h. MULU D1,D7
   i. MULU.L SomePlace, D0
   j. MULU Locate(A5), D6
   k. DIVS #12, D3
   l. DIVU #−6, D2
   m. DIVS.L #$FF00, D6
   n. AND #6,D0
   o. AND D6,A1
   p. OR D2,#%11110000

5. For the following blocks of code:

   A. indicate the contents of the destination register after the code has been executed
   B. indicate the state of each of the flags in the user byte of the status register after the code has been executed.

   a.
   ```
   MOVE  #44,D0
   MOVE  #86,D1
   ADD   D0,D1
   ```

   b.
   ```
   MOVE  #186,D0
   MOVE  #−99,D1
   ADD   D0,D1
   ```

   c.
   ```
   MOVE  #−186,D0
   MOVE  #99,D1
   ADD   D0,D1
   ```

   d.
   ```
   MOVE  #99,D0
   MOVE  #106,D1
   ADD.B D0,D1
   ```

e.
```
MOVE  #12,D0
MOVE  #10,D1
MULU  D0,D1
```

f.
```
MOVE  #8,D0
MOVE  #6,D0
MULU  D0,D1
```

g.
```
MOVE  #31,D0
MOVE  #-3,D1
MULS  D0,D1
```

h.
```
MOVE  #80,D0
MOVE  #-8,D1
DIVS  D0,D1
```

i.
```
MOVE  #80,D0
MOVE  #-8,D1
DIVU  D1,D0
```

j.
```
MOVE  #%11110000,D0
AND.B #%00110011,D0
```

k.
```
MOVE  #%11110000,D0
OR.B  #%00010011,D0
```

l.
```
MOVE  #$00AB,D0
AND   #$FFFF,D0
```

m.
```
MOVE  #$00AB,D0
OR    #$FFFF,D0
```

n.
```
MOVE  #$00AB,D0
EOR   #$F0F0,D0
```

o.
```
MOVE  #$124A,D0
NOT   D0
```

6. Indicate the contents of registers D0 and D1 when the block of code below finishes executing.

```
      MOVE  #6,D0
      MOVE  #0,D1
Top   ADD   #4,D1
      SUB   #1,D0
      CMP   #0,D0
      BNE   Top
      .......
```

7. Consider the following block of code:

```
      MOVE  #0,D0
      MOVE  #0,D1
      LEA   Start(A5),A0
Top   MOVE  (A0,D0),D2
      BEQ   Done
      ADD   D2,D1
      ADD   #2,D0
      BRA   Top
Done  .....
Start DS    20
```

A. What does this code do?
B. Why is the index register, D0, incremented by 2 rather than 1? Hint: consider the size of the addition instruction's operands.

8. A. What Pascal operation does this block of code simulate?

```
DIVS    Operand2,D0
AND.L   #$FFFF0000,D0
SWAP    D0
```

B. What Pascal operation does this block of code simulate?

```
DIVS    Operand2,D0
AND.L   #$0000FFFF, D0
```

9. Write an assembly language subroutine that will take an operand from register D0 and compute its square.

10. Write an assembly language subroutine that computes the factorial of a word-sized operand which is passed to the subroutine in D0 (n! = 1 * 2 * 3 * .... n – 1 * n).

11. Write an assembly language subroutine that checks an array of ten characters (stored in consecutive main memory locations) and returns the array position of the character which is alphabetically last. Place the result in register D7.

12. Write an assembly language subroutine that checks a character string stored in main memory and counts the occurrences of a given character within that string. The address of the first character in the string is passed to the subroutine in A0; the ASCII code of the character being counted is in D0. Though the length of the string is unknown, its last character is a double quote (").

13. One assembly language instruction you have not seen is a "shift." A left shift moves the bits in the operand one position to the left and puts a zero in bit 0. A right shift moves the bits one position right and fills the high-order bit with a 0.

    As an example, let's consider a byte-sized shift. The byte at the address $1A2B contains the quantity 01100110. The instruction **ASL $1A2B** (**ASL** = arithmetic shift left) produces the result 11001100. The instruction **ASR $1A2B** (**ASR** = arithmetic shift right) produces the result 00110011.

    What does a left shift do? What does a right shift do? Hint: the answer is closely tied to the fact that the contents of the byte is a *quantity* rather than an address or an ASCII code.

C H A P T E R S I X

THE PASCAL CONNECTION TO THE TOOLBOX AND OPERATING SYSTEM ROUTINES

Chapter Objectives

1. To review Pascal elementary data types
2. To review Pascal user-defined data types
3. To review Pascal data structures (arrays and records)
4. To review Pascal syntax for procedure and function calls
5. To take a first look at translating the Pascal syntax of the ToolBox and operating system routines into assembly language
6. To understand the general organization of the ToolBox and operating system routines
7. To learn more details about the trap mechanism that provides access to the ToolBox and operating system routines

Yes, this is an assembly language book, not a Pascal book. Nevertheless, the Macintosh's internal routines were created with the Pascal programmer in mind. It will therefore not only simplify the process of mastering the ToolBox and operating system routines, but make it possible for you to read Macintosh documentation if you are comfortable with Pascal data types, their assembly language equivalents and how additional data types and data structures are constructed from elementary data types.

Pascal Elementary Data Types

There are six elementary data types from which all other data types are developed – three numeric, two character, and one logical.

Numeric Data Types

Integers

Integers are stored as either INTEGER or LONGINT (longinteger). An INTEGER occupies two bytes. Whenever the specifications for a ROM routine require an INTEGER, you must set aside two bytes of storage somewhere. A LONGINT ocupies 4 bytes, which means you must allocate the full four bytes anywhere a LONGINT is required.

The most significant bit in an INTEGER is used as a sign bit. If bit 15 is clear, then the number is positive; if it is set, the number is negative. The remaining 15 bits hold the number. Therefore, the maximum value that can be stored in an INTEGER location is 32,767; the minimum is –32,768. A Pascal INTEGER is therefore exactly the same as the Macintosh's 16-bit word.

To set aside space for an INTEGER you must:

```
SymbolicAddress  DC.W  initial value
```

A LONGINT also retains the most significant bit as a sign bit. Bit 31 will hold a 0 for a positive number and a 1 for a negative number. The maximum quantity that you can store in a LONGINT is 2,147,483,647; the minimum is –2,147,483,648. A Pascal LONGINT is therefore exactly the same as the Macintosh's 32-bit longword.

To declare space for a LONGINT, use:

```
SymbolicAddress  DC.L  initial value
```

Integer and longintegers are stored using the two's complement system described in Chapter 5. Why use the two's complement form? The answer lies in how arithmetic operations are done. With a two's complement system, you can perform a subtraction using addition. In other words, to do a subtraction you take the two's complement of the subtrahend (the number on the bottom in a subtraction operation) and add it to the minuend (the number on the top). The result is the same as if you did a standard subtraction. A computer designed to use two's complement arithmetic, therefore, only requires hardware which can do addition; it doesn't need special subtraction circuitry.

There are times, when you're in the midst of developing a Macintosh assembly language application, that being able to handle two's complement numbers is very handy. For example, the File Manager (the part of the ToolBox that provides for file I/O) returns a result code in D0 after each call to one of its routines. A successful file operation has a result code of 0 , but all the other result codes are negative.

If you are monitoring the progress of the program with the debugger, then you can use that result code as a clue to why an attempted file operation failed. Suppose that the program attempted to write something to the disk, but the disk was full. The result code for a disk full error is −34, but the contents of D0 appear as $FFDE. Believe it or not, $FFDE is the two's complement representation of −34. To prove it, let's convert $FFDE back to its true magnitude form:

Step 1: Convert the hexadecimal digits to binary

$FFDE = %1111 1111 1101 1110

Step 2: Invert the digits

%1000 0000 0010 0001 (Note that the highest order bit does not participate in the magnitude of the number; it is a sign bit)

Step 3: Add 1

%1000 0000 0010 0010

Step 4: Convert the binary to hexadecimal

$%1000\ 0000\ 0010\ 0010 = -22_{16}$

Step 5: Convert the hexadecimal to decimal

$-22_{16} = -(16 * 2) + 2 = -34$

Real Numbers

Real numbers, stored as the Pascal data type REAL, occupy 4 bytes. The number is broken into three parts: the *mantissa* (the fractional part of the number), the *exponent* (the power to which 2 is raised and then multiplied by the mantissa), and the sign of the mantissa. All quantities are binary.

The Macintosh makes no use of the Pascal data type REAL. Arithmetic operations on numbers that contain fractional portions are handled by FP68K, the floating point arithmetic package. FP68K is discussed in detail in Chapter 12.

Character Data Types

The data type CHAR occupies two bytes. The ASCII code of the character is stored in the low-order byte (bits 0–7); the high-order byte is unused. Though it may seem like a waste of space to use 16 bits to store an eight-bit code, it is nonetheless the way the Macintosh was designed to handle single characters. Fortunately, whenever Macintosh needs to deal with more than one character at a time, the ASCII codes are packed into adjoining bytes.

The ToolBox routine **_DrawChar** requires data stored as CHAR, which is why we've been moving an entire word (e.g., $0040) onto the stack rather than just the eight bits occupied by an ASCII code. To allocate space for a CHAR, use:

```
SymbolicAddress   DC.W  initial value
```

Pascal also has a data type to handle strings — STRING[n]. The overall length of the string is n + 1 bytes. The first byte contains the length of the string. The rest of the bytes contain the ASCII codes of the characters. For example, STRING[255] (also written Str255) requires 256 bytes of storage and will accommodate a string of up to 255 characters. Note that even though the definition allows 255 characters, you need not use them all.

Since a STRING requires more space than a longword, it can be specified by using a constant block:

```
SymbolicAddress   DCB.B  length, initial value
```

For example, a Str255 data item could be accommodated by:

```
Label   DCB.B  256,""
```

Strings that are defined in assembly language programs are not automatically assembled with length bytes. By default, strings that are defined by **LEA** or **PEA** instructions are placed immediately after program code and are given a length byte. On the other hand, strings defined by any form of **DC** directive are allocated space in the place where they occur in the application source code. They do not have length bytes. This distinction can be important, since a number of ToolBox routines have parameters of type Str255 and therefore expect the first byte to be a length byte.

The default allocations can be overridden with the **STRING_FORMAT** assembler directive. The format of the directive is:

```
STRING_FORMAT   value
```

STRING_FORMAT's value is two bits. The first bit determines how **LEA** and **PEA** strings will be handled. If it has a value of 1 (the default), these strings will be assembled with a length byte. A value of 0 assembles the text without a preceding length byte but with a trailing 0.

The second bit affects the format of **DC** strings. A value of 0 (the default) produces strings with no length byte and no trailing 0 . A value of 1 will assemble the strings *with* a length byte.

If you wish both types of strings to be assembled with length bytes, use:

```
STRING_FORMAT 3
```

The 3 is the decimal equivalent of a two-bit number with a 1 in each bit.

The Logical Data Type

Pascal's final elementary data type is BOOLEAN. Though a BOOLEAN occupies two bytes, only one bit is important. Bit 8 holds a 1 if the word has the value of true, a 0 if the value is false; all other bits are cleared. If you define a BOOLEAN as:

```
SymbolicAddress DC.W initial value
```

then you can compare the symbolic address against 0 to test for a value of false, but you must test against 256 to check for a value of true.

User-Defined Data Types

As you probably remember, Pascal allows a programmer to combine the elementary data types to create new data types known as "user-defined data types." There are four user-defined types commonly used in the definitions of Macintosh ToolBox and operating system routines:

1. SignedByte – occupies one byte with its contents stored in two's complement form. A SignedByte can therefore hold integers in the range – 128 to +127.
2. Byte – occupies two bytes with the value stored in the low-order byte.
3. Ptr (a "pointer") – occupies four bytes and contains an address which indicates the starting location of a data structure. The Macintosh uses many different pointers; they can be identified by the presence of the characters **Ptr** in the data type name.
4. Handle – occupies four bytes and contains the address of a master pointer. (A Handle is a pointer to a Ptr.) As with pointers, the Macintosh uses many different handles. Handles have the characters **Handle** as part of their data type name.

While a number of ToolBox routines provide handles to data structures, it sometimes becomes necessary to use a pointer to that same data structure. In that case, an application must "de-reference" the handle. The code to do so appears as:

```
MOVE.L SomeHandle,A0
MOVE.L (A0),A0
```

The first line loads the handle itself into an address register. The second line says: take whatever you find at the address specified by the contents of A0, and put it back in A0. This will place the pointer in A0, since the contents of a handle storage location is a pointer.

We'll look at other user-defined types as we need them to work with ToolBox and operating system calls.

Pascal Data Structures

Pascal data structures come in two varieties — arrays and records. Arrays can be built from any previously defined data type, though all values in an array must be of the same type. Records, as well, can be created from any previously defined data type, but different data types are permitted within the record; each item in a record is termed a *field*.

Arrays

The Pascal syntax:

```
ArrayName = ARRAY [1..20] of INTEGER
```

creates a new data type called **ArrayName** that contains space for 20 values, each of which is an INTEGER. Therefore, the total length of this data structure is 20 words (40 bytes). To allocate space for it in an assembly language program, you might use:

```
SymbolicAddress  DCB.W  20,initial value
```

where the 20 refers to the length of the array.

When an array is PACKED, the computer will store the data as efficiently as possible, without regard to how that storage might affect access. For example:

```
NewArray = ARRAY [1..24] of BOOLEAN
```

will require 24 words of storage, since each BOOLEAN occupies an entire word. To allocate space for it in an assembly language program, you must write:

```
SymbolicAddress  DCB.W  24,0
```

But:

```
NewArray = PACKED ARRAY [1..24] of BOOLEAN
```

will require only 24 *bits* (one and a half words), since the boolean values will be crammed one next to the other. Defining the packed array for assembly language use requires only:

```
SymbolicAddress  DCB.B  3,0
```

As a further example, consider the Pascal data type Str255, which is defined as:

```
Str255 = PACKED ARRAY [1..256] of CHAR
```

Instead of occupying one word per character as in the CHAR data type, each eight-bit ASCII code is packed in a single byte, and the entire string will occupy up to 256 bytes. (Don't forget that the first byte contains a number indicating how many characters there are in the string.) On the other hand:

```
StringArray = ARRAY [1..256] of CHAR
```

would occupy 512 bytes, since each non-packed character requires an entire word.

Records

In terms of dealing with ToolBox and operating system routines, you will encounter records more frequently than arrays. Records are commonly used to group information about various entities within the Macintosh. For example, whenever you create a menu, the Mac stores data about that menu in a menu record. That record is defined as:

```
MenuInfo = RECORD
             menuID       :INTEGER;
             menuWIDTH    :INTEGER;
             menuHeight   :INTEGER;
             menuProc     :Handle;
             enableFlags  :PACKED ARRAY [0 ..31] of BOOLEAN;
             menuData     :Str255;
           END;
```

This definition creates a new data type called **MenuInfo** which represents a record consisting of six fields of data. Whenever you create a menu, the Macintosh will return a pointer to a pointer (the Menu Handle) that will tell you where this information is stored.

How much storage will this menu record use? You can determine the length of any record by adding up the length required by each of its fields. In the menu record, each of the first three fields requires one word, the Handle data type requires two words, the packed array is 32 bits long and therefore requires 2 words, and the string is up to 256 bytes (128 words) long. Therefore, each menu record will take up a maximum of 135 words, or 270 bytes.

The menu record is an example of a record that will be generated for you by the Macintosh; you gain access to it by the handle that is returned by the system when you create the menu. At times, though, you will need to define records within your programs so that you can either access fields within the records after the Macintosh creates them, or pass data to ToolBox and operating system routines in a record.

For example, every time an "event" happens to the system (an event could be a keypress, a click of the mouse, a disk insertion, or a signal from an I/O device, etc.), the Macintosh generates an event record, recording data about the event. An event record has the structure:

```
EventRecord = RECORD
              what        :INTEGER;
              message     :LONGINT;
              when        :LONGINT;
              where       :Point;
              modifiers   :INTEGER;
      END;
```

If you examine the contents of **what**, then you can determine what kind of event occurred. (**What** will contain a code identifying the type of event.) **Where** lets you know where the mouse pointer was when the event occurred. The data type **Point** (a user-defined data type) consists of two numbers which give the coordinates of the mouse pointer in a Cartesian coordinate system which is superimposed on the screen. (See Chapter 7 and the discussion of windows for more information.)

Since the Sample program in Chapter 3 is designed to respond to mouse and keyboard events, the program must set aside space for the event record at the end of the program code. (If the storage had been allocated with **DS**, the space would be in the applications globals area.) The definition appears as:

```
EventRecord
What        DC    0
Message     DC.L  0
When        DC.L  0
Point       DC.L  0
Modify      DC    0
```

Just as with the structure of TAPE.MASTER that was defined in Chapter 5, we can access the starting address of the structure by referencing the symbolic address **EventRecord**, or we can access a single field by using its individual symbolic address. For example, **What** will reference the address of the word that contains the code representing the type of event that the system recorded.

This works only because the assembler allocates storage in the order in which it encounters **DC** and **DS** directives. If the allocation directives for a record are placed physically one after the other in the source code, they will be allocated physically contiguous storage locations.

Interacting with the File Manager (the group of operating system routines that control file I/O) is probably the most complex task we must tackle when writing Macintosh assembly language programs, at least in terms of the associated data structures. File Manager routines require some data as input and will return additional data when the routines are finished, using extremely large records known as parameter blocks. An example of this usage appears in Chapter 4 in the discussion of the instruction **LEA**. (Complete discussion of the File Manager appears in Chapter 11.)

Procedure and Function Calls

Procedures and functions are two types of Pascal subprograms. When used in a Pascal program, the data used by these subprograms may be declared globally in the program's **var** block. In that case, the programmer has the option of merely letting the subprogram use whatever data it needs without bothering to explicitly transfer the data into and out of the subprogram. However, the ToolBox and operating system routines, all of which are defined as Pascal functions and procedures, cannot use global data because they are *external* to the program which calls them: that is, the code for the ToolBox and operating system routines is never a part of the source code of the application in which they are being used. Use of the Macintosh's built-in routine therefore requires careful attention to the process of moving data to and from procedures and functions.

The data passed to a subprogram are called *parameters*. Parameters that are only used as input to a subprogram are known as *value parameters*. Parameters that are modified within the subprogram and then passed back to the main program are called *variable parameters*. Each call to a procedure or function involves not only the name of the subprogram but a list of the parameters that will be passed in and out of the subprogram.

Procedures and functions differ primarily in how they return information to the main program. A procedure returns data only through variable parameters specified in the call's parameter list. A function, though, returns an additional result. This result might be a handle to a data structure or a boolean indicating whether or not the function successfully completed the required operation.

Access to the ToolBox and operating system routines is through either a Pascal procedure or function call. Macintosh technical documentation presents them in their Pascal syntax and generally leaves it up to the assembly language programmer to simulate the calling sequence.

The **__DrawChar** routine, which you have already seen, is written in Pascal as:

```
PROCEDURE DrawChar (ch: CHAR);
```

The parameter list (**ch: CHAR**) appears in parentheses after the name of the procedure (**DrawChar**). The **ch** is the variable name given to the parameter; **CHAR** refers to its data type. As an assembly language programmer, you will not necessarily be concerned with variable names, but with the data types, since they specify the size and format of the data you must prepare before calling the procedure. **ch** is a value parameter; it is used only as input to the procedure.

Parameter lists are not limited to a single parameter. For example:

```
PROCEDURE InsertMenu (menu: MenuHandle; beforeID: INTEGER)
```

requires two parameters, the handle to a menu record and an integer indicating the relative position of this menu in the menu list (i.e., when this menu is placed in the menu bar, between which of the other menus should it be placed?). Parameter names are separated from their data types by colons. If more than one parameter has the same data type, the parameter names will be separated by commas. (See the discussion on **BlockMove** below for an example.) Parameters with different data types are separated by semicolons. Variable parameters are preceded by **VAR**; value parameters have nothing to distinguish them. Both of **InsertMenu**'s parameters are therefore value parameters; they serve only as input to the procedure.

To call a ToolBox procedure from an assembly language program, you must first push the parameters, in order from left to right as they appear in the parameter list, onto the stack. Then you call the procedure. To draw a character using **DrawChar** for example:

```
MOVE  $0040, -(SP)
```

first places the ASCII code of one character onto the stack. Because the Pascal data type is **CHAR**, an entire word is moved. Once the character is on the stack, then:

```
__DrawChar
```

initiates the call to the ToolBox routine. The procedure takes the parameters off the stack while it is executing, so that when it terminates, none remain on the stack.

ToolBox functions are handled in approximately the same way. The main difference is that before beginning to push the function's parameters onto the stack, a program must push an empty space for the function's result. The space for

the result is always deepest in the stack. When the function is finished, all of the parameters will have been removed from the stack; the result will be on top so that it can be easily recovered.

For example, the ToolBox function **MenuSelect** identifies which menu item received a click from the mouse. The Pascal definition of the function is:

FUNCTION MenuSelect (startPt: Point) : LongInt

The parameter **startPt** is the coordinates where the mouse was clicked. The data type **Point** refers to a user-defined data structure that is four bytes long and contains the coordinates of where the mouse was when the mouse button was clicked. The result of this function is the number of the menu item that was chosen. Since that data type of the result is **LongInt**, four bytes must be set aside to hold it. Therefore, the first step in the set-up sequence is to clear space on the stack for the result:

CLR.L -(SP)

Then, the point can be moved onto the stack:

MOVE.L Point (**Point** comes from the event record described above)

Finally, all that remains is to call the function:

_MenuItem

When a function finishes, you must always recover the result:

MOVE.L (SP)+,D0

NOTE: Regardless of whether your program will use the result in any way, be sure to remove it from the stack. If the result is not removed, its presence will disrupt the operation of further procedure and function calls and will probably cause **RTS** instructions to fail in unexpected ways.

Probably the hardest thing about simulating the Pascal syntax for assembly language calls to ToolBox routines is deciding whether to put the parameter itself on the stack or to merely push a pointer to the parameter. Here are a few guidelines that should help:

1. Push pointers to variable parameters. For example, the procedure **GlobalToLocal** converts a point from the screen's coordinate system to the coordinate system of whatever window that point is within. In Pascal, the procedure is defined as:

   PROCEDURE GlobalToLocal (VAR pt: Point)

The point will be passed into the procedure, converted, and then passed out. Since the procedure needs an address to store the converted coordinates, the address of the point is placed on the stack rather than the value of the point itself. Therefore, to call **GlobalToLocal**, you would:

```
PEA   Point
_GlobalToLocal
```

2. Push pointers to records. In other words, when the data type of a parameter is a record or an array rather than a single value, only a pointer to the beginning of the data structure is necessary.
3. Push pointers to parameters that occupy more than 4 bytes of space.
4. Otherwise, move the parameter onto the stack using the **MOVE** instruction. When moving parameters, pay particular attention to the size of the parameter. Note that if you move a byte, the Macintosh will automatically push another unused byte onto the stack to keep the stack pointer on an even address.

Operating System procedures and functions are described with Pascal syntax just like ToolBox routines, but they do not get their parameters from the stack. Instead, Operating System routines take their parameters from registers. Operating System functions also return their results in registers. Unfortunately, the only way to know which parameters should be placed in which registers is to consult *Inside Macintosh*; merely examining the procedure or function definition will not give you that information. An example of the use of one Operating System routine follows.

An Overview of the Toolbox and Operating System Routines

One of the things that makes the Macintosh both a pleasure and a pain to program in assembly language is the presence of so many prewritten routines. Most are in ROM, though some are present only on disk. They fall into two major groups: those known as the ToolBox and those that are part of the operating system. In either case, they are organized into "Managers," each of which relates to one general function.

The ToolBox

The ToolBox consists of 13 ROM managers and three sets of routines on disk:

1. The **Resource Manager** provides tools that manage resources. Resources are constructs such as windows and menus that an application will use. Most

applications will store resources in a file that is separate from the source code during the development process and will need to use at least the Resource Manager routine that opens the appropriate resource file.

2. **QuickDraw** contains all of Macintosh's graphics routines. Even applications that contain no graphics must make use of QuickDraw routines, since they control the location of all screen display operations and provide for the manipulation of text display characteristics.
3. The **Font Manager** is a small set of routines that are rarely accessed directly by a programmer. Instead, they are called by QuickDraw when a program requests font manipulations.
4. The **ToolBox Event Manager** contains routines that monitor things that happen to the system. Events (discussed in detail in Chapter 8) include occurrences such as a click of the mouse button, the insertion of a disk, or the press of a key on the keyboard. Interaction with the Event Manager forms the central control structure of any Macintosh application.
5. The **Window Manager** handles the definition, disposition, and manipulation of windows. Any application that adheres to the standard Macintosh user interface will make significant use of these routines.
6. The **Control Manager** does for controls what the Window Manager does for windows. Controls include scroll bars in windows and buttons (those hot-dog shaped balloons that appear in alert and dialog boxes). Control Manager routines may be called directly by a program or may be called by the Dialog Manager (see below).
7. The **Menu Manager** provides routines that create and manipulate menus. Most applications use the Menu Manager extensively.
8. **TextEdit** is a powerful set of routines that provide for the entry, display, and editing of text. Even a totally graphics-based application cannot avoid TextEdit, since some of the standard desk accessories (which all Macintosh applications should support) allow text editing.
9. The **Dialog Manager** allows an application to create, manipulate, dispose, and monitor events in dialog and alert boxes. Virtually every Macintosh program will use dialogs and alerts in some way.
10. The **Desk Manager** contains the routines that support desk accessories. They allow an application to invoke a specific desk accessory and to then turn management of that desk accessory over to the system.
11. The **Scrap Manager** provides the capability to transfer text and graphics between applications via the Clipboard. Whether or not an application will interact with the Scrap Manager is determined by the characteristics of the specific application.
12. The **ToolBox Utilities** are a diverse set of routines that cover some logical operations and bit manipulations.

13. The **Package Manager** is a gateway to the non-ROM ToolBox routines. The non-ROM routines are grouped into three packages which are loaded into RAM the first time they are called by an application. The packages handled by the Package Manager are:
    a. The **Binary-Decimal Conversion Package** converts ASCII strings of decimal characters into binary numbers that can then be used in arithmetic operations.
    b. The **International Utilities Package** contains a group of routines that make it possible to write non-English applications; also has some useful string comparison routines.
    c. The **Standard File Package** contains the standard dialog boxes that gather information about opening, closing, and saving files.

The Operating System Routines

Like the ToolBox, the operating system's routines are divided into managers. Eight are in ROM; two managers and three packages are on disk.

1. The **Memory Manager** handles the allocation of main memory while an application is running. Most Memory Manager routines affect the application heap.
2. The **Segment Loader** is the part of the operating system that actually loads a program into memory so it can be executed. For small applications, the Segment Loader is transparent to the programmer. It is invoked when a user double-clicks on a program icon. However, large applications that will not fit all at once into main memory can be broken up into chunks known as segments. In that case, the programmer must explicitly use Segment Loader routines to manage the swapping of segments between the disk and main memory.
3. The **Operating System Event Manager** contains the routines that actually detect hardware events such as mouse button and key presses. The events are passed directly to the ToolBox Event Manager, which can then be tapped by a programmer. An application rarely accesses the Operating System Event Manager directly.
4. The **File Manager** provides routines that create, open, close, read to, and write from files. They provide an unprecedented amount of flexibility in file I/O.
5. The **Device Manager**, like the File Manager, deals with I/O, but on the device rather than the file level. There are three device drivers in ROM:
    a. The **Disk Driver** (takes care of the disk drives)
    b. The **Sound Driver** (handles the Macintosh's speaker)
    c. The **Serial Drivers** (manages the two serial communications ports)

6. The **Vertical Retrace Manager** handles system actions which must be repeated at regular intervals while an application is running. These include incrementing the system clock, checking to see if the stack and heap have run into each other, and looking for hardware events such as a disk insertion or a change in the status of the mouse button. The only time an application will use the Vertical Retrace Manager is if it wishes to insert an activity of its own among those that the operating system is performing automatically.

7. The **System Error Handler** is that part of the operating system that provides the alert box with the little bomb in the upper left-hand corner. It is invoked whenever the system detects an error from which the system cannot recover, such as a binary instruction code which has no meaning to the 68000, or an address which is larger than the Macintosh's address range. This is another manager which is rarely tapped directly by an application program.

8. The **Operating System Utilities** are another miscellaneous set of "nifty" routines. They provide some string comparison (the string comparisons in the International Utilities Package are better), provide block move capabilities, and give access to the system's date and time.

9. The **Printing Manager** is not in ROM but rather is kept on disk. Along with the appropriate **Printer Driver**, the Macintosh can then support a theoretically infinite number of different printers. Any application that supports printing will make extensive use of the Printing Manager's routines.

10. The **AppleTalk Manager** is the Macintosh's gateway to the AppleTalk telecommunications network. It contains a number of disk-based routines to manage AppleTalk access as well as a pair of RAM-based device drivers.

11. The **Disk Initialization Package** is also on disk. It is called by the Standard File Package whenever a disk needs to be initialized. It is rarely called directly by an application program.

12. The **Floating-Point Arithmetic** and **Transcendental Functions Packages**, both of which are kept on disk, provide for arithmetic operations which cannot be handled within a single 32-bit register.

A Couple of Things to Be Aware Of

There is a conceptual problem with the way the ToolBox and Operating System routines are grouped. The Managers themselves tell you nothing about the sequence of calls necessary to perform a specific program action. For example, the routine that detects and identifies what sort of event has occurred is a part of the Event Manager. If the event was a mouse down event (the mouse button was clicked), then you must use a Window Manager routine to discover where the mouse button was pressed, even if it was pressed in the menu bar. Assuming that the mouse down event was in the menu bar, then Menu Manager routines can determine which menu and what item within that menu was selected.

Figuring out which routine to call when is one of the most baffling tasks in creating any Macintosh application, regardless of the language in which an application is written. Therefore, as you read on in this book, you will generally find descriptions of ToolBox and operating system calls grouped by function rather than by manager to aid you in understanding the sequencing of activities within an application.

Though the ToolBox and operating system routines are mostly in ROM, they are nonetheless programs. That means that they make use of the 68000's internal registers. If an application has placed information that must be retained in address and/or data registers, that information may be lost during a call to one of the Mac's routines. There are two ways to get around the problem.

The first is to put information that the application requires in some other form of storage by assigning it to storage locations defined by **DC** or **DS** directives. The second is to temporarily save the contents of the registers on the stack.

The instruction **MOVEM** (move multiple registers) simplifies the task of placing the contents of a series of registers on the stack. The general form of the instruction is:

MOVEM.L register list, – (SP)

To retrieve the contents of the registers:

MOVEM.L (SP) + ,register list

The register list accepts either a series of individual registers separated by **/** or a range of registers indicated by a starting and ending register number. For example:

MOVEM.L D1/D2/A0 – A4, – (SP)

will place the contents of D1, D2, A0 , A1, A2, A3, and A4 on the stack in that order.

When retrieving information stored on the stack, the register list must be in the same order as when the information was stored. The system will correctly pull the information from the stack and place it in the appropriate registers. To retrieve the information stored in the example above, use:

MOVEM.L (SP) + ,D1/D2/A0 – A4

Be very aware of what is happening to the stack when attempting to use it for temporary storage of CPU registers. Consider the situation when it becomes necessary to save register contents before jumping or branching to a subroutine. The subroutine instruction pushes a return address onto the stack. That return address is "on top" of the register contents. Therefore, the application must not attempt to restore the contents of the registers until after the program has returned from the subroutine: that is, the return address must be pulled from the stack before the registers can be properly restored. If it is necessary to have the contents

of the registers within the subroutine, then the instruction to save them should occur after the jump or branch to subroutine instruction.

When should an application save the contents of its registers? There are two approaches you can take. The conservative approach says save all registers every time an application makes a call to a ToolBox or operating system routine. The second method is initially to not save any registers and then monitor program activity with the debugger to determine specifically which registers are altered and must therefore be saved. In general, the ToolBox and operating system routines use D0-D2 and A0-A4, though there are many exceptions.

Calling Toolbox and Operating System Routines — The Trap Mechanism

All the ToolBox and operating system routines you have seen so far are invoked in assembly language source code with a name that begins with an underbar. The Assembler translates those routine names into machine language instructions that the Macintosh can understand.

When assembled, all calls to ToolBox and operating system routines — except those of the Printing Manager — begin with $A, or %1010; the rest of the instruction word contains information that identifies the particular routine being called. The 68000 microprocessor has no instructions with codes that begin with %1010. Therefore, it "traps" those instructions. Under most circumstances, the microprocessor would return a system error indicating that it encountered an unrecognizable instruction. The Macintosh operating system, however, intercepts the microprocessor's detection of the trap. It interprets the trap as a reference to the ToolBox Dispatch Table discussed in Chapter 2. Because instructions that begin with %1010 are not part of the microprocessor's hardware instruction set, they are known as "unimplemented instructions" or "line 1010 unimplemented instructions." They allow a computer manufacturer to enhance the 68000 instruction set by adding custom instructions that are implemented in software.

Trap words are associated with names by using the assembler directive **.TRAP**. For example, the routine that draws a single character has a trap word of $A883. To give it a name, the following could be included in program code:

```
.TRAP __DrawChar  $A883
```

For the programmer's convenience, trap words for all ROM routines are assigned names in the file MacTraps.D (found on MDS2). It should be INCLUDEd at the beginning of each application developed on a 512K machine. There may not

be enough memory in a 128K machine to assemble a program that contains the entire MacTraps.D file. In that case, you will need to define explicity any traps the program uses with the **.TRAP** directive.

Using Toolbox and Operating System Routines — Simplifying the Sort and Search

The straight-insertion sort and the binary search have one basic process in common — they compare strings. The sort also moves large blocks of code. It would simplify the code for these two utilities considerably if they could use prewritten routines to accomplish the comparison and move activities.

There are actually three different routines that do string comparisons. One is an Operating System routine — **EqualString**. The problem is that this function only returns a boolean value indicating whether the two strings being compared are equal or unequal. That is not enough information for either the sort or the search; both need to know direction (i.e., is the SearchString greater than or less than the string in the array?).

Tucked within the International Utilities Package are two string comparison functions. One is exactly like **EqualString (IUIDString)**; but the other, **IUMagString**, returns the kind of result the sort and search require — a 0 if the strings are equal, a −1 if the first string is less than the second, and a +1 if the first string is greater than the second one. Depending on how you look at it, there is one drawback to using **IUMagString**; upper-case and lower-case letters are evaluated as different characters, with lower-case coming after upper-case. (**EqualString** and **IUIDString** ignore the upper- and lower-case distinction.)

IUMagString is specified as:

```
FUNCTION IUMagString (aPtr, bPtr: Ptr; aLen, bLen:INTEGER):
    INTEGER;
```

The first two parameters are of the same data type — Ptr. They are pointers to the start of the two strings which are to be compared. The third and fourth parameters are both integers — the number of bytes in each string. The result is an integer as described above.

In terms of the sort, one of the strings is contained in the data structure identified by **NewRecord**. The second is somewhere within **TapeArray**. We'll use the string in the array as the "a" string. Therefore, to find its starting address, we need to compute its offset from the beginning of the array, just as we did before. (Take the record number and multiply by 64, the length of a record.) If the offset is

in D6 (as it is after a call to Compute Offset1) and the address of **TapeArray** is in A3, then a pointer to the start of the beginning of the "a" string is equal to:

```
ADDA  D6,A3
```

The address of **NewRecord** goes into A2. We will need to compare 30 characters, since the tape name field is 30 characters long.

The set-up sequence therefore involves first pushing an empty word onto the stack to contain the result and then each of the parameters in order:

```
CLR.W     -(SP)        ;space for integer result
MOVE.L    A3,-(SP)     ; "a" pointer
MOVE.L    A2,-(SP)     ; "b" pointer
MOVE.W    #30,-(SP)    ;characters in "a" string
MOVE.W    #30,-(SP)    ;characters in "b" string
```

At this point it might seem that we're ready to call the function. Using:

```
_IUMagString
```

though, it will not work in this case. **IUMagString** is part of a package and therefore doesn't exist as a separate call. Instead, whenever you need a routine that is part of a package, first push a number that identifies the routine onto the stack and then call the package as a whole. The International Utilities Package is Package #6; **IUMagString** is routine #10. Therefore, to initiate **IUMagString**:

```
MOVE.W  #10,-(SP)
_Pack6
```

(For further information on using Macintosh's packages, see Chapter 12).

The result of **IUMagString** is recovered by the instruction:

```
MOVE.W  (SP)+,D0
```

Since a **MOVE** instruction sets the condition codes, the value of the result can be checked using one or more of the **Bcc** variations without any further manipulation.

To see how **IUMagString** simplifies the sort and search routines, take a look at Listings 6.1 (the sort) and 6.2 (the search).

A prewritten routine that moves blocks of main memory would simplify considerably one of the major tasks of the straight-insertion sort. **BlockMove** is an operating system procedure that does just that. It is defined as:

```
PROCEDURE BlockMove (sourcePtr, DestPtr: Ptr; byteCount: Size);
```

This definition alone does not contain enough information to call the routine. *Inside Macintosh*, though, indicates that:

1. A pointer to the starting location of the bytes to be moved (the source pointer) should be placed in A0;
2. A pointer to the starting location of where the bytes should be moved to (the destination pointer) should be placed in A1;
3. The total number of bytes to be moved should be placed in D0 and that the size of this operand is longinteger.

Listing 6.1 Straight-Insertion Sort with Block Moves

```
        MOVE  TotalRecords,D1
        LEA   TapeArray(A5),A2
        CMP   #Ø,D1
        BEQ   InsertNew       ;if first record, insert immediately
        SUBQ  #1,D1           ;otherwise, adjust for record #'s beginning with Ø
Checking

        JSR   ComputeAddress1 ;Address returned in A3

        MOVE.L D1,-(SP)       ;save D1 on stack
        CLR.W -(SP)           ;space for result
        MOVE.L A3,-(SP)       ;pointer to record in array
        PEA   NewRecord(A5)   ;pointer to new record
        MOVE.W #3Ø,-(SP)      ;characters to look at in first string
        MOVE.W #3Ø,-(SP)      ;characters to look at in second string
        MOVE.W #1Ø,-(SP)      ;ID for IUMagString
        _Pack6                ;invoke the package
        MOVE.W (SP)+,DØ       ;recover result
        MOVE.L (SP)+,D1       ;recover former contents of D1

        CMP   #Ø,DØ
        BLE   JustBeforeInsert ;found place to insert record
        BGT   MoveOld               ;move existing record down

MoveOld
        MOVE  D1,D5
        ADDQ  #1,D5           ;record # to move to
        JSR   ComputeAddress1       ;offset returned in A3
        JSR   ComputeAddress2       ;offset returned in A4

        MOVE.L A3,AØ          ;source pointer for block move
        MOVE.L A4,A1          ;destination pointer for block move
        MOVE.L #64,DØ               ;64 bytes will be moved
        _BlockMove                  ;move an entire record

        SUBQ  #1,D1                 ;move back a record
        CMP   #-1,D1                ;does new record go in first position?
        BEQ   JustBeforeInsert
        BRA   Checking
```

(continued)

```
JustBeforeInsert
        ADDQ  #1,D1                         ;insert just below where comparing

InsertNew
        MOVE  D1,D5

        JSR     ComputeAddress2

        LEA     NewRecord(A5),AØ    ;pointer to source (the new record)
        MOVE.L A4,A1                ;pointer to destination
        MOVE.L #64,DØ               ;number of bytes to move
        _BlockMove                  ;move a record

        LEA     TotalRecords,AØ
        ADDQ  #1,(AØ)                       ;increment number of records

ComputeAddress1
        MOVE.L D1,D6                ;offset = record # * 64 bytes
        MULU  #64,D6
        MOVE.L A2,A3
        ADDA.L D6,A3
        RTS

ComputeAddress2
        MOVE.L D5,D7
        MULU  #64,D7
        MOVE.L A2,A4
        ADDA.L D7,A4
        RTS
```

Listing 6.2 Sequential Search with String Comparison Routine from the International Utilities Package

```
        LEA     TapeArray(A5),A2        ;start of tape array
        MOVE  TotalRecords,D1
        SUBQ  #1,D1             ;bottom pointer
        MOVE  D1,D3
        SUBQ  #1,D3             ;save last record-1 # for future reference
        MOVE  #Ø,D2             ;top pointer

MidPoint
        MOVE  D2,D5             ;find middle record #
        ADD     D1,D5
        DIVU    #2,D5
        AND.L #$ØØØØFFFF,D5     ;mask off remainder
        CMP     #1,D5
        BLE     TopRec                  ;handle first two records
        CMP     D5,D3
        BLE     BottomRec               ;handle last two records

        JSR     ComputeAddress2
        MOVEM.L     D1-D5/A1-A2,-(SP)    ;save registers
```

(continued)

Listing 6.2 (continued)

```
        CLR.W -(SP)                     ;space for result
        MOVE.L A4,-(SP)                 ;pointer to record in tape array
        PEA    NewRecord(A5)            ;pointer to search string
        MOVE.W #3Ø,-(SP)                ;number of characters to compare
        MOVE.W #3Ø,-(SP)                ;number of characters to compare
        MOVE.W #1Ø,-(SP)
        _Pack6                          ;invoke the package
        MOVE.W (SP)+,DØ                 ;recover result
        MOVEM.L     (SP)+,D1-D5/A1-A2   ;restore registers

        CMP    #Ø,DØ            ;check result of string compare
        BGT    TopHalf          ;array greater than search string
        BLT    BottomHalf       ;array less than search string

        LEA    RecordCounter,AØ
        MOVE   D5,(AØ)
        JSR    DisplayOneRecord     ;must be equal - record has been found
        MOVE   ReturnFlag(A5),DØ
        CMP    #Ø,DØ            ;which module called this routine?
        BEQ    KeepGoing        ;call was from Select
        RTS                     ;call was from Change or Delete

KeepGoing
        JSR    DisplayDialog3   ;display find & wait dialog box
        JSR    DisplayWindows;clear text edit windows
        RTS                     ;return to Select menu

BottomHalf
        MOVE   D5,D2            ;move top pointer down
        BRA    NoFindCheck
TopHalf
        MOVE   D5,D1            ;move bottom pointer up
NoFindCheck
        CMP    D2,D1
        BMI    NoFind           ;pointers have crossed
        BRA    MidPoint         ;find new middle record and go again
NoFind
        JSR    DisplayDialog1           ;displays "none found" dialog box
        JSR    DisplayWindows           ;clear screen and text edit records
        RTS                     ;return to Select menu

TopRec      MOVE  #Ø,D5
        JSR    OneCheck
        MOVE   #1,D5
        JSR    OneCheck
        BRA    NoFind

BottomRec
        MOVE   D3,D5
        JSR    OneCheck
        ADDQ   #1,D3
        MOVE   D3,D5
        JSR    OneCheck
        BRA    NoFind
```

(continued)

```
OneCheck
        JSR     ComputeAddress2

        MOVEM.L     D1-D5/A1-A2,-(SP)
        CLR.W -(SP)                     ;space for result
        MOVE.L A4,-(SP)                 ;pointer to array
        PEA     NewRecord(A5)           ;pointer to search string
        MOVE.W #3Ø,-(SP)                ;number of characters to compare
        MOVE.W #3Ø,-(SP)                ;number of characters to compare
        MOVE.W #1Ø,-(SP)
        _Pack6                          ;invoke the package
        MOVE.W (SP)+,DØ                 ;recover result
        MOVEM.L     (SP)+,D1-D5/A1-A2

        CMP     #Ø,DØ
        BNE     WrongOne                ;correct record not found

        LEA     RecordCounter,AØ
        MOVE    D5,(AØ)
        JSR     DisplayOneRecord
        MOVE    ReturnFlag(A5),DØ
        CMP     #Ø,DØ                   ;where does this call originate?
        BEQ     OneCheckContinues       ;call comes from Select
        MOVE.L      (SP)+,DØ;pull extra subroutine return address from stack
        RTS                             ;call comes from Change or Delete

OneCheckContinues
        JSR     DisplayDialog3
        JSR     DisplayWindows
        MOVE    #9,DØ
        MOVE.L (SP)+,D7         ;pop subroutine return address off stack
        RTS                     ;return directly to "Select" routine
WrongOne
        MOVE    #9,DØ
        RTS                     ;return to Top or Bottom
```

When **BlockMove** terminates, a result code will be placed in D0, indicating whether or not an error occurred.

One situation in which the sort moves data is to move an existing record down in the array. Therefore, the source of the data to be moved is the current record and the destination is one record below it. This requires two addresses in **TapeArray** that are computed by the subroutines ComputeAddress1 and ComputeAddress2. A pointer to the current record is returned in A3, and a pointer to the record below is returned in A4. To set-up for **BlockMove**, then:

```
MOVE.L      A3,A0       ;pointer to current record
MOVE.L      A4,A1       ;pointer to record just below
MOVE.L      #64,D0      ;record is 64 bytes long
```

Operating System routines are called just like ToolBox routines:

_BlockMove

In many cases, a program will not bother to check the result of an operation such as a block move. Since the result is in a register, though, and not on the stack like the results of ToolBox functions, it can be safely ignored.

To see where **BlockMove** fits into the flow of the straight-insertion sort, see Listing 6.1.

Questions and Problems

1. Write an assembler directive that will set aside storage space in the applications globals area for each of the following Pascal data structures:

   a.
   ```
   TYPE Point = RECORD
          v:      INTEGER;
          h:      INTEGER
        END;
   ```

   b.
   ```
   TYPE Rect = RECORD
          top:    INTEGER;
          left:   INTEGER;
          bottom: INTEGER;
          right:  INTEGER
        END;
   ```

   c.
   ```
   TYPE Rect = RECORD
          topLeft:     Point;          {assume that data type Point as
          bottomRight: Point           defined in a above}
        END;
   ```

   d.
   ```
   TYPE Region = RECORD
          rgnSize:     INTEGER;        {assume the data type Rect as
          rgnBBox:     Rect            defined in b or c above}
        END;
   ```

   e.
   ```
   TYPE Cursor = RECORD
          data:        ARRAY [0..15] of INTEGER;
          mask:        ARRAY [0..15] of INTEGER;
          hotSpot:     Point           {assume Point as in a above}
        END;
   ```

f.
```
TYPE
      Style = INTEGER;
      FMInput = PACKED RECORD
       family:        INTEGER;
       size:          INTEGER;
       face:          Style;
       needBits:      BOOLEAN;
       device:        INTEGER;
       number:        Point;          {assume Point as in a }
       denom:         Point
      END;
```

g.
```
TYPE  ScrapStuff = RECORD
       ScrapSize:     LONGINT;
       ScrapHandle:   Handle;
       ScrapCount:    INTEGER;
       ScrapState:    INTEGER;
       ScrapName:     StringPtr
      END;
```

2. Listed below are some Pascal data type statements for data structures used as ToolBox routine parameters. For each:

A. decide whether the parameter itself or a pointer to the parameter should be placed on the stack and
B. write the assembly language statements that will place the parameter or its pointer on the stack.

For this exercise only, assume that space has been allocated in the applications globals area for the data structures and that each has the symbolic address **DataType**.

Example: TYPE Pointer = Ptr; Answer: When used as a *value* parameter, push the pointer itself: **MOVE.L DataType(A5),(SP)+**. When used as a *variable* parameter, push the address of the pointer: **PEA DataType(A5)**.

a.
```
TYPE  TEHandle = Handle;   {used as a value parameter}
```

b.
```
TYPE  TEHandle = Handle;   {used as a variable parameter}
```

c.
```
TYPE  Point = RECORD       {used as a value parameter}
       v:              INTEGER;
       h:              INTEGER
      END;
```

d.
```
TYPE  Point = RECORD       {used as a variable parameter}
       v:              INTEGER;
       h:              INTEGER
      END;
```

e.
```
TYPE  Rect = RECORD        {used as a value parameter}
        topLeft:      Point;
        bottomRight:  Point
      END;
```

f.
```
TYPE  Rect = RECORD        {used as a variable parameter}
        topLeft:      Point;
        bottomRight:  Point
      END;
```

g.
```
TYPE  Str03 = PACKED ARRAY [0 ..3] of CHAR;
```

h.
```
TYPE  Str255 = PACKED ARRAY [0 ..255] of CHAR;
```

3. Consider the program skeleton below:

```
                    :
                    :
                    :
                    MOVEM.L     D0/D1/A0 – A4,(SP)+
                    JSR         StartOfSubroutine
                    :
                    :
                    {end of main program}
StartOfSubroutine
                    :
                    :           {body of subroutine goes here}
                    :
                    MOVEM.L     – (SP), D0/D1/A0 – A4
                    RTS
```

A. What problem can you see with the statements in this program skeleton? Hint: think about the order in which operands and addresses are placed on the stack.

B. What simple re-arrangement of the statements will solve the problem?

CHAPTER SEVEN

SETTING UP THE DESKTOP: WINDOWS AND MENUS

Chapter Objectives

1. To learn the steps necessary to create a Macintosh window
2. To understand the purpose of resource files and know how to prepare one for use by a Macintosh application
3. To explore the ToolBox routines that manipulate windows
4. To learn the steps necessary to create a Macintosh menu
5. To explore the ToolBox routines that manage the menu bar

As we discussed in Chapter 1, a major element in a successful Macintosh application is adherence to the standard Macintosh user interface. Two of the distinguishing characteristics of that interface are windows and pull-down menus.

Creating Windows

The ToolBox routines that manipulate windows are grouped together under the heading of the Window Manager. These routines provide facilities for not only creating windows, but for changing their size and position on the screen.

Before using any Window Manager routines, first initialize QuickDraw; the Window Manager relies on many QuickDraw routines. Then call the routine which initializes the Window Manager. The calling sequence is:

```
PEA   -4(A5)
_InitGraf          ;initializes QuickDraw
_InitWindows       ;initializes the Window Manager
```

Usually, this is done at the very beginning of a program, immediately after the statements that INCLUDE equates files. In fact, it is important to perform these and the other initialization routines that we will encounter in a specific order. Macintosh's ROM routines are deeply interconnected and some of the initialization routines rely on others in order to function properly. Failure to initialize in the correct order will cause a system error when you attempt to execute your program.

There are two ways to define windows. The first is to place all of the window specifications within the application program itself. The second is to create a source file (defined below) which contains a template for the window and to access that template from within the application. In either case, a number of parameters must be present to completely describe the window. These include its boundaries (how big it should be), its type, its title, whether it is visible or invisible, whether it should have a GoAway box, and where it should be placed relative to other windows on the screen (e.g., in front or in back).

Window Boundaries

Windows are specialized *graphics ports* (known as *grafports*) in which the Macintosh can draw. A grafport (the concept originates with QuickDraw, the set of graphics routines that underlie nearly everything Macintosh does) is basically an area in which the Macintosh can execute graphics procedures. Grafports can overlap and move from front to back on the screen, providing the basis for overlapping windows.

Grafports have many characteristics, but most important for working with windows is the coordinate system that defines them. Superimposed on the Macintosh screen is a coordinate grid. If we assume that the origin (0,0) is in the upper left-hand corner (just below the menu bar), then the screen is 512 *pixels* wide and 342 *pixels* tall. The term *pixel* is short for "picture element" and refers to one dot on the screen. The Macintosh screen coordinate system appears in Figure 7.1. Windows are rectangles that have corners defined in that coordinate system. Note that this is not necessarily the only coordinate system that can be superimposed on the screen, but it is the one that is used when defining windows. The 512 x 342 coordinate grid is often referred to as the screen's *global* coordinates.

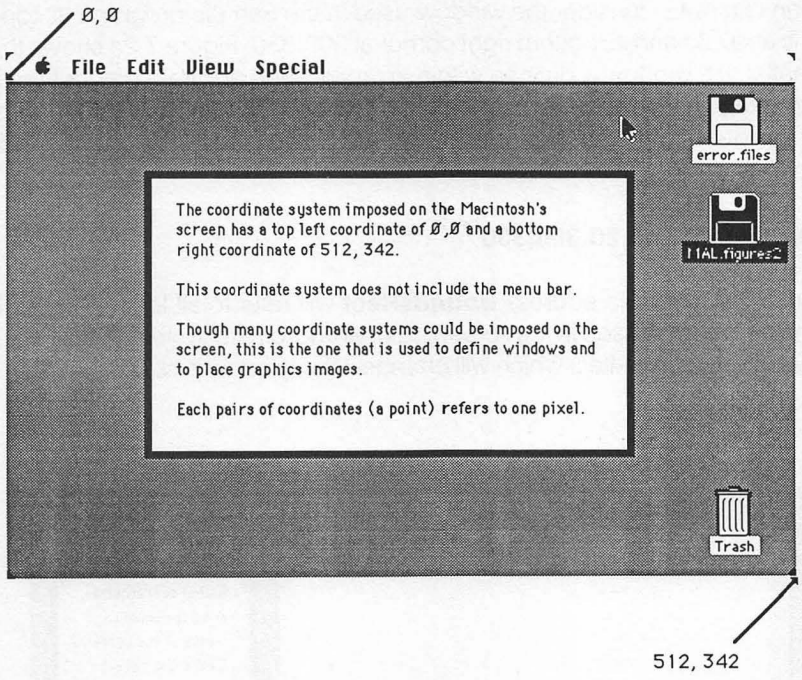


Figure 7.1 The Macintosh Screen's Coordinate System

The rectangles that define window boundaries are contained in the user-defined data type **Rect**. In the Pascal syntax:

```
TYPE Rect = RECORD CASE INTEGER OF
     0:     (top:       INTEGER;
             left:      INTEGER;
             bottom:    INTEGER;
             right:     INTEGER);
     1:     (topLeft:   Point;
             botRight:  Point)
     END;
```

What this means is that there are two choices for defining the corners of a rectangle, though for all intents and purposes, they work out the same. You can either provide four separate positions that indicate the top, left, bottom, and right positions of the rectangle; or provide two points, one for the top left corner of the rectangle and the other for the bottom right. A point is another user-defined data type that puts together an X and Y coordinate to locate a specific pixel.

As an example, consider the window used in the Sample program. Its top left corner is at 40,20 and its bottom right corner at 300,350. Figure 7.2a shows those coordinates. If a window is defined within an application program (rather than in a resource file), then the rectangle which describes the window boundaries is usually assigned to a symbolic address. In the Sample program, the "boundary rectangle" is:

BoundsRect 40,20,300,350

Any use of the symbolic address **BoundsRect** will refer to all four integers. The coordinates are expressed in the screen's global coordinate system. These are the window's initial coordinates, which will change if the window is sized.

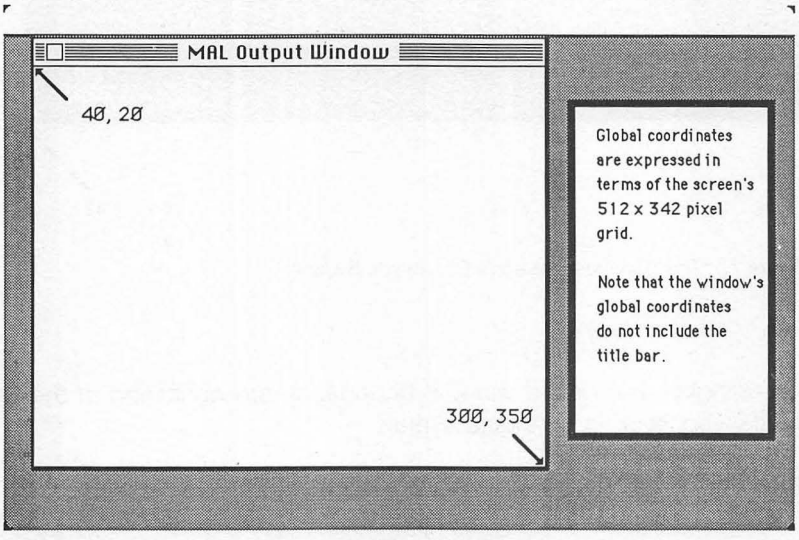


Figure 7.2(a) Using Global Coordinates to Define a Window

Windows have a second coordinate system called a *local* coordinate system. In a local coordinate system the point 0,0 is assigned to the upper left-hand corner of a window, regardless of the size of the window or where it is currently placed on the screen. For example, if window has global screen coordinates of 40, 20, 300, 350, the top left point of 40, 20 is translated to 0,0 for the window's local coordinate system.

The bottom local coordinate for a window is equal to the bottom global coordinate minus the top global coordinate plus 1 (e.g., 300 − 40 + 1 = 261). The right local coordinate is computed in a similar way; subtract the left global coordinate from the right global coordinate and add 1 (e.g., 350 − 20 + 1= 331). The boundaries of this window's initial local coordinate system are therefore 0, 0, 261, 331, as shown in Figure 7.2b.

The bottom right local coordinates of a window will change as the window is sized. Though the top left local coordinates will remain at 0, 0, the bottom right coordinates will increase and decrease with the size of the window.

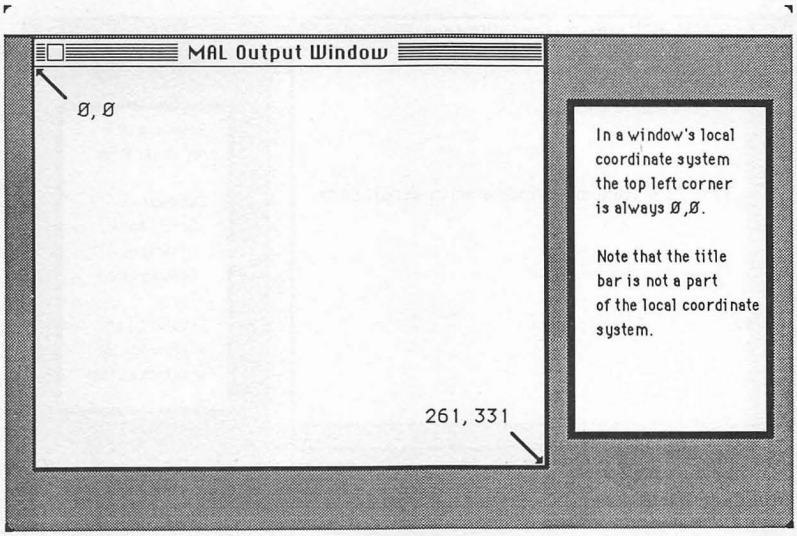


Figure 7.2(b) A Window's Local Coordinate System

Window Types

The Macintosh provides six pre-defined window types. These will be adequate for the majority of applications. Each type has an identifying number (see Table 7.1). If ToolEqu.D is INCLUDEd in your source code, you can use the symbolic address assigned to the number rather than using the number itself.

Symbolic Address	ID #	Comments
documentProc	Ø	Standard document window
dBoxProc	1	Alert or modal dialog box (heavy inner border)
plainDBox	2	Plain window with single outline border
altDBoxProc	3	Plain window with a shadow on the right and bottom
noGrowDocProc	4	Standard document window that cannot contain grow icon
rDocProc	16	Round cornered window for desk accessories

Table 7.1 Pre-defined Window Types and Their ID Numbers

The window type **documentProc** is a standard document window (see Figure 7.3a). It has a title bar, square corners, and may contain a size box and scroll bars. **noGrowDocProc** (Figure 7.3b) is the same as a **documentProc** box but cannot contain a size box and scroll bars.

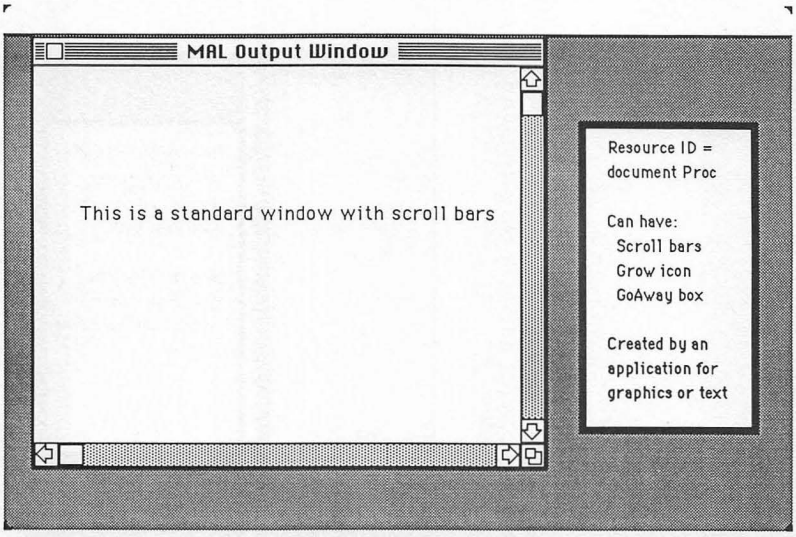


Figure 7.3(a) Standard Document Window with Scroll Bars

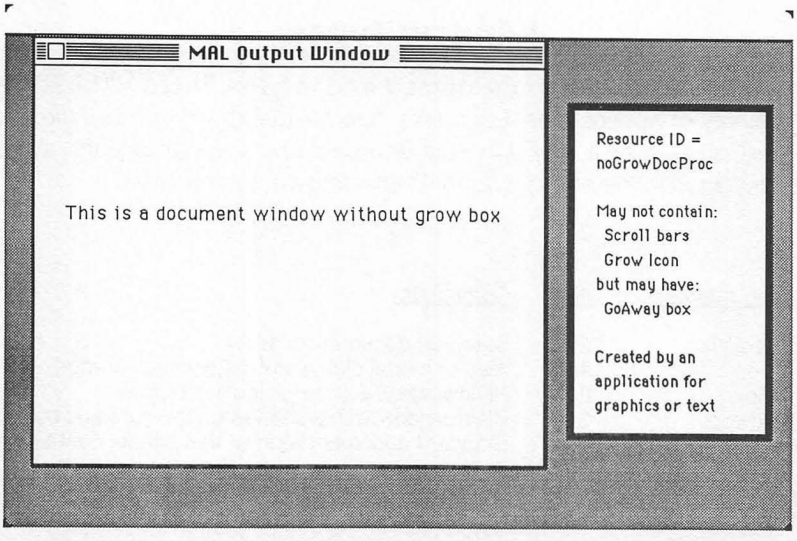


Figure 7.3(b) Standard Document Window without Grow Icon

plainDBox (Figure 7.3c) is simply a rectangle with a solid border. It has no title or scroll bars. If you use **altDBoxProc** (Figure 7.3d), you'll get a plain box with a shadow along the right and bottom borders. **dBoxProc** (Figure 7.3e) will produce a plain window with an inner border. This type of window is generally used as an alert box.

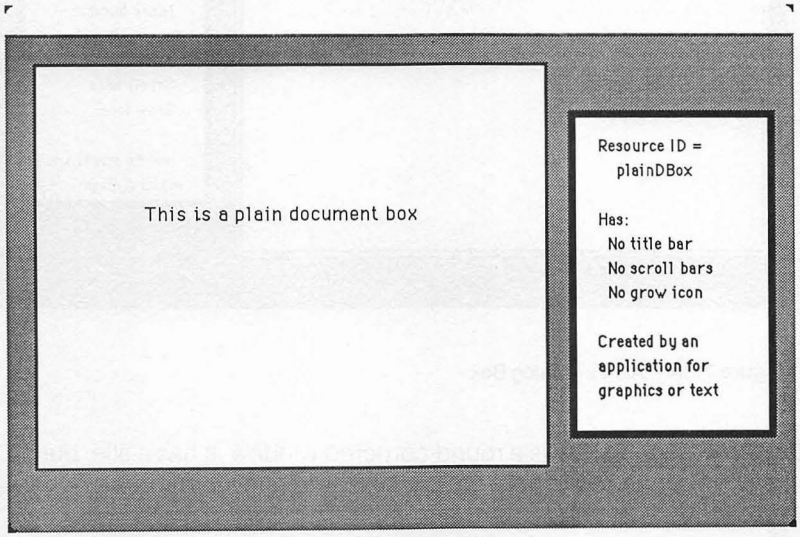


Figure 7.3(c) Plain Document Box

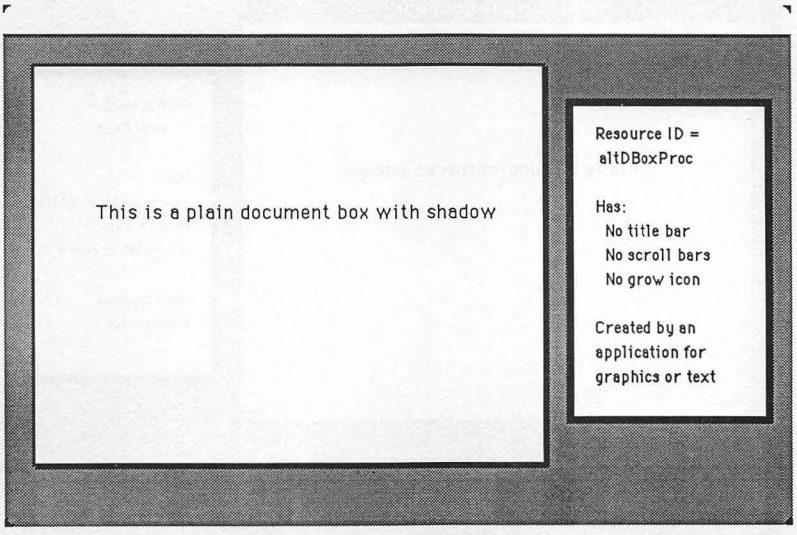


Figure 7.3(d) Plain Document Box with Shadow

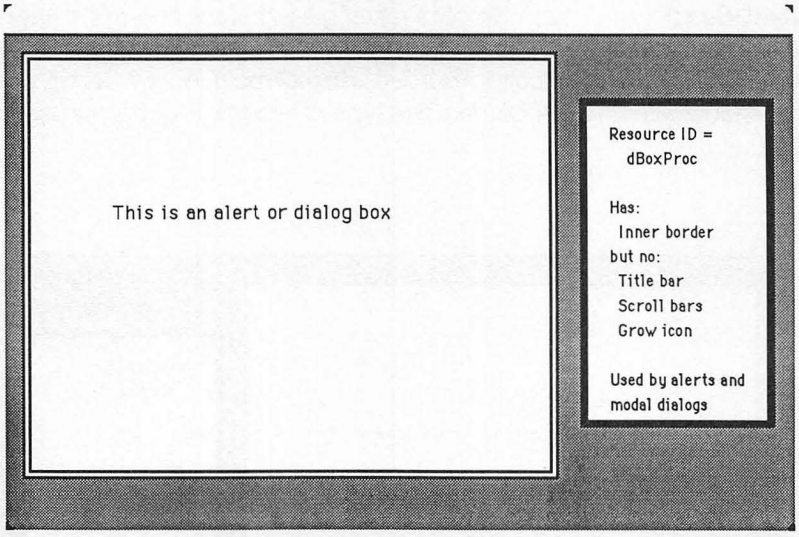


Figure 7.3(e) Alert or Dialog Box

rDocProc (Figure 7.3f) is a round-cornered window. It has a title, but no scroll bars. It is most often used to hold desk accessories and therefore will generally not appear in an application program unless that program is defining its own desk accessories.

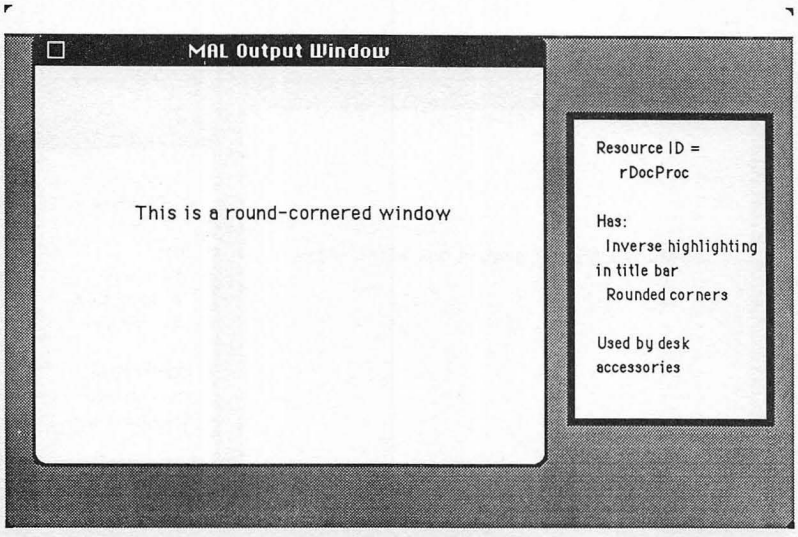


Figure 7.3(f) Round-cornered Window

The Window Record

Information about the windows an application uses are kept in *window records*, one for each window. The structure of a window record is as follows:

```
WindowRecord = RECORD
        port:          GrafPort;       the window's grafport
        windowKind:    INTEGER;        the window's type
        visible:       BOOLEAN;        TRUE if visible
        hilited:       BOOLEAN;        TRUE if highlighted
        goAwayFlag:    BOOLEAN;        TRUE if goAway region
        spareFlag:     BOOLEAN;        currently unused
        strucRgn:      RgnHandle;      structure region
        contRgn:       RgnHandle;      content region
        updateRgn:     RgnHandle;      update region
        windowDefProc: Handle;         window definition function
        dataHandle:    Handle;         used by windowDefProc
        titleHandle:   StringHandle;   window's title
        titleWidth:    INTEGER;        width of title in pixels
        controlList:   Handle;         handle to first control
        nextWindow:    WindowPeek;     next window in list
        windowPic:     PicHandle;      pic. for drawing window
        refCon:        LONGINT;        reference value
END;
```

An application can ignore many of the fields in a window record, but some do require further mention. In particular, an application may need to get to the three "region" parameters: the structure, content, and update regions. The term *region* comes from QuickDraw. It refers to some area that can be bounded by a rectangle but is not necessarily rectangular in shape. In other words, a region can be described by the rectangle that most closely encloses its contents. A region is defined by a simple record:

```
Region = RECORD
        rgnSize:       INTEGER;
        rgnBox:        Rect
END;
```

rgnSize contains the number of bytes in the region. **rgnBox** is the rectangle that encloses it.

Windows have three regions. The structure region includes the window's outside outline and its title bar, if it has one. The content region is everything inside the window, including scroll bars. The update region contains those parts of a window that have been changed by the actions of an application and therefore need to be redrawn. All three regions can change while an application is executing.

It may be necessary for an application to retrieve the rectangles that describe any of these three regions. To do so, the application must:

1. Get the pointer to the window record.
2. Use an offset into the window record to retrieve the region's handle. Offsets into a window record are defined in the ToolBox equates file.
3. De-reference the handle to get a pointer to the region record.
4. Add 2 to the pointer to the region record to skip over the region size parameter. The result will be the starting address of the region rectangle.

As an example, let's look at finding the structure rectangle for a window:

```
MOVE.L    WindowPtr,A0      ;get pointer to window record
MOVE.L    strucRgn(A0),A0   ;get handle to structure region
MOVE.L    (A0),A0           ;get pointer to region record
ADDA      #2,A0             ;adjust address to skip over
                            ;region size
```

Other parameters from the window record that an application might need will be discussed with the program activities that require them.

Defining Windows within an Application Program

The Window Manager routine **NewWindow** will set up and draw a window whose parameters are specified wholly within the application program. In Pascal, the routine appears as:

```
FUNCTION NewWindow (wStorage: Ptr; boundsRect: Rect; title: Str255;
    visible: BOOLEAN; procID: INTEGER; behind: WindowPtr;
    goAwayFlag: BOOLEAN; refCon: LongInt) : WindowPtr;
```

Note first of all that **NewWindow** is a function; it returns something called **WindowPtr** (the *window pointer*). The window pointer is the address of the location in the applications globals area of the window record. Many Window Manager routines need this window pointer as a parameter so they can operate on the correct window.

Since a window pointer contains an address, it will require a longword (4 bytes) of space. Therefore, the first step before calling **NewWindow** is to reserve space on the stack for the **WindowPtr** result:

```
CLR.L -(SP)
```

Then all the remaining parameters must be placed, in order, on the stack.

wStorage refers to a pointer to where the window record will be stored. It must reserve enough space for the entire window record. Therefore, **wStorage** should be defined as:

```
wStorage    DCB.W    windowsize,0 or
wStorage    DS       windowsize
```

where **windowsize** is defined in the ToolEqu.D file as the number of words in a window record. As long as ToolEqu.D has been INCLUDED in your source code, it isn't necessary to know the actual size of the window record. Using symbolic addresses rather than actual quantities is always preferable. For example, if the size of a window record changes at some later date, you will only need to use the updated equates file rather than changing your application program.

Since **wStorage** is a pointer, push it onto the stack using **MOVE.L**. Whenever a parameter is 4 bytes or less in length, put the parameter itself on the stack.

It is possible to allocate space for the window record on the application heap rather than in a program's code (using **DC**) or the applications globals area (using **DS**). To do so, use a value of 0 for **wStorage**.

boundsRect is the coordinates of the boundaries of the window's rectangle. As discussed above, the boundary rectangle should be assigned to a symbolic address. That address is placed on the stack with **PEA**, since the coordinates themselves occupy 8 bytes and are therefore too long to be placed on the stack themselves.

The title of the window can be simply included as a string in quotes. However, the string itself is not pushed on the stack. Like the boundary rectangle, it occupies more than 4 bytes.

```
PEA  'Text of the Title'
```

will push a pointer to the string **Text of the Title** onto the stack and place the string at the end of the program code.

visible is a boolean that indicates whether the window should initially be visible or invisible. If it has a value of TRUE, the window will be visible; otherwise, the window will be defined by **NewWindow** but not drawn. A boolean occupies a word of space. Therefore, to create a visible window, you would:

```
ST  -(SP)
```

Though **ST** only affects one byte, the system will automatically push an unused byte onto the stack to keep the contents of the stack pointer even.

The **procID** is one of the six pre-defined window types mentioned above. Since **procID** is an integer, simply **MOVE** the appropriate constant onto the stack. For example:

```
MOVE  #documentProc,-(SP)
```

will indicate that this window should be a standard document window.

behind indicates where this new window should be placed relative to other windows on the screen. If **behind** contains a pointer to the window record of another window, the new window will be placed directly behind that window. On the other hand, if **behind** is 0, the new window will be placed behind all the other windows. A value of −1 for **behind** will place the new window in front. Since **behind** is a pointer, it requires a longword of space:

```
MOVE.L  #-1,-(SP)
```

The **goAwayFlag** is a boolean that determines whether or not a GoAway box will appear in the title bar of the window. A value of TRUE draws a GoAway box; FALSE leaves it out.

The final parameter, **refCon**, sets up space for the window's reference value. A reference value is anything a programmer wishes to assign. It can be used in any way an application desires. In most cases, an application will rarely use it and should therefore give it a value of 0.

The complete **NewWindow** calling sequence appears as:

```
CLR.L       -(SP)          ;space for window pointer result
PEA         wStorage       ;pointer to storage for window record
PEA         boundsRect     ;coordinates of window corners
PEA         'Text of Title' ;title of the window
ST          -(SP)          ;visible window
MOVE        documentProc   ;window's resource ID
MOVE.L      #-1,-(SP)      ;window goes in front of all others
SF          -(SP)          ;no GoAway box
CLR.L       -(SP)          ;room for reference value
__NewWindow                ;calls the routine
```

When **NewWindow** finishes, the window pointer will be left on top of the stack. Since the window pointer is essential to so many other Window Manager routines, it is vital that a program retrieve that window pointer before doing anything else. Space for the window pointer should be prepared by defining:

```
WindowPointer  DC.L  0
```

or

```
WindowPointer  DS.L  1
```

Then, immediately after defining the window, the pointer can be moved to **WindowPointer** with:

```
LEA         WindowPointer,A0
MOVE.L      (SP)+,(A0)
```

Using Resource Files to Create Windows

Using **NewWindow** is really the hard way to create a window. It is far more efficient to place the window definition parameters in a resource file which an application program can then tap. Changes to parameters can then be made in the resource file without requiring modification of the source code.

A resource file is a text file that has been compiled by the Resource Compiler, RMaker. It may contain not only window definitions, but definitions for things like menus and dialog boxes. To create a resource file, enter the Editor and type the resource definitions. Resource source files should be named with an extension of **.R**. (For example, the resource source file for the video tape index is called **Tapes.R**.)

The format of a resource file is very rigid. The first line contains the name of the file to which RMaker should write the compiled file. While the Video Tape Index program was being developed, the first line of its resource file read:

```
tape.index: Tapes.Rsrc
```

For each resource you wish to define, first identify the type of resource to which the definition applies. For example, to define a window:

```
TYPE WIND
```

The word **TYPE** is a signal that a new resource definition is beginning. **WIND** refers to one of 12 predefined resource types — in particular, a window.

The remainder of a window definition might appear as:

```
 ,1
A Sample Window
40 20 300 350
Visible GoAway
0
0
```

The second line contains a space, followed by a comma and then a sequence number for the window. Since it is possible to have many window definitions in the same resource file, each must be assigned a unique sequence number. By referring to that sequence number, the Macintosh can access the window definitions in any order. The space preceding the comma is required.

The text of the window title appears directly below the sequence number. It should not be in quotes. Even if you are defining a window type that doesn't have a title, it is useful to include one anyway simply for documentation.

The coordinates of the window's boundary rectangle follow immediately on the next line, separated by spaces. Their order is top, left, bottom, right.

The fifth line of a window definition indicates whether the window is visible or invisible and whether or not it should have a GoAway box. Use the appropriate word (**Visible, Invisible, GoAway, noGoAway**), though only the first character is actually used by the Macintosh.

A resource file will not accept the symbolic addresses assigned to window resource ID's in the ToolEqu.D file. Therefore, on the sixth line of a window definition you must use the numeric values to indicate what type of window should be drawn. The 0 in the example above refers to a standard document window (**documentProc**).

The final line of the window definition contains the window's reference value. If no reference value is needed, use 0 as a placeholder.

Once a resource file has been created by the Editor, it must be compiled using RMaker. Enter RMaker either by transferring to it from the Editor or by double-clicking on its icon from the Finder. Once you "open" a resource source file, the compilation proceeds automatically. A successful compilation produces a binary file with the name specified on the first line of the resource file's source code (e.g., the original compiled resource file for the video tape index was **Tapes.Rsrc**).

Before an application program can use the information in a separate resource file, that file must be opened. Therefore, immediately after initializing all the managers, open the resource file the program will be using. The routine that does so, **OpenResFile**, is part of the Resource Manager. The calling sequence for **OpenResFile** is:

```
FUNCTION OpenResFile (fileName: Str255) : INTEGER;
```

OpenResFile returns an integer which contains a reference number for the file. It is rarely used. Nevertheless, since the reference number is left on the stack, you must be sure to remove it after calling the routine, since an extra parameter left on the stack will disrupt stack operations.

The sequence to open the separate resource file for the video tape index appears as:

```
CLR          -(SP)                  ;space for result
PEA          'Tape.index:Tapes.Rsrc' ;name of resource file
_OpenResFile
MOVE         (SP)+,D0               ;discard unused result
```

Once a window has been defined in a resource file, creating it from an applications program is very straightforward. The routine to use is **GetNewWindow**:

```
FUNCTION GetNewWindow (windowID: INTEGER; wStorage: Ptr;
    behind: WindowPtr) : WindowPtr;
```

windowID refers to the sequence number assigned to the window definition in the resource file. The other parameters are exactly the same as those for **NewWindow**: **wStorage** is a pointer to where the window record will be stored, **behind** determines the window's placement on the screen, and **WindowPtr** is the window pointer result.

To create the window defined by the sample window definition above (assuming it has a **windowID** of 1), you would code:

```
CLR.L     -(SP)              ;space for window pointer result
MOVE      #1,-(SP)           ;window ID
PEA       wStorage           ;pointer to storage for window record
MOVE.L    #-1,-(SP)          ;put this window in front
_GetNewWindow
LEA       WindowPointer,A0   ;get address for window pointer
MOVE.L    (SP)+,A1           ;retrieve window pointer from stack
MOVE.L    A1,(A0)            ;store window pointer
```

The video tape index program uses seven different windows. The portion of **Tapes.R** that contains the window definitions appears in Listing 7.1. Note that **TYPE WIND** is not repeated. Once RMaker has encountered a single **TYPE** statement, it assumes that all resource definitions that follow are of the same type until another **TYPE** appears.

Each window has its unique sequence number. While sequence numbers may not repeat within the same type of resource, they may be duplicated within another type (e.g., the eight menus that the program uses are numbered 1-8 even though the windows are numbered 1-7).

The main window is a standard document window (see Figure 7.4) with the title **Video Tape Index**. It acts more or less like a placemat for the remaining windows, which hold text as it is entered or displayed. Windows 2-6 are plain document windows (the window resource ID is 2). Though these windows have no titles when drawn, the resource file contains titles so the windows can be easily identified. The seventh window is another standard document window.

How do you figure out the coordinates for the window boundaries? Unfortunately, there is no easy way. Trial and error generally works best. The boundaries of the video tape index text windows changed six or seven times before they were properly placed. Making such changes with the definitions in a resource file is quick and easy; doing it with window definitions in an application is tedious and time consuming.

Listing 7.1 Resource Templates for Video Tape Index Windows

```
TYPE WIND                                   ;; window tempates follow
,1                                          ;; sequence number
Video Tape Index                                  ;; title
4Ø 1Ø 3ØØ 5ØØ                               ;; boundary rectangle
visible NoGoAway                            ;; visible but no GoAway Box
Ø                                           ;; window type (documentProc)
Ø                                           ;; reference value

,2                                          ;; sequence number
Tape Name                                   ;; title for documentation only
5Ø 24Ø 7Ø 49Ø
visible NoGoAway
2                                           ;; window type (plainDBox)
Ø

,3
Producer
75 24Ø 95 415
visible NoGoAway
2
Ø

,4
Date
1ØØ 24Ø 12Ø 283
visible NoGoAway
2
Ø

,5
Rating
125 24Ø 145 269
visible NoGoAway
2
Ø

,6
Tape Number
15Ø 24Ø 17Ø 276
visible NoGoAway
2
Ø

,7
Annotation
2Ø5 2Ø 28Ø 49Ø
visible NoGoAway
Ø
Ø
```

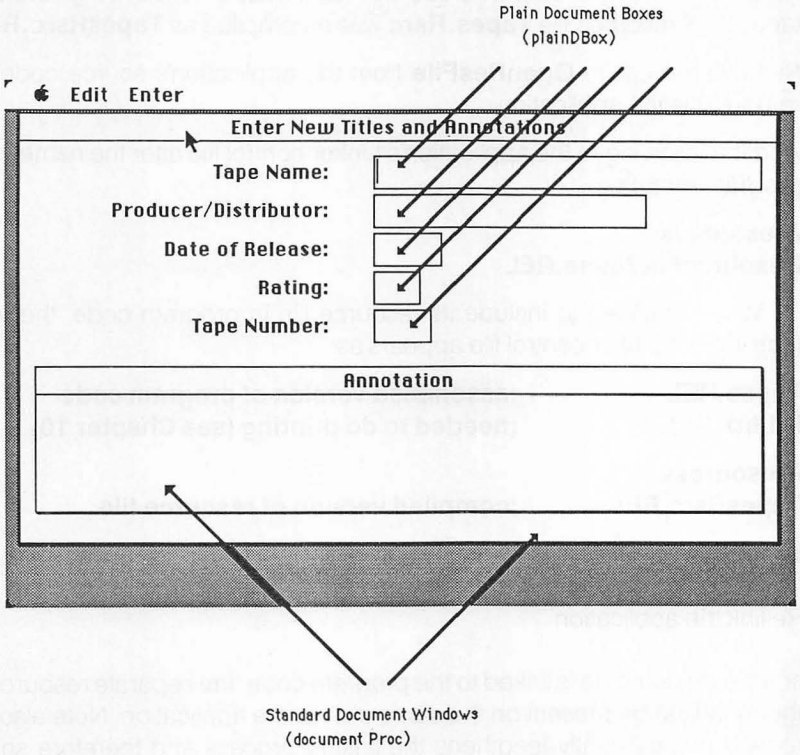


Figure 7.4 Window Types Used by the Video Tape Index Program

Programming Technique — Making a Resource File Part of Program Code

While an application is being developed it is convenient to keep the resource file separate from the program code; such an arrangement facilitates changes in the resource definitions. Once an application is completely debugged and its resource definitions no longer changing, the resources can be linked into the application itself. To make resource definitions parts of an application, do the following:

1. Rename the RMaker output file so that it has a **.REL** extension (e.g., the video tape index resource file **Tapes.Rsrc** was recompiled as **TapesRsrc.REL**).
2. Remove the call to **OpenResFile** from the application's source code and reassemble the application.
3. Add the following to the application's Linker control file after the names of all program modules:

   /Resources
   ResourceFileName.REL

   When modified to include its resource file in program code, the video tape index's Linker control file appears as:

```
Tapes.REL          ;assembled version of program code
PrLink.REL         ;needed to do printing (see Chapter 10)

/Resources
TapesRsrc.REL      ;compiled version of resource file

$
```

4. Re-link the application

Once the resource file is linked to the program code, the separate resource file no longer needs to be present on the same disk as the application. Note also that this procedure significantly lengthens the linking process and therefore should really be the last step in preparing an application.

Manipulating Windows

If you have run the video tape index program, you will have noticed that as you select an option from the main **Options** menu, the title of the main, background window changes to match the option selected. The text windows — hidden when the program begins — appear. Whenever you select **Quit** from within one of the program functions, the text windows disappear and the main window's title reverts to **Video Tape Index**. These functions are accomplished with a few of the many routines that permit the manipulation of windows once they have been created.

Changing a Window's Title

Changing a window's title is accomplished with the **SetWTitle** routine:

```
PROCEDURE SetWTitle (theWindow: WindowPtr; title: Str255);
```

To use it, move the appropriate window pointer to the stack and then push a pointer to a string for the title. For example, changing the video tape index's main window's title from **Video Tape Index** to **Enter New Titles and Annotations** requires:

```
MOVE.L      MainWindowPtr, -(SP)
PEA         'Enter New Titles and Annotations'
_SetWTitle
```

Making Windows Appear and Disappear

It is possible, at any time, to make any window visible or invisible. This does not change the position of the windows relative to one another; it merely affects whether or not they can be seen.

To make a previously invisible window visible, use:

```
PROCEDURE ShowWindow (theWindow: Ptr);
```

Move the window pointer onto the stack and then call the routine. For example:

```
MOVE.L      SomeWindowPtr, -(SP)
_ShowWindow
```

Using **ShowWindow** on a window that is already visible will have no effect.

The routine to make a previously visible window invisible is **HideWindow**:

```
PROCEDURE HideWindow (theWindow: Ptr);
```

Changing a Window's Position in the Plane

How much of a window is visible also depends on which other windows are in front of it. Two routines, **BringToFront** and **SendBehind** directly affect window position.

BringToFront will make the window in the procedure call the front-most window on the screen:

```
PROCEDURE BringToFront (theWindow: Ptr);
```

SendBehind can place a particular window behind all other windows or behind any other window on the desktop:

```
PROCEDURE SendBehind (theWindow: Ptr;
    behindWindow: Ptr);
```

The parameter **theWindow** is a pointer to the window that should be moved. **behindWindow** is a pointer to the window behind which **theWindow** should be placed. If **behindWindow** is 0, then **theWindow** will be sent to the very back.

BringToFront and **SendBehind** do not, however, make a window *active*. As stated in Chapter 1, regardless of how many windows occupy the screen at any given time, only one can be active. An active window is highlighted, though the specifics of the highlighting depend on the type of window. For example, for standard document windows, highlighting means that the title will appear in the title bar surrounded by horizontal lines. When a standard document window is inactive, the title bar still contains the title but the horizontal lines disappear. Drawing can only occur in active windows.

The routine **SelectWindow** is the best way to activate a window:

```
PROCEDURE SelectWindow (theWindow: WindowPtr);
```

A call to **SelectWindow** will do the following:

1. Unhighlight whatever window was most recently active;
2. Bring the window being activated to the front (i.e., does the same thing as **BringToFront**);
3. Highlight the window; and
4. Let the program know that one window is deactivated and another activated (this generates two "events," which are discussed in Chapter 8).

Whenever possible, it is better to use **SelectWindow** rather than **BringToFront**. You should also not use **SendBehind** to deactivate a window, since using **SelectWindow** takes care of it for you.

The Video Tape Index program uses repeated calls to **SelectWindow** to manage its windows. If the main window is brought to the front by **SelectWindow**, it effectively hides the text entry windows since it is so much bigger. Therefore, each time the program returns from a subroutine that performs one of the **Options**, it executes:

```
MOVE.L      MainWindowPtr, -(SP)
_SelectWindow
```

Selecting each of the text entry windows in turn brings them in front of the main window. The actions which follow involve set-up for text entry and will therefore be discussed in detail in Chapter 9.

Preparing Windows That Will Change Size

If an application needs to give the user the ability to size a window, that window should contain a grow icon (two overlapping squares). In document windows, the

grow icon always appears in the lower right-hand corner of a window. A grow icon is displayed by the routine **DrawGrowIcon**:

```
PROCEDURE DrawGrowIcon (theWindow: WindowPtr);
```

If the window indicated by **theWindow** (a pointer to the appropriate window record) is active, **DrawGrowIcon** will draw the outline of the grow icon area, the icon itself, and the outline of the area that should contain scroll bars for that window. If the window is inactive, only the grow icon area and the scroll bar areas will be drawn.

For details on how to use the grow icon to size windows, see the section in Chapter 8 on handling mouse down events in grow regions.

Setting Up Scroll Bars

One of the things that the Macintosh does very well is scrolling through large documents. The scroll bars that provide that facility are grouped with buttons and check boxes under the heading of *controls*. Controls are graphics images that allow the user to control program action in some way.

Most controls, like buttons and check boxes, only appear in dialog and alert boxes. They are handled by Dialog Manager routines (see Chapter 9). Generally, the only controls an application will deal with directly are scroll bars.

Information about a control is stored in a control record that is located by a handle:

```
ControlRecord = RECORD
        nextControl:    ControlHandle;    next control
        contrlOwner:    WindowPtr;        control's window
        contrlRect:     Rect;             boundary rectangle
        contrlVis:      BOOLEAN;          TRUE if visible
        contrlHilite:   BOOLEAN;          TRUE if highlighted
        contrlValue:    INTEGER;          current value
        contrlMin:      INTEGER;          minimum value
        contrlMax:      INTEGER;          maximum value
        contrlDefProc:  Handle;           definition function
        contrlData:     Handle;           used by contrlDefProc
        contrlAction:   ProcPtr;          default action proc.
        contrlRefCon:   LONGINT;          reference value
        contrlTitle:    Str255;           title
END;
```

While an application will not need to retrieve data from most of these fields, there are two that are of some importance. Like windows, controls can be assigned arbitrary reference values (**contrlRefCon**) by an application. Since it may be necessary to identify what type of control a control record describes, the reference value can be used to hold that information. For example, some of the sample code

in Chapter 8 must distinguish between vertical and horizontal scroll bars. Therefore, each was assigned a unique reference value. Remember that reference values are assigned arbitrarily by an application and have no meaning to the system other than what an application gives them.

The first parameter in the record, **nextControl**, is also of some importance. Controls belong to windows. The handle to the control record of a window's first control will be stored in the **wControlList** parameter of the window record. The rest of a window's controls are linked together in a chain through the **nextControl** field of the control record. In other words, the handle to the next control in the list is found in the **nextControl** field. A window's last control will have a **nextControl** value of 0. A window without any controls will have a **wControlList** value of 0. This type of organization is known as a *linked list*. An application can find all of a window's controls by threading its way down the list, from one **nextControl** field to the next.

Scroll bars, like windows, can be defined either within an application or from a template in a resource file. Using a resource file is the simpler of the two procedures.

The scroll bars in the program that created Figure 7.3b were defined with the following entries in a resource file:

```
TYPE CNTL
  ,1                    ;unique resource ID#
horizontal              ;title for documentation only
245 0 261 316           ;boundary rectangle
Visible                 ;visible or invisible?
16                      ;procedure ID that stands for scroll bar
0                       ;application-defined reference value
0 100 1                 ;minimum maximum value

  ,2                    ;unique resource ID#
vertical                ;title for documentation only
0 316 245 331           ;boundary rectangle
Visible                 ;visible or invisible?
16                      ;procedure ID that stands for scroll bar
0                       ;application-defined reference value
0 100 1                 ;minimum maximum value
```

Control templates have a type of **CNTL**. As with windows, each control in the resource file must be assigned a unique number, its resource ID, which is the first line in the template. The space preceding the comma is required.

The third line may contain the title of the control. Since scroll bars do not have titles, that line is ignored by the system and can therefore be used just as documentation to identify the control. The third line in the control template is the boundary rectangle that defines where the control should be drawn. Coordinates are expressed in the local coordinate system of the window in which the control will appear. For scroll bars, the boundary rectangle should be 16 pixels wide. A

horizontal scroll bar will begin at the right edge of the window and end 15 pixels before its left edge, leaving room for the grow icon (a 15 x 15 pixel square). Vertical scroll bars will begin at the top of the window and end 15 pixels above the bottom, again to leave room for the grow icon.

As discussed earlier in this chapter, the window in Figure 7.3b has global coordinates of 40, 20, 300, 350. It is therefore 261 pixels high (top – bottom + 1) and 331 pixels wide (right – left + 1), giving it local coordinates of 0, 0, 261, 331. These latter coordinates were used to determine the boundary rectangles of the scroll bars. For example, the horizontal scroll bar has a top coordinate of 245 (261 – 16) to accommodate the width of the scroll bar, a left coordinate of 0 so the scroll bar will begin at the right edge of the window, a bottom coordinate of 261, and a left coordinate of 316 (331 – 15) to accommodate the grow icon.

Line four in the control template indicates whether the control is initially visible or invisible. Visible controls will be drawn when the control is created. The fifth line indicates what type of control the definition is for. Scroll bars have a procedure ID of 16. As with windows, the procedure ID's must be used as integers; the symbolic addresses assigned to them in the ToolBox equates file cannot be substituted.

Line six contains the optional reference value. This longinteger can be assigned any value in the resource file and accessed and changed while the application is running. If you will not use a reference value, simply assign it a value of 0.

The three parameters in the final line of the control template are the minimum value the control can take, the maximum value the control can take, and its initial value. The initial value for scroll bars should always be 1; this will ensure that the scroll bars are drawn and active when the control is created. A scroll bar is an analog scale; each movement within it represents movement of a certain percentage of a document. Therefore, its minimum value should be set to 0 or 1. The maximum value is rather arbitrary, but the larger the maximum value, the greater the sensitivity of the scale. For example, if a scroll bar has a range of 0 to 10, then the document will have, in effect, 10 positions to which it can be scrolled, each presenting a move of 10% through the document. On the other hand, a maximum value of 100 divides the scale into 100 pieces, permitting far smaller movements within the document.

Once a control template has been defined in a resource file and the resource file successfully compiled with RMaker, the control is created by **GetNewControl**:

```
FUNCTION GetNewControl (controlID: INTEGER; theWindow:
    WindowPtr) : ControlHandle;
```

GetNewControl returns a longinteger result which is a handle to the control record. All the other routines which affect controls need the handle to locate the record. Therefore, the control handle must be saved after it is pulled from the stack.

The parameter **controlID** is the resource ID number from the first line of the control template in the resource file. The second parameter is a pointer to the window in which the control will be drawn.

The program that drew Figure 7.3b created scroll bars with the following code:

```
CLR.L       -(SP)                   ;space for control handle result
MOVE        #1,-(SP)                ;the horizontal scroll bar
MOVE.L      WindowPtr,-(SP)         ;window pointer
_GetNewControl

LEA         BottomControlHandle,A0
MOVE.L      (SP)+,(A0)              ;retrieve handle

CLR.L       -(SP)                   ;space for control handle result
MOVE        #2,-(SP)                ;the vertical scroll bar
MOVE.L      WindowPtr,-(SP)         ;window pointer
_GetNewControl

LEA         SideControlHandle,A0
MOVE.L      (SP)+,(A0)
```

The above sequence will only display the control bars. It does not take care of moving them or moving the text in the window. For intercepting mouse down events in scroll bars, see Chapter 8. Chapter 9 includes a discussion of scrolling text within a window.

Closing and Disposing of Windows

If an application needs to remove a window from the screen (rather than making it invisible or hiding it behind another window), there are two routines that will do so. **CloseWindow** is used when an application allocated its own storage for the window record:

PROCEDURE CloseWindow (theWindow: WindowPtr);

This routine removes the window from the screen and deletes it from the application's window list. Since storage for the window record was allocated by the application, that block of storage is unaffected when the window is closed. Any other data structures associated with the window are deleted from memory.

On the other hand, if an application did not give the window creation routine a storage area for the window record, but rather indicated that the window record should be placed on the heap (a **wStorage** value of 0), **DisposWindow** is used to remove it:

PROCEDURE DisposWindow (theWindow: WindowPtr);

DisposWindow will not only remove the window from the screen and the window list, but will release the memory used to store the window record.

Once a window has been closed with either **CloseWindow** or **DisposWindow**, it cannot be used again unless it is redefined by another call to **NewWindow** or **GetNewWindow**.

Creating Menus

Like windows, menus can be created either completely within an application program, or they can be retrieved from a template in a resource file. Creating menus within an application is far more cumbersome than creating a window within an application. It is far easier to always use a resource file for menu definitions.

Defining Menus

Resource file menu definitions begin with:

```
TYPE MENU
```

and, like window definitions, are followed by a second line containing a sequence number unique to that menu. (As mentioned earlier, sequence numbers need only be unique within resource type.)

The complete definition for the Video Tape Index's **Options** menu appears as:

```
TYPE MENU
  ,3
Options
Enter
Change
Delete
Select
Print
Quit/Q
```

The third line of the definition is the window's title. The remaining lines are the options that will appear when the window is pulled down. The **/** after **Quit** indicates that **Quit** has a keyboard equivalent. When the menu is pulled down, **Quit** will appear with a cloverleaf- Q to its right and the Macintosh will interpret that key sequence as equivalent to selecting **Quit** from the menu with the mouse. Use as many keyboard equivalents for as many menu items as you wish, but the equivalents should be unique.

All Macintosh applications support at least two, and often three, standard menus. The Apple menu (its title appears as an apple symbol) provides access to the Macintosh's built-in desk accessories; these should be available in all applications. Some of the desk accessories also require the ability to edit text. Therefore, applications should have an Edit menu, even if the remainder of the program does no text editing at all. Finally, most applications will have a File menu that handles the opening, saving, printing, and closing of files.

To define the Apple menu, use:

```
TYPE MENU
  ,1
\14
```

The \ indicates that the title of the menu is not a character string, but an ASCII code. In the Macintosh's extended ASCII character set, 14 represents the solid apple symbol. No menu items are part of this definition; they are added later.

An Edit menu also has a standard format:

```
TYPE MENU
  ,2
Undo/Z
(-
Cut/X
Copy/C
Paste/V
Clear
```

The fourth line of this definition (**(-**) prints a line across the width of the menu. Note then when numbering the items in a menu, this line counts as an item, even though it's not an option. The line will be printed unhighlighted (dimmed, or light-grey). A left parenthesis preceding any menu item indicates that the item should be dimmed. The order of the items in an Edit menu and their keyboard equivalents are standard and should be used as shown if your application is to conform to the standard Macintosh user interface.

The remainder of the video tape index's menu templates appear in Listing 7.2. Note that the keyboard equivalents have been selected to be as mnemonic as possible (e.g., cloverleaf- A stands for "Add a new record"). Also notice that while cloverleaf- Q stands for **Quit** in all of these menus, no more than one of them is present in the menu bar at any given time.

Listing 7.2 Templates for Application-Specific Menus Used in the Video Tape Index

```
TYPE MENU                          ;; menu templates follow
 ,3                                ;; sequence number
Options                                    ;; menu title
Enter                              ;; menu item #1
Change                                     ;; menu item #2
Delete                             ;; menu item #3
Select                             ;; menu item #4
Print                              ;; menu item #5
Quit/Q                             ;; menu item #6 (has keyboard equivalent -
                                     cloverleaf-Q)


 ,4                                ;; sequence number
Enter                              ;; menu title
Add/A                              ;; menu item #1 (with keyboard equivalent)
Quit/Q                             ;; menu item #2 (with keyboard equivalent)

 ,5
Change
Find Record/F
Save Change/S
Abandon Change/A
Quit/Q

 ,6
Delete
Find Record/F
Delete/D
Cancel/C
Quit/Q

 ,7
Select
Display All
Display All Titles
Select One Title
Select by Producer
Select by Date
Select by Rating
Select by Tape Number
Quit/Q

 ,8
Print
Print All
Print All Titles
Quit/Q
```

Defining the Menu Record

Just as information about windows is stored in window records, information about menus is stored in menu records. Before attempting to create a menu record, though, you must first initialize the Menu Manager with:

```
__InitMenus
```

(The routine has no parameters.) This initialization should be placed directly after **InitWindows**.

The application must also allocate storage space for a handle to each menu record that the program will create. Since a menu handle contains a pointer to the menu record, it requires a longword of space. For example:

```
AppleHandle  DC.L  0
```

will set aside space for the handle to the apple menu (the one that gives access to the desk accessories).

Assuming that space has been allocated for the menu handle, a menu record is created by the **GetRMenu** routine:

```
FUNCTION GetRMenu (resourceID: INTEGER) : MenuHandle;
```

resourceID refers to the sequence number you assigned to a particular menu. The function call returns the handle to the menu record. It also automatically adds menu items where menu items are specified in the resource definition. (If you were defining a menu within an application, a call to another routine would be required to add menu items to the menu record.)

To create the Video Tape Index's Apple menu, the strategy is:

```
CLR.L     -(SP)          ;space for menu handle result
MOVE#1,-(SP)             ;menu number 1
__GetRMenu

LEA  AppleHandle,A0      ;address to store menu handle
MOVE.L    (SP)+,(A0)     ;pull handle off stack and store
```

The menu handle is required by most Manager Routines and therefore must be recovered for subsequent use.

While menu items are automatically added to all menus that have them listed in the resource file, the Apple menu is a special case. The desk accessories must be added in a separate step. To understand what is happening, consider that, to the Macintosh, desk accessories are resources, just like windows and menus. They are stored in the system's resource file, which is opened by the system whenever any application is executed.

Adding the desk accessories to the Apple menu is accomplished by identifying a type of resource (in this case **DRVR**) and instructing the Macintosh to find all resources of that type and add them to the menu in question. The ToolBox routine that does this is **AddResMenu**:

```
PROCEDURE AddResMenu (theMenu: MenuHandle;
    theType: ResType);
```

ResType refers to a four-character string that identifies the resource type (e.g., **WIND** identifies a window resource type and **MENU** a menu resource type). Locating and appending the desk accessories requires:

```
MOVE.L      AppleHandle,-(SP)    ;menu handle on stack
MOVE.L      #'DRVR',-(SP)        ;4 characters take 4 bytes
_AddResMenu
```

It is important to remember that while the menu records have been created, their handles saved, and menu items added where appropriate, no menu bar has been drawn. Getting the menu bar to appear with just the menus you want, and in the order you want, is a two-step process.

Managing the Menu Bar

Issuing a call to the routine that draws the menu bar will display only those menus that are part of the *menu list*. In fact, every menu for which a menu record has been created does not have to be part of the menu list; in fact, only those menus which should be displayed at any given time are members of the list. Inserting into and removing from the menu list is the way an application controls the menus available to the user.

Menu list insertion is done with the **InsertMenu** routine:

```
PROCEDURE InsertMenu (theMenu: MenuHandle;
    beforeID: INTEGER);
```

The parameter **beforeID** refers to the position in the menu bar where the menu referenced by **theMenu** (the menu handle of the menu to be inserted) should be placed relative to other menus currently in the list. If **beforeID** is 0, then the new menu will appear to the right of all others. On the other hand, if **beforeID** contains the sequence number of a menu already in the menu list, the new menu will be inserted to the left of the menu indicated by **beforeID**.

To delete a menu from the menu list use:

```
PROCEDURE DeleteMenu (menuID: INTEGER);
```

where **menuID** is the sequence number of the menu to be removed.

InsertMenu and **DeleteMenu** do not affect the appearance of the menu bar. Therefore, any time a change is made to the menu list, the menu bar must be redrawn. The ToolBox routine:

```
PROCEDURE DrawMenuBar;
```

will take care of it. **DrawMenuBar**, which has no parameters, is simply called by:

```
_DrawMenuBar
```

The Video Tape Index has eight different menus (templates for six of which appear in Listing 7.2), though no more than three are in use at any one time. The Apple and Edit menus are always present. The third menu varies with which section of the program is currently being executed. For example, when the program is launched, the three menus are **Apple, Edit,** and **Options**. The *Options* menu has one item for each of the program's five functions and a Quit option.

If one of the five program functions is selected, the **Options** menu is removed from the menu list. A menu corresponding to the selected function is inserted into the list and the menu bar redrawn. For example, the following code prepares the menu bar for adding new titles:

```
MOVE    #3,-(SP)              ;the Options menu is #3
_DeleteMenu

MOVE.L  EnterHandle,-(SP)     ;put handle of Enter menu on stack
CLR     -(SP)                 ;new menu will go at end of menu list
_InsertMenu

_DrawMenuBar                  ;this makes the changes visible
```

When the user exits the function (by selecting Quit from the function's menu), the function menu is removed, the **Options** menu re-inserted, and the menu bar redrawn. To return to the main program after entering new titles, the code is:

```
MOVE    #4,-(SP)              ;the Enter menu is #4
_DeleteMenu

MOVE.L  OptionsHandle,-(SP)   ;appropriate handle goes on stack
CLR     -(SP)                 ;put menu at end of menu list
_InsertMenu

_DrawMenuBar                  ;changes only visible after this call
```

The Video Tape Index has no File menu, since this particular application does not provide the user with file handling options. (See Chapter 11 for details on Macintosh file management.)

Controlling the Appearance of Menu Items

In some instances, you may wish to have a menu present in the menu bar while some of its menu items are not available to be selected. For example, the desk accessories which allow you to enter text support the UnDo operation. The Video Tape Index, though, supports all the text editing functions *except* UnDo. Therefore, when a desk accessory is being used, the UnDo item of the Edit menu should be highlighted (displayed in dark type), but when the user is entering text into the application's text windows, the UnDo item should be dimmed to indicate that it is not available.

The procedures **DisableItem** and **EnableItem** take care of dimming and highlighting menu items, respectively. To do so, they need two pieces of information: which menu and what item within that menu. Therefore, they appear as:

```
PROCEDURE DisableItem (theMenu: MenuHandle;
    item: INTEGER);
```

and

```
PROCEDURE EnableItem (theMenu: MenuHandle;
    item: INTEGER);
```

When counting the menu items to decide what number to use for **item**, remember to include lines as items. For example, UnDo is item 1 in the Edit menu, but Cut is item 3. To disable Clear, the assembly language statements would be:

```
MOVE.L      EditHandle, -(SP)      ;put menu handle on stack
MOVE  #6, -(SP)
__DisableItem
```

On occasion, it is appropriate to disable an entire menu without removing it from the menu list. For example, the video tape index program disables the Edit menu when the user is printing. Since no editing is possible during print operations, it makes little sense to have an active Edit menu. A disabled menu will appear with its title dimmed. To disable an entire menu, call **DisableItem** with an item number of 0. Then call **DrawMenuBar** to redraw the entire menu bar. To re-enable the menu, call **EnableItem** with an item number of 0 followed again by a call to **DrawMenuBar**.

If you were to write a program that went this far with its menus — getting them from the resource file, inserting the desk accessory items, forming the menu list, and drawing the menu bar — you would discover that the menus did not pull down to display the menu items. There is yet another Menu Manager routine that handles pulling down the menus and registering a menu selection from the mouse. This routine is called in response to something that happens within an application — an *event*. Managing events and the actions that result from them is covered in Chapter 8.

Menus have a further function which may not be instantly obvious – they can help to establish a structure for an application program. Figure 7.5 presents a hierarchical block diagram of the Video Tape Index program. Note that each major program block, or module, corresponds to a separate menu. The function menus are all subordinate to the main Options menu. The code that handles each function is therefore written as a subroutine that can be called from the main program which is controlled by the Options menus.

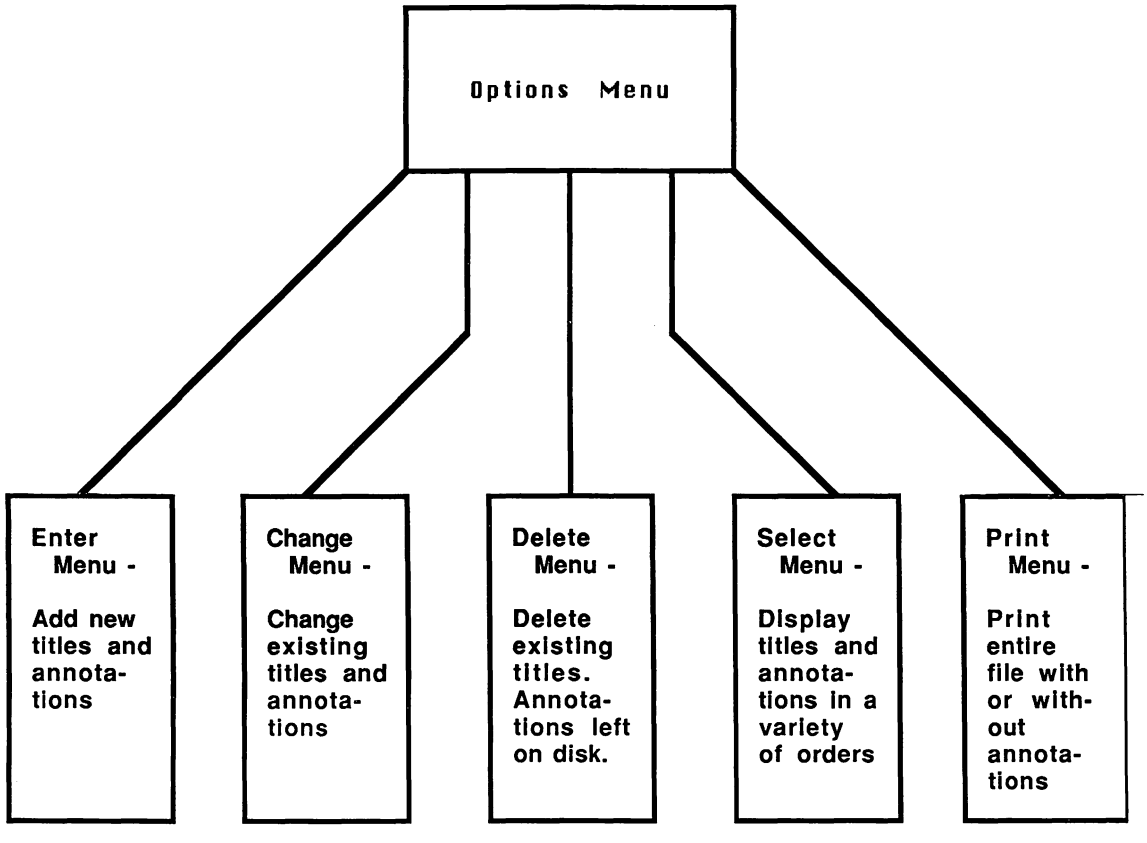


Figure 7.5 Gross Block Diagram of Video Tape Index Program Structure

Questions and Problems

1. For each global window boundary rectangle below, indicate the top left and bottom right points of its local coordinate system.

   a. 10, 10, 200, 200
   b. 40, 40, 500, 500
   c. 200, 10, 250, 100

2. Assume that you want to define a standard document window with a boundary rectangle of 50, 20, 275, 120. The window should be visible, have a GoAway box, and be placed in front of any other windows already on the screen. It can have a title of your own choosing.

   A. Write the assembly language code that will define this window within a program. Be sure to set aside storage for any data structures your code will use. Retrieve the window pointer from the stack.
   B. Write a resource file template for the same window.
   C. Write the assembly language code that will create the window defined by the template in B.

   Be sure to allocate space for any necessary data structures and retrieve the window pointer from the stack.

3. For the window defined in problem 2 write blocks of code that will perform the following operations. (Assume that each operation is independent of any of the others.)

   A. change the title to something other than the original title
   B. make the window invisible
   C. make the window active
   D. close the window

4. Write code to prepare the window defined in problem 2 for scroll bars:

   A. write code to draw a grow icon
   B. write the control templates to define vertical and horizontal scroll bars in a resource file
   C. write code to draw the scroll bars defined by the templates you wrote for B.

5. Write a resource file template to define a standard File menu. Include options to open a new file, open an existing file, close a file, print a file, save a file, and quit the program. Include keyboard equivalents as appropriate. (For a sample of how a standard File menu might appear, see Figure 1.2.)

6. Write assembly language code to create the menu defined by the template of problem 5. Define data structures as needed. Retrieve and store the menu handle.

7. Write assembly language code to insert the menu from problem 6 into the menu list. Finish the process by redrawing the menu bar.

8. Write assembly language code to:

   A. disable the entire File menu from problem 6
   B. disable only the options which open files

   In which case must you re-draw the menu bar?

CHAPTER EIGHT

CONTROLLING PROGRAM ACTIONS: MONITORING EVENTS

Chapter Objectives

1. To understand how events are used to control program actions
2. To be able to handle mouse down events in a variety of locations
3. To be able to process key down events as equivalents for menu selections
4. To understand the sequence of steps required to update a window

The System Event Mechanism

Macintosh applications are controlled by *events*. An event is anything that happens to the computer. A click on the mouse button is an event; pressing or releasing a key on the keyboard is an event. Most events that an application handles are those generated by users, though some are generated by the Macintosh itself. The most common types of events that a program will process are:

1. Null events — the system reports that nothing has happened since the last time you checked.
2. Mouse down events — the mouse button was pushed.

3. Mouse up events — the mouse button was released.
4. Key down events — a key was pressed.
5. Key up events — a key was released.
6. Update events — something has disrupted the contents on a window and it needs to be redrawn in some way. This type of event is posted by the system when, for example, a window that was previously obscured by another window is brought to the front.
7. Activate events — a text window needs to be activated or deactivated. This type of event is posted by the system whenever you call **SelectWindow**.

   There is a point of potential confusion with regard to activate events. While the event is called "activate," it is generated by two distinct situations. In the first instance, a window must be deactivated; in the other, a window must be activated. Calls to **SelectWindow** produce two activate events. The first one posted to the event queue is for the window being deactivated; the second is for the window being activated.
8. Disk insertion events — a disk was inserted into a disk drive.
9. Abort events — cloverleaf- . was typed to abort an activity.

Other types of events include:

10. Auto-key events — generated by continuing to hold down a key.
11. Network events — relevant to an application that interacts with the AppleTalk network.
12. I/O driver events (currently not used).

13-16. Four events that can be defined by an application.

These constitute the maximum of 16 possible types of events.

As events occur they are posted to the *event queue* in first-in, first-out order. The nature of the events also determines to some extent the order in which they will be detected. Activate events have the highest priority (deactivate is first, followed by activate) and are not actually posted to the event queue. Keyboard, mouse, disk, and abort events have the next priority. Update events come after those just mentioned, and null events are of the lowest priority.

When an event is detected, the Macintosh generates an *event record* for it. An event record has five fields:

```
what:       INTEGER;
message:    LONGINTEGER;
when:       LONGINTEGER;
where:      Point;
modify:     INTEGER;
```

The **what** field identifies what type of event the event record represents. Event types are represented by numeric codes. To identify what type of event has occurred, an application must compare the contents of the **what** field of the event record with the type codes for whatever events the program needs to trap. If SysEqu.D is INCLUDEd in an application, you can avoid using the numeric codes and reference the event types by their symbolic addresses. For example:

nullEvt	**represents the code for a null event;**
mButDwnEvt	**represents the code for a mouse down event;**
updatEvt	**represents the code for an update event;**
activateEvt	**represents the code for an activate event.**

Consult Table 8.1 to see the remainder of the symbolic addresses associated with event types. Using the symbolic addresses rather than the type codes makes a program more readable and easier to debug.

The meaning of the **message** field depends on the type of event being posted:

1. For keyboard events — the key that was pressed. The low-order byte contains the ASCII code for the key; the high-order byte indicates whether any modifier keys, such as the shift, cloverleaf, or option keys, were also held down.
2. For update and activate events — a pointer to the window where the event occurred
3. For disk insert events — the drive number where the event occurred
4. For abort events — the key that was pressed. The low-order byte contains the ASCII code for the key; the high-order byte identifies any modifier keys that were also held down.
5. For mouse and null events — the field has no meaning

An application commonly compares the **message** field to its own window pointers to determine which windows need updating and activating. **message** is used less frequently to directly read the keyboard for text entry; that function is handled by the TextEdit routines discussed in Chapter 9.

when indicates the time when an event was posted. For most applications, this field is of less importance than any of the others.

where gives the coordinates of the mouse when the event was posted. These coordinates are *global* (i.e., expressed in terms of the 512 by 342 coordinate grid imposed on the entire screen). **where** is used in conjunction with routines that identify where a mouse down event occurred.

modify holds information about the state of a number of Macintosh keys; the **modify** word works as a series of flags. If set, each flag indicates that a particular key was pressed. **modify** monitors the mouse button, the cloverleaf key, the shift key, the caps lock key, and the options key. It also records whether an "activate" event represents the deactivating or activating of a window. Take a look at Table 8.2 to see the bit assignments in **modify**.

Symbolic Address	Event Type	Comment
nullEvt	Ø	no event has occurred
mButDwnEvt	1	mouse down
mButUpEvt	2	mouse up
keyDwnEvt	3	key down
keyUpEvt	4	key up
autoKeyEvt	5	auto key
updatEvt	6	update (note that *updatEvt* is not a misprint)
diskInsertEvt	7	disk insertion
activateEvt	8	activate
abortEvt	9	abort (pressing cloverleaf-.)
netWorkEvt	1Ø	network (Appletalk)
ioDrvrEvt	11	I/O driver (not used)
app1Evt	12	application defined
app2Evt	13	application defined
app3Evt	14	application defined
app4Evt	15	application defined

Table 8.1 Symbolic Addresses Assigned to Event Types in the System Equates File

Symbolic Address	Bit Number	Comment
activeFlag	Ø	Set if window is activated, cleared if deactivated
changeFlag	1	Set if system window changes, cleared otherwise
btnState	7	Set if mouse button down, cleared if up
cmdKey	8	Set if cloverleaf key was pressed, cleared otherwise
shiftKey	9	Set if shift key was pressed, cleared otherwise
alphaLock	1Ø	Set if caps lock is engaged, cleared otherwise
optionKey	11	Set if optionkey was pressed, cleared otherwise

Table 8.2 Symbolic Addresses Associated with the Bits in an Event Record's Modify Word

When retrieving events from the event queue, an application can choose to receive all events in order or only events of a specific type. Events can be filtered out by using a specific *event mask*. It is no accident that there are 16 possible event types. Each type corresponds to one bit in an integer, or word, length event mask. For example, if bit 0 is set, then the mask will include null events. If bit 1 is set, the mouse will also include mouse down events. The bit positions that represent the various types of events appear in Table 8.3.

The Macintosh will accept a mask of -1 to select every event, the mask which should be used in most instances. In other words, an application should retrieve

every event from the queue and then compare the **what** field of the event record against the types of events the application wishes to process.

In some special cases it may be necessary to construct a special mask. For example, when managing its windows and TextEdit records, the Video Tape Index program must remove some spurious activate and deactivate events from the event queue. Table 8.3 indicates that activate events are selected when bit 9 is set. Therefore, the mask used to remove those events is %0000000100000000 or more simply, **256**.

Bit Number	Event Type
Ø	No event reported
1	Mouse down
2	Mouse up
3	Key down
4	Key up
5	Auto key
6	Update
7	Disk insertion
8	Activate
1Ø	Network
11	Device driver
12 - 15	Application defined

Setting any given bit in a mask word will instruct **GetNextEvent** to report events of that type. For example, if bits 1 and 3 are set, **GetNextEvent** will report only mouse down and key down events. A mask of -1 will select all types of events.

Table 8.3 The Structure of an Event Mask

As part of the initialization process, an application should flush the event queue to remove any events that may have been posted prior to the application's execution. Usually this occurs immediately after the various managers have been initialized with a call to **FlushEvents**. **FlushEvents** is an operating system routine:

PROCEDURE FlushEvents (eventMask, stopMask: INTEGER);

The event mask is constructed as described above. The stop mask says "return all events that meet the event mask until an event that matches the stop mask is encountered." In most cases, use a stop mask of 0 to indicate that all events specified by the event mask should be removed.

FlushEvents expects to find both of its parameters in D0 – the event mask in the low-order word and the stop mask in the high-order word. It is easiest to load the register with one **MOVE** statement:

MOVE.L $0000FFFF,D0

This installs a stop mask of 0 and an event mask of −1 (the $FFFF represents −1 as a two's complement integer).

The procedure is then called by using:

```
_FlushEvents
```

Normally, **FlushEvents** is called only once, at the start of an application.

Retrieving Events

Before an application can retrieve events from the event queue, it must prepare storage for the event record. The event record data structure can be defined to be part of the application itself (using **DC**) or assigned to the applications globals area (with **DS**). The Video Tape Index places its event record storage within the program:

```
EventRecord
What        DC    0
Message     DC.L  0
When        DC.L  0
Point       DC.L  0
Modify      DC    0
```

Using **EventRecord** will reference the entire 16-byte data structure. Each field can also be referenced separately using its own symbolic address.

Programmers who wish to keep all read/write storage in the applications globals area should use:

```
EventRecord  DS.B  16
```

which will set aside the required 16-byte area. The start of the fields within the record are then handled as offsets. They are part of the predefined equates in SysEqu.D (e.g., evtNum, evtMessage, etc.).

Events are retrieved from the event queue with the ToolBox routine **GetNextEvent**:

```
FUNCTION GetNextEvent (eventMask: INTEGER; VAR theEvent:
    EventRecord) : BOOLEAN;
```

GetNextEvent returns a boolean that is set to false if the event is one that should be handled by the system (and not by the application program) or a null event. The event mask is as discussed above. Only those events which fit the mask will be reported by the call to **GetNextEvent**.

The event details are returned in the event record data structure. It is passed as a variable parameter rather than placed on the stack as the function result. Therefore, a call to **GetNextEvent** appears as:

```
CLR     -(SP)          ;space for boolean result
MOVE    #-1,-(SP)      ;-1 is the preset mask for all events
PEA     EventRecord    ;since EventRecord is a variable parameter,
                       ;push pointer
_GetNextEvent
```

Calls to **GetNextEvent** form the basis of the loop that controls selection of program actions. Figure 8.1 shows you pseudocode for an event loop. In general, the strategy is to begin by checking the event queue for an event. If none is reported, the loop simply returns to check again. If an event was posted, then the application must isolate the event number from the event record and compare it to the numbers representing each type of event the program must handle. When a match is discovered between a posted event and one the application will deal with, the program should branch to a module that handles that event. In this way, the event loop determines the structure of the program.

```
Repeat
        Retrieve an event from event queue;
        If an event has been posted then
                Retrieve event number from event record;
                Repeat
                        If event number equals an event this program monitors then
                                Branch to portion of program that handles that event
                Until event number equals an event this program monitors OR all
                        possible event numbers have been checked;
Until users selects Quit.
```

Figure 8.1 Pseudocode for an Event Loop

The event loop in the Sample program is deceptively simple. Since that program's only function is to open a window, print a string, and wait for a key or mouse button press, the event mask selects only those two events (a mask of

%0000000000111110); the program either finds a mouse or keyboard event, or it doesn't:

```
Event  CLR    -(SP)              ;space for boolean result
       MOVE   #%0000000000111110,-(SP)  ;event mask
       PEA    EventRecord        ;pointer to event record storage
       _GetNextEvent

       MOVE   (SP)+,D0           ;recover boolean result
       CMP    #0,D0
       BEQ    Event              ;no event — loop to keep checking

       RTS                       ;return to Finder
```

The reason that this loop is so simple is that it can detect the occurrence of a desired event merely by checking the boolean result of the call **GetNextEvent**. Since the action to be taken is identical whether the event is a key or mouse button press (return to the Finder), there is no need to differentiate between the two types of events. In terms of meaningful Macintosh applications, this is an unrealistic situation.

The Video Tape Index must handle four different types of events. Its main event loop, which traps three types of events, appears in Listing 8.1. Note that this event loop uses an event mask of −1 to select all types of events and then makes comparisons with specific event numbers to identify the particular events it must handle.

Listing 8.1 Video Tape Index Main Event Loop

```
Event
        CLR     -(SP)           ;Space for boolean result
        MOVE    #-1,-(SP)       ;Mask for keyboard - select all events
        PEA     EventRecord     ;Place to receive event info
        _GetNextEvent           ;Get next event from queue

        MOVE    (SP)+,D0        ;Recover event result
        CMP     #0,D0
        BEQ     Event           ;If no event, branch to look again

        MOVE    What,D0                 ;Recover event ID
        CMP     #mButDwnEvt,D0          ;Was mouse button pressed?
        BEQ     MouseEvent

        CMP     #keyDwnEvt,D0           ;Was key pressed?
        BEQ     KeyEvent

        BRA     Event           ;Look for another event
```

Each of the program's function modules also have their own event managers. These trap all four kinds of events: mouse down, key down, update, and activate. Code for the module which finds and displays data can be found in Listing 8.2. As you can see, the structure of this loop is essentially the same as the main event loop. This is one situation where repeated code is not necessarily a negative characteristic.

Listing 8.2 Function Event Loop from the Video Tape Index Program

```
SelectEvent
        CLR             -(SP)               ;space for event type
        MOVE            #-1,-(SP)           ;event mask of -1 selects all events
        PEA             EventRecord         ;place to store event record
        _GetNextEvent                       ;get next event from event queue

        MOVE            (SP)+,DØ            ;recover boolean result
        CMP             #Ø,DØ               ;Ø result means no event occurred
        BEQ             SelectEvent         ;if no event, branch to keep looking

        MOVE            What, DØ            ;recover event type
        CMP             #mButDwnEvt, DØ     ;mouse down event?
        BEQ             SelectMouseEvent    ;branch to handle event

        CMP             #keyDwnEvt,DØ       ;key down event?
        BEQ             SelectKeyEvent      ;branch to handle event

        CMP             #activateEvt, DØ    ;activate event?
        BEQ             SelectActivateEvent ;branch to handle event

        CMP             #updatEvt, DØ       ;update event?
        BEQ             SelectUpdateEvent   ;branch to handle event

        BRA             SelectEvent         ;some unwanted type of event occurred - must
                                            ;keep checking
```

Though it is possible to write a significant Macintosh application with only one event loop, in most cases doing so creates "spaghetti code," code that is so intertwined with unconditional branches (**JMP** and **BRA**) that it is virtually impossible to follow and even more difficult to modify and debug. The Video Tape Index opts for clear program structure over the tightest, shortest possible code. Unfortunately, such a choice may not be viable if you are writing a large application for the 128K Mac.

Handling Mouse Down Events

The primary task with which an application is faced when a mouse down event occurs is figuring out where the mouse button was pressed. The three major locations an application usually examines are:

1. the menu bar
2. the content area of a window defined by an application
3. a system window (one created, for example, by a desk accessory)

In some applications, the mouse button might also be pressed in the drag region of a window, in a GoAway box, or in a grow box.

The Window Manager routine **FindWindow** identifies where the mouse button was pressed:

```
FUNCTION FindWindow (thePt: Point; VAR whichWindow:
    WindowPtr) : INTEGER;
```

thePt refers to the screen coordinates where the mouse button down event occurred. It can be obtained from the **point** field of the event record. On function return, the variable parameter **whichWindow** will contain the pointer to the window record of the window posting the event. The integer result contains a code that corresponds to the event's general location (e.g., 1 = in the menu bar, 2 = in a system window, etc.). Symbolic addresses for each of the result codes are established in the ToolEqu.D file; the complete set also also appears in Table 8.4

A call to **Find Window** therefore appears as:

Symbolic Address	Result Code	Comment
inDesk	Ø	not in a window or the menu bar
inMenuBar	1	in the menu bar
inSysWindow	2	in a system window (e.g., a desk accessory)
inContent	3	in the content area of an application definewindow
inDrag	4	in the drag region of an application defined window
inGrow	5	in the grow region of an application defined window
inGoAway	6	in the GoAway box of an application defined window
inButton	1Ø	in a push button
inCheckBox	11	in a check box
inUpButton	2Ø	in up button area of a scroll bar
inDownButton	21	in down button area of a scroll bar
inPageUp	22	in page up area of a scroll bar
inPageDown	23	in page down area of a scroll bar
inThumb	129	in thumb area of a scroll bar

Table 8.4 Symbolic Addresses Associated with FindWindow Result Codes

A call to **Find Window** therefore appears as:

```
CLR          -(SP)              ;space for integer result
MOVE.L       Point,-(SP)        ;a field from the event record
PEA          WhichWindowPtr     ;must be defined with DC or DS
_FindWindow
```

The integer result should then be immediately pulled off the stack:

```
MOVE  (SP)+,D0
```

The code in D0 can then be compared against the codes for locations the application needs to monitor. For example:

```
CMP  #inMenuBar,D0
```

will determine whether the mouse button was clicked anywhere in the menu bar. The constant **inMenuBar** is defined in the ToolBox equates file.

FindWindow also returns location codes for:

1. in a system window
2. in the content region of an application window
3. in the drag region of a window (the title bar)
4. in the grow region
5. in a GoAway box

All of these locations have constants defined for them in the ToolBox equates file.

When a match is found with a location code, the application should branch to handle that particular situation. Each location requires that the program execute a different series of actions. They are discussed separately below.

Mouse Down Events in Menu Bars

There is a single ToolBox routine **MenuSelect**, that pulls down menus (displaying the menu items), highlights the menu title, and records which menu and which item within that menu were selected. Any time a program records a mouse down even in the menu bar, it should call **MenuSelect**:

```
FUNCTION MenuSelect (startPt: Point) : LONGINTEGER;
```

MenuSelect's longinteger result has two parts. The high-order word contains the sequence number of the menu. This is the number assigned to the menu in the

resource file. The low-order word contains the number of the selected menu item. (Remember: when numbering menu items, things such as lines across the menu, like that beneath UnDo in an Edit menu, count as items as far as **MenuSelect** is concerned.) The parameter **startPt** is again the **Point** field from the event record.

A call to **MenuSelect** therefore appears as:

```
CLR.L       -(SP)          ;space for longinteger result
MOVE.L      Point,-(SP)    ;from the event record
_MenuSelect
```

MenuSelect's result should be pulled from the stack and put into two integer storage locations. Making this work properly takes a bit of care. First, two integer locations should be defined using either **DC** or **DS**:

```
WhichMenu   DC   0
WhatItem    DC   0
```

These declarations should be placed physically next to each other (in the order above) in the program. This ensures that when the storage is allocated during assembly, **WhatItem** will occupy the word immediately after **WhichMenu** in memory. Then:

```
MOVE.L      (SP)+,D2          ;pulls result from stack
LEA         WhichMenu,A0      ;get address for high-order word
MOVE.L      D2,(A0)
```

The important step above is this last one — it moves a longinteger rather than just an integer. The high-order word of the result therefore goes into the word associated with the symbolic address **WhichMenu**. Since the location of **WhatItem** is physically right after **WhichMenu**, the low-order byte is automatically stored in the right place. This bit of tricky maneuvering saves several program steps (i.e., having to save **WhichMenu**, mask off the high-order byte, and then save **WhatItem** explicitly).

Since **MenuSelect** does not unhighlight a menu title, every call to **MenuSelect** needs to be followed by a call to **HiLiteMenu**, which will remove the highlighting:

```
PROCEDURE HiLiteMenu (menuID: INTEGER);
```

This easiest way to handle this is not to determine exactly which menu needs to have its title unhighlighted, but to unhighlight all menus. To do so, simply use a **menuID** of 0, which will automatically unhighlight any menu title which is highlighted.

The next task is to compare the contents of **WhichMenu** with the sequence numbers of the menus currently in the menu bar. These sequence numbers are

the ones assigned to the menus in the application's resource file. When a match is found, the program must then branch to handle actions based on the specific menu.

Assuming that an application adheres to the standard Macintosh user interface, there will be at least three sorts of menus that it must deal with: the Apple menu that selects the desk accessories; the Edit menu which may reflect text editing in an application window or a desk accessory; and application menus (those specific to the particular program). Most applications will also have a standard File menu.

Implementing the Desk Accessories

Most of the work involved with handling the Macintosh's standard desk accessories is done by the ToolBox itself. In order for them to be properly updated, however, an application must make repeated calls to **SystemTask**. This procedure (it has no parameters and so is simply called with **___SystemTask**) should be placed in an application's event loop. If an application has more than one event loop, it should appear in each of them. If **SystemTask** is not called frequently enough, desk accessories such as the alarm clock will not function properly.

The first task in processing a desk accessory is to identify which desk accessory has been selected. The routine **GetItem** will return the text of a selected menu item:

```
PROCEDURE GetItem (theMenu : MenuHandle; item: INTEGER;
    VAR itemString: Str255);
```

The first parameter is the handle of the Apple menu. The item should come from **WhatItem** which was retrieved earlier from the call to **MenuSelect**. The result of this procedure — the name of the desk accessory — should go into a storage location that has been defined with a length of 16 words (since that is the maximum length of a desk accessory name):

```
DeskAccName     DCB.W     16,0
```

or

```
DeskAccName     DS.W      16
```

The call to **GetItem** appears as:

```
MOVE.L      AppleHandle, -(SP)    ;menu handle goes on stack
MOVE        WhatItem, -(SP)       ;from MenuSelect
PEA         DeskAccName(A5)       ;assumes DS declaration
__GetItem
```

At this point, the application has enough information to open the desk accessory and turn its execution over to the system. This is accomplished using **OpenDeskAcc**, a routine that is part of the Desk Manager:

```
FUNCTION OpenDeskAcc (theAcc: Str255) : INTEGER;
```

The result of **OpenDeskAcc** can be ignored. Nevertheless, the call must allocate space for the result and retrieve it from the stack. The parameter **theAcc** is the desk accessory name retrieved in the call to **GetItem**. To call **OpenDeskAcc** use:

```
CLR      -(SP)                ;space for useless result
PEA      DeskAccName(A5)      ;assumes storage defined with DS
_OpenDeskAcc
MOVE     (SP)+,D0             ;removes useless result from stack
```

Once an application calls **OpenDeskAcc**, the desk accessory is opened for the user. The system will handle things such as key down events, but the application should continue to monitor the event queue, looking for mouse down events in system windows.

Handling Edit Functions in Desk Accessories

When a user makes a selection in the Edit menu, there are two possibilities: either the edit request concerns a system window (e.g., the note pad) or an application window. Edit functions in application windows will be discussed later in Chapter 9 along with the other TextEdit routines, but this is an appropriate place to consider how to differentiate between the two sources of edit requests and how to handle those in system windows.

The strategy for telling system edit requests from application edit requests is very straightforward. An application should simply attempt to let the system handle the request. If it can, it will. If the system is unable to handle an edit (because it occurred in an application window) it will return a result of FALSE. A FALSE result therefore means that the application must handle the edit itself.

Editing in system windows is taken care of by a single ToolBox routine:

```
FUNCTION SysEdit (editCmd: INTEGER) : BOOLEAN;
```

The **editCmd** is equal to the item number from the edit menu less 1, assuming that the items in the Edit menu have been set up in the standard order.

To initiate a system edit, then:

```
MOVE  WhatItem,D0   ;retrieve original menu item number
SUBQ  #1,D0         ;adjust the item number to suit SystemEdit
CLR   -(SP)         ;space for boolean result
MOVE  D0,-(SP)      ;put adjusted item number on stack
_SysEdit            ;let the system handle the edit request
MOVE  (SP)+,D1      ;get result to verify if request was handled
```

Control returns to the application when the edit has been completely processed.

Handling Mouse Down Events in Application Menus

Precisely what occurs as the result of selecting any given menu item will obviously depend on the nature of the menu. Nonetheless, the strategy for identifing the item selected is the same – compare **WhatItem** against each of the item numbers present in the selected menu. When a match is found, branch to a program module that implements the particular function. (For an example, see Listing 8.3, the code that selects actions from the Video Tape Index's Options menu.)

Listing 8.3 Selecting Program Actions Based on Menu Selections (from the Video Tape Index)

```
(a)     Options     MOVE  WhatItem,DØ   ;Move item selected to DØ
(b)                 CMP   #1,DØ
                    BNE   Item2
(c)                 JSR   Enter         ;Enter new tapes

        Item2       CMP   #2,DØ
                    BNE   Item3
                    JSR   Change        ;Modify existing tapes

        Item3       CMP   #2,DØ
                    BNE   Item4
                    JSR   Delete        ;Delete tapes

        Item4       CMP   #4,DØ
                    BNE   Item5
                    JSR   Select        ;Retrieve info

        Item5       CMP   #5,DØ
                    BNE   Item6
                    JSR   Print         ;Print lists

        Item6       CMP   #6,DØ
                    BEQ   Quit          ;Exit the program
```

The basic strategy behind the code in Listing 8.3 is based on knowing the order in which menu items were listed in the resource file. Listing 8.3 figures out which item in the Options menu was selected. The item list for that Options menu is:

Enter
Change
Delete
Select
Print
Quit

The Macintosh assigns the number 1 to the first item in the list (**Enter**), a 2 to the second (**Change**), and so on. The quantity stored in **WhatItem** (retrieved from the event record) therefore corresponds to the number of whichever item was selected. The only way to identify the particular item is to begin comparing the quantity in **WhatItem** with the numbers of menu items. That is exactly what the code in Listing 8.3 is doing.

WhatItem is first moved into a data register (a). The comparisons begin at (b), where the item selected is compared against a 1, the number that stands for **Enter**. If a match is found, program control is transferred to a subroutine that handles entering new records (c). Since blocks of code that correspond to individual menu items can be selected repeatedly while the program is running, it makes sense in terms of program structure to place each block in a separate subroutine. The procedure is repeated for each possible item until a match is found.

Handling Mouse Down Events in System Windows

If a call to **FindWindow** determines that a mouse down event has occurred in a system window (i.e., a desk accessory), then the application can simply turn control over to the system to handle the event. A call to **SystemClick** will process any type of mouse down event in a system window:

```
PROCEDURE SystemClick (theEvent: EventRecord;
    theWindow: WindowPtr);
```

SystemClick needs the entire event record (push its address onto the stack) and the result of **FindWindow**, generally stored in a location like **WhichWindowPtr**. The pointer can simply be moved onto the stack.

SystemClick will handle all manner of mouse down events in system windows. It will, for example, close a desk accessory if the mouse down event occurred in the desk accessory's GoAway box. It handles the mouse down events that operate the calculator. It will also select and make active a desk accessory that was previously deactivated by selection of another window. **SystemClick** will drag, scroll, and size system windows as well.

Handling Mouse Down Events in Application Windows

A mouse down event in the content region of an application-defined window (identified by the constant **inContent**) usually means one of two things: if the window is inactive, then it should be brought to the front of the screen and activated; if it is already active, then the mouse down event most often indicates that the cursor should be moved, regardless of whether the window contains text to be edited or pictures to be drawn.

The first task after identifying a mouse down event in an application window, then, is to discover whether or not the window posting the event is active. The Window Manager routine **FrontWindow** will return a pointer to whichever window is in front of all others on the screen (this will be the active window):

```
FUNCTION FrontWindow : WindowPtr;
```

Note that this function has no parameters. To call it, allocate space on the stack for a longinteger result and then issue the function call. After the result is retrieved from the stack, it can be compared to **FindWindow**'s result. If the two pointers match, then the event occurred in the active window and the cursor should be moved. (See the discussion of TextEdit later in Chapter 9 for details.) If the pointers do not match, then a window must be activated. Such a code sequence might appear as:

```
CLR.L     -(SP)          ;space for longinteger result
__FrontWindow            ;get pointer to active window
MOVE.L    (SP)+,A0       ;recover pointer to active window
CMP.L     WhichWindowPtr,A0
                         ;check active window against clicked window
BNE       Mustactivate   ;routine which activates clicked window
; followed by code to move the cursor in the active window
```

A window should be activated by calling **SelectWindow**. (See Chapter 7 for details.) This will bring the window to the front of the screen, deactivate and unhighlight the current window, and highlight the new active window as appropriate. It will also generate a deactivate event for the previously active window, and activate and update events for the new active window.

Mouse Down Events in Application Windows With Scroll Bars

If an application window contains scroll bars, then the procedure for processing mouse down events in the content area of that window is more complex than described above. After detecting an event in the content area, the application must then determine whether or not the mouse down event was in the scroll bars.

The Control Manager routine **FindControl** will identify which control, if any, was the site of the mouse down event:

FUNCTION FindControl (thePoint: Point; theWindow: WindowPtr;
VAR whichControl: ControlHandle) : INTEGER;

FindControl returns two results. The first is the handle to the control record of the control that posted the mouse down event. If the mouse down event was not in a control, the control handle will be set to 0. The function's integer result corresponds to the part of the control that was clicked.

Scroll bars have five parts (see Figure 8.2). The numbers in parentheses in Figure 8.2 correspond to each part's identification number. One of these numbers will be returned as **FindControl**'s integer result for a mouse down event in a scroll bar.

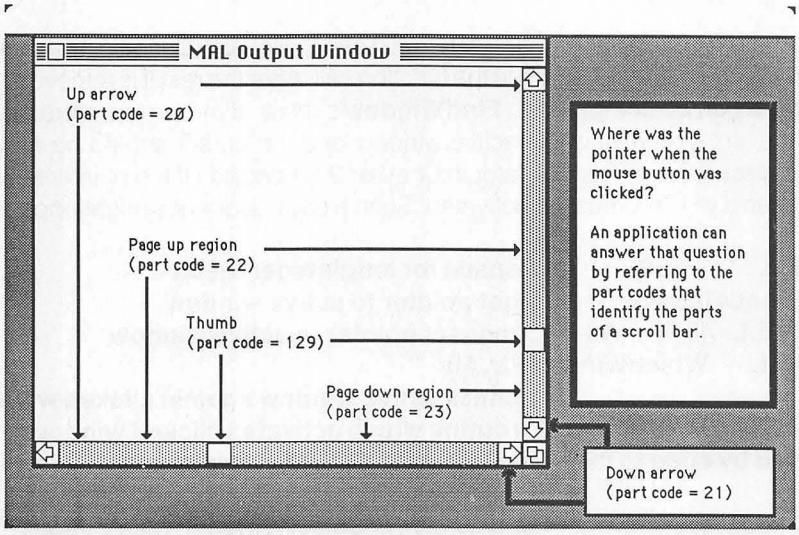


Figure 8.2 The Parts of a Scroll Bar

FindControl needs to know the point where the mouse button was clicked. Unfortunately, the Event Manager returns the point in global coordinates and **FindControl** requires local coordinates. The QuickDraw routine **GlobalToLocal** (discussed further in Chapter 9) will handle the conversion:

PROCEDURE GlobalToLocal (VAR pt: Point);

An application might use the following code to determine whether a mouse down event occurred in a scroll bar:

```
PEA             Point           ;push address so value can return
_GlobalToLocal                  ;convert

CLR             -(SP)           ;space for part code result
MOVE.L          Point,-(SP)     ;coordinates now local
MOVE.L          WhichWindowPtr,-(SP)
                                ;result of call to FindWindow
PEA             WhichControlHandle
                                ;push address so value can return
_FindControl

MOVE            (SP)+,D0        ;retrieve part code
CMP             #0,D0
BEQ             InContentRegion
                                ;not in scroll bar

;continue to process event in scroll bar
```

If **FindControl** returns a part code greater than 0, then the mouse down event was indeed in a scroll bar (this assumes that there are no other controls in the window). The application should then call **TrackControl**:

```
FUNCTION TrackControl (theControl: ControlHandle; startPt:
    Point; actionProc: ProcPtr) : INTEGER
```

TrackControl performs a number of important tasks. If the user has pressed the mouse button in the thumb of a scroll bar, **TrackControl** will continue to drag that thumb as long as the mouse button is held down. If the mouse button is pressed in the up or down arrow, **TrackArrow** will highlight the arrow until the mouse button is released.

TrackControl's result is either the part code for the part of the control that posted the mouse down event, or 0. A value of 0 indicates that the user moved the mouse pointer from the part of the control where the event originally occurred. If that is the case, the application should abort processing the event and return to the top of the event loop.

The parameter **theControl** refers to the result of **FindControl**. **startPt** is the same point, in local coordinates, that was passed to **FindControl**. The third parameter, **actionProc**, is an optional pointer to a routine that should be executed while the user continues to hold down the mouse button. It can be set to 0 if there is action procedure.

Calling **TrackControl** would therefore appear as follows:

```
CLR         -(SP)           ;space for part code result
MOVE.L      WhichControlHandle,-(SP)
                            ;FindControl result
MOVE.L      Point,-(SP)     ;in local coordinates
CLR.L       -(SP)           ;no action procedure
_TrackControl

MOVE        (SP)+,D0        ;retrieve part code result
CMP         #0,D0           ;has user moved to different part
                            ;of control?
BEQ         Event           ;Yes - go to top of event loop

;otherwise, scroll the content of the window appropriately
```

The actual scrolling of text will be discussed in Chapter 9, when we talk about TextEdit.

Handling Mouse Down Events in GoAway Regions

If a document window has been defined with a GoAway box (also known as a close box), then the application should check the result of **FindWindow** against the constant **inGoAway** (equated to the value of 6 in the ToolBox equates file). A mouse down event in a GoAway box indicates that the window should be closed.

To adhere to the standard Macintosh user interface, the GoAway box should be highlighted as long as the mouse button is pressed. The Window Manager routine **TrackGoAway** will do so:

```
FUNCTION TrackGoAway (theWindow: WindowPtr; thePt: Point):
    BOOLEAN;
```

The parameter **theWindow** is the pointer to the window record of the window posting the event; it is the result of a call to **FindWindow**. **thePt** is the point where the mouse down event occurred. It is expressed in global coordinates and can therefore be taken directly from the event record. The boolean result is set TRUE if the mouse pointer was still in the GoAway box when the mouse button was released; it is set FALSE if the pointer was moved. In the latter case, the user has effectively cancelled the request to close the window, and the application should simply return to the top of the event loop to check for another event.

Code to handle a mouse down event in a GoAway box might appear as follows:

```
CLR.B       -(SP)          ;space for boolean result (system will
                           ;push extra byte to keep stack pointer
                           ;even)
MOVE.L      WhichWindowPtr,-(SP)   ;from FindWindow
MOVE.L      Point,-(SP)    ;from the event record
_TrackGoAway

MOVE.B      (SP)+,D0       ;retrieve boolean result
CMP         #0,D0          ;did user move pointer?
BEQ         Event          ;Yes - go get another event

;application must continue by closing the window
```

Closing the window may involve simply calling **CloseWindow** or **DisposWindow** to remove the window from the screen or from memory. If the contents of the window should be saved to disk before closing, then the application may execute a disk save routine before closing the window. (See Chapter 11 for details.)

Handling Mouse Down Events in Drag Regions

In a standard document window, the drag region is the bar in which the title appears. Mouse down events in that area indicate that the user wishes to move the window somewhere else on the desktop.

The Window Manager routine **DragWindow** will handle the entire process:

```
PROCEDURE DragWindow (theWindow: WindowPtr; startPt:
    Point; boundsRect: Rect);
```

The first two parameters are identical to those for **TrackGoAway**. The third parameter, **boundsRect**, is a rectangle in global coordinates that describes the boundaries within which the window can be moved. While the rectangle could theoretically encompass the entire screen, it is generally 4 pixels in from each edge of the screen to ensure that at least 4 pixels of a document window's title bar will always be seen.

DragWindow will continue to drag an outline of the window around the screen until the user releases the mouse button. At that point, assuming the mouse pointer is within the boundary rectangle, the window will be redrawn in its new location. If the mouse pointer is not within the boundary rectangle, the window will be left in its original spot.

As an example, assume that a boundary rectangle has been defined with coordinates 4 pixels in from each edge of the screen (remember that the screen is 342 pixels high and 512 pixels wide):

```
BoundaryRect  DC  4,4,338,508
```

A call to **DragWindow** would then appear as:

```
MOVE.L      WhichWindowPtr, – (SP)     ;from FindWindow
MOVE.L      Point, – (SP)              ;from the event record
PEA         BoundaryRect
_DragWindow
BRA         Event                      ;go get another event
```

It is important to remember that **DragWindow** does not change the size of a window; it merely moves it around the screen.

Handling Mouse Down Events in Grow Regions

If a mouse down event occurs in the grow icon, the user wishes to change the size of the window. Sizing a window requires a sequence of calls to at least five Window Manager routines:

1. Make calls to **InvalRect** to place any parts of the window that you know will need to be changed into the window's *update region*. The update region holds all of the parts of the window that have been disturbed by some program function and therefore need to be updated. If anything is present in the update region, the system will generate an update event for the window. If a window contains scroll bars, they should be placed in the update region.
2. Call **GrowWindow** to get an outline of the new size that will follow the outline of the mouse pointer until it is released. **GrowWindow** returns the coordinates of the bottom right corner of the new size. When a window is sized, its top left corner is anchored on the screen; only the position of the bottom right corner changes.
3. Call **SizeWindow** to actually change the size of the window.
4. Update the window. This may include re-drawing scroll bars and the grow icon based on the window's new size. For a summary of the update process, see the end of this chapter.
    a. Call **BeginUpdate** (among other things, clears out the update region)
    b. Call **EraseRect**
    c. Re-draw window contents
    d. Call **HideControl** to get rid of the old scroll bars
    e. Call **MoveControl** to move the scroll bars
    f. Call **SizeControl** to change the size of a scroll bar's rectangle

g. Call **ShowControl** to make the scroll bars appear
h. Call **DrawGrowIcon** to redraw the grow region
i. Call **EndUpdate**

Let's now look at a code that will implement the above sequence. The window that will be sized is the window with scroll bars from Figure 7.3b. The first step in the process is to take care of ensuring that the scroll bars get into the update region. To do so requires two calls to **InvalRect**, one for each scroll bar:

```
PROCEDURE InvalRect (badRect: Rect);
```

In order to call this routine, an application needs to know only the scroll bars' boundary rectangles. But if the boundary rectangles change each time the window is sized, how can the application keep track of them? The coordinates in the resource file will no longer be valid once a window has been sized. The answer lies in the control record. The coordinates of a control's current boundary rectangle are contained in the third field of the control record:

```
MOVE.L      BottomControlHandle,A0      ;get handle
MOVE.L      (A0),A0                     ;get pointer
LEA         cntrlRect(A0),A0            ;get starting address of
                                        ;boundary rectangle
MOVE.L      A0,-(SP)                    ;pushes pointer to
                                        ;rectangle
_InvalRect

MOVE.L      SideControlHandle,A0        ;get handle
MOVE.L      (A0),A0                     ;get pointer
LEA         cntrlRect(A0),A0            ;address of rectangle
MOVE.L      A0,-(SP)                    ;push pointer
_InvalRect
```

The second step is to call **GrowWindow**:

```
FUNCTION GrowWindow (theWindow: WindowPtr; startPt: Point;
    sizeRect: Rect); LONGINT;
```

theWindow comes from a call to **FindWindow**; it is the window reporting the mouse down event. **startPt** is the **point** field from the event record, the place where the mouse pointer was when the button was first pressed. **sizeRect** is a rectangle that defines the maximum size that the window can be. For this example, **sizeRect** will be defined as 4 pixels in from each edge of the screen (4,4,338,508):

```
CLR.L       -(SP)                   ;space for coordinate result
MOVE.L      WhichWindowPtr,-(SP)
                                    ;from FindWindow
MOVE.L      Point,-(SP)             ;from event record
```

```
PEA         SizeRect            ;defined as constant
_GrowWindow
MOVE.L      (SP)+,D0            ;retrieve result
```

GrowWindow's result is a longinteger containing the new bottom right coordinates of the window. The high-order word contains the bottom (vertical) coordinate and the low-order word the right (horizontal) coordinate. These coordinates must, in turn, be passed to **SizeWindow**:

```
PROCEDURE SizeWindow(theWindow: Window; w,h: INTEGER;
    fUpdate: BOOLEAN);
```

The parameter **theWindow**, as before, comes from the call to **FindWindow**. **w** refers to the new horizontal coordinate of the bottom right corner or the window, **h** to the new vertical coordinate. At first it may seem that these are in the opposite order from which they were returned by **GrowWindow**. They are not. The horizontal coordinate should be deeper in the stack than the vertical coordinate, since it appears first in the procedure's parameter list. Therefore, if the entire longinteger from **GrowWindow** is moved onto the stack as a unit, its low-order word will appear as an integer that is just below its high-order word, placing the two coordinates in the proper order.

fUpdate is a flag that indicates whether or not the system should generate an update event if the sizing changes the window's contents. A value of TRUE, the setting most commonly used, tells the system to do so:

```
MOVE.L      WhichWindowPtr,-(SP)    ;from FindWindow
MOVE.L      D0,-(SP)                ;coordinates recovered
                                    ;above from GrowWindow
ST."ST"     -(SP)                   ;yes - generate update
                                    ;event
_SizeWindow
```

The final major step in the process of sizing a window is to update the new window. All updates begin with a call to **BeginUpdate** and should then erase the window. Note that since the QuickDraw routine **EraseRect** works on the current grafport, the application must first ensure that the window posting the mouse down event is the current grafport (see Handling Update Events):

```
MOVE.L      WhichWindowPtr,-(SP)    ;from FindWindow
_BeginUpdate
MOVE.L      WhichWindowPtr,A0
MOVE.L      contRgn(A0),A0          ;retrieve handle to content
                                    ;region of window from
                                    ;window record
```

```
MOVE.L    (A0),A0          ;turn handle into pointer
ADD       #2,A0            ;skip over integer to get to
                           ;region rectangle
MOVE.L    A0,-(SP)         ;coordinates of content
                           ;region
_EraseRect
```

Preparing for the call to **EraseRect** above presents a similar problem as did the calls to **InvalRect**: this block of code should be general enough to work regardless of which window posted the mouse down event. Therefore, the boundary rectangle of the area which should be erased cannot be defined explicitly within the program code. The coordinates must be retrieved from the window record. The process is somewhat indirect. First, a handle to the record that defines the content region is pulled from the window record. (We are not interested in updating the structure region.) That handle is de-referenced to get a pointer. The actual rectangle begins two bytes past the address contained in the pointer; as discussed in Chapter 7, the first two bytes of a region record contain the size of the region. Therefore, if the quantity 2 (for two bytes) is added to the pointer to the region record, we will have the address of the start of the region's boundary rectangle, which in turn can be passed to **EraseRect**.

Once the current contents of the window have been erased, the application should redraw the contents as appropriate. This may involve calls to QuickDraw routines or to special TextEdit updating routines (see Chapter 9).

The application must then update the scroll bars. First, the existing scroll bars must be hidden:

```
PROCEDURE HideControl (theControl: ControlHandle);
```

In order to write general code that will apply to any of an application's windows, there has to be some way to retrieve the handles for a particular window's controls. This can be done by using both the window record and the records of any controls associated with the window. As discussed in Chapter 7, the window record maintains a handle to the first control in its control list. Each control record maintains a handle to the next item in the control list.

There is no field in a control record that explicitly indicates what type of control that record represents. Therefore, as mentioned in Chapter 7, the reference value field can be used for an application assigned code to identify control types. In the example below, a horizontal scroll bar was arbitrarily given a reference value of 1 and a vertical scroll bar a reference value of 2; other controls were given higher values.

```
MOVE.L    WhichWindowPtr,A0
MOVE.L    wControlList(A0),A0    ;handle to first control
BEQ       EndTheUpdate           ;handle is 0 — window
                                 ;has no controls
```

```
    MOVE.L      (A0),A1                 ;get pointer
    MOVE.L      contrlRfCon(A1),D7      ;get reference value
    CMP         #2,D7
    BGT         AnotherControl          ;not a scroll bar
    MOVE.L      A0,-(SP)                ;push handle on stack
    _HideControl
AnotherControl
    MOVE.L      nextContrl(A1),A0       ;handle to next control
    BEQ         NextStep                ;no more controls
    MOVE.L      (A0),A1                 ;get pointer
    MOVE.L      controlRfCon(A1),D7     ;get reference value
    CMP         #2,D7
    BGT         AnotherControl          ;not a scroll bar
    MOVE.L      A0,-(SP)
    _HideControl
    BRA         AnotherControl
```

The "next step" is to actually move the control:

```
PROCEDURE MoveControl (theControl: ControlHandle;
    h,v: INTEGER);
```

The location to which this routine moves a control is specified by giving the control new top left coordinates in the local coordinate system of its window. **h** is the horizontal (left) coordinate and **v** the vertical (top). An application can determine these coordinates from the bottom right coordinates returned by **GrowWindow**. First **Growwindow**'s global coordinates are converted to local coordinates. Then, for a horizontal scroll bar, the vertical coordinate will be 16 less than the the bottom. (The horizontal coordinate will remain at 0.) For a vertical scroll bar, the vertical coordinate will remain 0 and the horizontal coordinate will be 16 less than the right. Assume that **GrowWindow**'s result is in D0 and that the handle to a control record for a scroll bar is in A0. Remember that this example has arbitrarily assigned vertical scroll bars a reference value of 2 and horizontal scroll bars a reference value of 1. Also note that the two coordinates returned by **GrowWindow** must be stored in RAM so their address can be passed to **GlobalToLocal**:

```
    MOVE.L  D0,Points(A5)           ;store coordinates in RAM
    PEA     Points(A5)
    _GlobalToLocal                  ;convert the coordinates

    MOVE    Points(A5),D0           ;recover local coordinates

    MOVE    D0,D1                   ;get low order word (right)
    SWAP    D0                      ;flip the words in the register
    MOVE    D0,D2                   ;get high order word (bottom)
    MOVE.L  (A0),A1                 ;pointer to control record
    MOVE.L  contrlRfCon(A1),D7      ;control value
```

```
        CMP     #1,D7
        BNE     Vertical            ;this is a vertical control bar

        SUB     #16,D2              ;adjust vertical coordinate
        MOVE    #0,D1               ;horizontal coordinate stays 0
        BRA     RoutineSetUp

Vertical
        SUB     #16,D1              ;adjust horizontal coordinate
        MOVE    #0,D2               ;vertical coordinate stays 0

RoutineSetUp
        MOVE.L  A0,-(SP)            ;push handle onto stack
        MOVE    D1,-(SP)            ;horizontal coordinate goes first
        MOVE    D2,-(SP)            ;vertical coordinate
        _MoveControl                ;move the control
```

Once the top left corners of the scroll bars have been anchored in their new positions, the bottom right coordinates must be changed with a call to **SizeControl**:

```
PROCEDURE SizeControl (theControl: ControlHandle; w,h:
    INTEGER);
```

The parameters **w** and **h** correspond respectively to the new right and bottom coordinates of the control, expressed again in the local coordinates of the control's window. Neither horizontal nor vertical scroll bars can use the coordinates returned by **GrowWindow** directly. A horizontal scroll bar will have a **w** value of 15 less than that returned by **GrowWindow** to allow space for the grow icon; **h** will not need to be altered. A vertical scroll bar can accept **w** from **GrowWindow**'s result but must subtract 15 from the horizontal coordinate. Assume again that **GrowWindow**'s result is in D0 (now in local coordinates since they were converted before the call to **MoveWindow**) and that the handle to a control is in A0:

```
        MOVE    D0,D1               ;get horizontal coordinate
        SWAP    D0                  ;exchange register halves
        MOVE    D0,D2               ;get vertical coordinate
        MOVE    (A0),A1             ;pointer to control record
        MOVE.L  contrlRfCon(A1),D7  ;reference value
        CMP     #1,D7               ;horizontal or vertical scroll
                                    bar?
        BNE     Vertical2           ;must be vertical

        SUB     #15,D1              ;adjust horizontal coordinate
        BRA     PassParameters

Vertical2
        SUB     #15,D2              ;adjust vertical coordinate
```

```
PassParameters
    MOVE.L    A0,-(SP)          ;put handle on stack
    MOVE      D1,-(SP)          ;horizontal coordinate goes
                                first
    MOVE      D2,-(SP)          ;vertical is next
    _SizeControl
```

To be on the safe side, an application should follow **SizeControl** with a call to **ShowControl**, to be sure that the control is displayed:

```
PROCEDURE ShowControl (theControl: ControlHandle);
```

If the control is invisible, **ShowControl** will make it visible. If the control is already visible, **ShowControl** will have no effect.

Finally, the update process should be completed with a call to **EndUpdate**. Code for these last two steps might appear as:

```
MOVE.L      A0,-(SP)            ;control handle in A0
_ShowControl

MOVE.L      WhichWindowPtr,-(SP)
_EndUpdate
```

Handling Key Down Events

Most applications will have a variety of uses for key down events. Primarily, they can be used to display text on the screen or, in combination with the cloverleaf key, they can substitute for using the mouse to make a menu selection.

The first step in processing a key down event is therefore to determine which, if any, of the modifier keys were held down in conjunction with the key press. The modifier flags are stored in the high-order byte of the **Modify** field from the event record. If the cloverleaf key was pressed, bit 0 of that byte will be set (i.e., the byte will have a value of 1). This gives the entire modifier word, by the way, a value of 256.

To test for the cloverleaf key, an application could:

```
MOVE.B      Modify,D0           ;get high-order byte only
CMP.B       #1,D0               ;compare with cloverleaf value
BEQ         KeyboardCommand     ;branch to handle command
```

The same result could also be obtained by:

```
MOVE        Modify,D0           ;get entire modifier word
CMP         #256,D0             ;compare with cloverleaf value
BEQ         KeyboardCommand
```

If **Modify** does reveal that the cloverleaf key was pressed along with some other key, then the application can assume that it was intended to be a substitution for a mouse selection from a menu. The information needed to process such a selection is identical to that needed to process a mouse down menu selection — which menu and which item within that menu.

MenuKey is a single routine that will return both the menu and the item numbers corresponding to the keyboard equivalent selected by a cloverleaf command. It assumes that a press of the cloverleaf key has already been detected and therefore only needs to know what additional character was pressed at the same time. That character can be found as part of the event record's **Message** field. More precisely, it is in the low-order word of that field. The address of the character is therefore two bytes beyond the beginning of **Message** and can be indicated by using **Message + 2** as the effective address.

MenuKey's format is:

```
FUNCTION MenuKey (ch: CHAR) : LONGINTEGER;
```

It should be called by using:

```
CLR.L       -(SP)               ;space for longinteger result
MOVE        Message+2,-(SP)     ;put character on the stack
_MenuKey
```

MenuKey returns its result in exactly the same format as **MenuSelect**. The menu number is in the high-order word and the item number in the low-order word. Therefore, immediately after issuing the call to **MenuKey**, an application can branch to join the same processing sequence that occurs after **MenuSelect**, including retrieving the result and unhighlighting the menu title.

Key down events that are not accompanied by the cloverleaf key generally indicate text that should be displayed on the screen by TextEdit. Processing of these events is discussed in Chapter 9.

Handling Update Events

An update event is posted to the event queue whenever a window is newly activated or when something has occurred to disrupt the display of the window's

contents. The latter is usually the result of one window overlaying another. For example, if you open a desk accessory while in the midst of one of the Video Tape Index's functions that permit text editing, the desk accessory's window has the potential of covering one or more of the text entry windows and their prompts (which are actually displayed on the main window). Any window which covers another erases the contents of the windows underneath it. When the front window is closed or moved to the back, any windows which are uncovered will be minus their contents. An update event alerts the application that the newly exposed windows need to have their contents redrawn.

Updating in text windows is handled by a special TextEdit routine. Updating the contents of other windows can be done in two ways: either by drawing only the region of the window that needs updating, or by erasing the entire window and redrawing all of its contents. The latter is far easier to implement.

Regardless of whether you are updating text windows or other windows, all update processes must start with a call to **BeginUpdate** and finish with a call to **EndUpdate**. These two routines manage a portion of the window known as the *update region*. Update regions are important if you are attempting to do an update by redrawing only that portion of a window's contents that have been erased. Even if the update will erase the window and completely redraw it, the process must nonetheless be bracketed by these two routines.

Each takes the pointer of the window to be updated as a parameter:

```
PROCEDURE BeginUpdate (theWindow: WindowPtr);
PROCEDURE EndUpdate (theWindow: WindowPtr);
```

The easiest way to update a non-text window is therefore to:

1. Call **BeginUpdate**
2. Erase the window (using **EraseRect**)
3. Redraw the window's contents (procedure will vary with the window in question)
4. Call **EndUpdate**

Since the prompts for the Video Tape Index's text entry windows are drawn on the main window, any time a desk accessory is opened while one of the four text entry functions are in process, those prompts will be disturbed. Immediately after the desk accessory is closed, the main window must therefore be updated. The code to do so appears as:

```
MOVE.L     MainWindowPtr, -(SP)     ;window pointer
_BeginUpdate                        ;start update process

MOVE.L     MainWindowPtr, -(SP)     ;can only draw in
_SetPort                            ;current grafport
```

```
PEA         MainWindowRect          ;boundary rectangle
_EraseRect                          ;erase the window
JSR         DisplayPrompts          ;redraw window contents
MOVE.L      MainWindowPtr,-(SP)     ;window pointer
_EndUpdate                          ;finish update process
```

Note that update events that occur while the program is in its main event loop can be ignored since the main window has no content at that point.

A Word About Activate Events

In most cases, activate events can be ignored. Since **SelectWindow** handles highlighting and unhighlighting windows, usually the only time an application needs to respond to an activate event is when a text edit window has been selected. Activating and deactivating text entry windows takes care of respectively displaying and removing the straight-line cursor (see Chapter 9).

Pulling Things Together Thus Far – WindowPlay

In Listing 8.4 you will find the source code for a demonstration program called WindowPlay. Its resource file appears in Listing 8.5. This program uses many of the concepts and techniques presented in Chapters 7 and 8, including defining windows and menus and trapping a variety of events. It is very short for a complete Macintosh assembly language application and really doesn't do any useful work, but it does illustrate how to create and manipulate windows and menus.

WindowPlay has a template for one window of each window type in its resource file. The windows can be displayed by selecting the window type from the Windows menu, creating a display like the one in Figure 8.3. The windows overlap on the screen, but their position in the plane can be changed by clicking on a window with the arrow cursor. Those windows which support title bars can be closed by clicking in their GoAway boxes. Any active (frontmost) window can be closed by selecting Close from the File menu.

Listing 8.4 WindowPlay

```
            Include MacTraps.D
            Include ToolEqu.D
            Include SysEqu.D

            PEA    -4(A5)
            _InitGraf                    ;initialize QuickDraw
            _InitFonts                   ;initialize Font Manager
            MOVE.L #$ØØØØFFFF,DØ
            _FlushEvents                 ;flush all events from event queue
            _InitWindows                 ;initialize Window Manager
            _InitMenus                   ;initialize Menu Manager
            CLR.L  -(SP)
            _InitDialogs                 ;initialize Dialog manager
            _TEInit                      ;initialize Text Edit
            _InitCursor                  ;get arrow cursor

            CLR    -(SP)
            PEA    'MAL.files:WindowPlay.Rsrc'
            _OpenResFile                 ;open the resource file
            MOVE   (SP)+,DØ              ;discard unused result

; ---------- Set up the menus ----------------------------------
            CLR.L  -(SP)                 ;space for handle
            MOVE   #1,-(SP)              ;menu sequence number
            _GetRMenu                    ;get Apple menu template
            MOVE.L (SP)+,AppleHandle(A5)        ;retrieve and store handle

            MOVE.L AppleHandle(A5),-(SP)        ;put handle back on stack
            MOVE.L #'DRVR',-(SP)         ;resource type for desk accessories
            _AddResMenu                  ;get desk accessories

            MOVE.L AppleHandle(A5),-(SP)        ;handle back on stack
            CLR    -(SP)                 ;this menu goes after all others
            _InsertMenu                  ;put menu in menu list

            CLR.L  -(SP)                 ;repeat the process for the other menus
            MOVE   #2,-(SP)
            _GetRMenu
            MOVE.L (SP)+,FileHandle(A5)

            MOVE.L FileHandle(A5),-(SP)
            CLR    -(SP)
            _InsertMenu

            CLR.L  -(SP)
            MOVE   #3,-(SP)
            _GetRMenu
            MOVE.L (SP)+,EditHandle(A5)

            MOVE.L EditHandle(A5),-(SP)
            CLR    -(SP)
            _InsertMenu

            CLR.L  -(SP)
            MOVE   #4,-(SP)
            _GetRMenu
            MOVE.L (SP)+,WindowHandle(A5)                    (continued)
```

```
        MOVE.L  WindowHandle(A5),-(SP)
        CLR     -(SP)
        _InsertMenu

        _DrawMenuBar                ;finally, make it all appear

        MOVE    #Ø,D7               ;initialize window counter

;-----------------------Event loop comes next to control actions ------------------------------
Event   _SystemTask                 ;update desk accessories

        CLR     -(SP)               ;space for boolean result
        MOVE    #-1,-(SP)           ;mask to select all events
        PEA     EventRecord(A5)             ;address of event record
        _GetNextEvent               ;retrieve event from queue

        MOVE    (SP)+,DØ            ;recover result
        CMP     #Ø,DØ               ;did event occur?
        BEQ     Event               ;no event

        MOVE    EventRecord(A5),DØ  ;this retrieves 1st word of record - the event type

        CMP     #mButDwnEvt,DØ              ;mouse button pressed?
        BEQ     MouseEvent

        CMP     #keyDwnEvt,DØ               ;key pressed?
        BEQ     KeyEvent

        BRA     Event               ;not an event this program handles

; ---------------------------------- Handle key down events ----------------------------------------

KeyEvent
        MOVE    EventRecord+evtMeta(A5),DØ                  ;get modify word
        BTST    #cmdKey,DØ          ;cloverleaf key held down?
        BEQ     Event               ;not a menu selection

        CLR.L   -(SP)               ;space for menu item selection
        MOVE    EventRecord+evtMessage+2(A5),-(SP)  ;put character pressed on stack
        _MenuKey                    ;identify menu and item

        BRA     Selections          ;join menu processing

; ---------------------------------- Handle mouse down events ----------------------------------------
MouseEvent
        CLR     -(SP)               ;space for "what" result
        MOVE.L  EventRecord+evtMouse(A5),-(SP)      ;place where event occurred
        PEA     WhichWindowPtr(A5)  ;window affected goes here
        _FindWindow                 ;determine which window posted event
        MOVE    (SP)+,DØ            ;recover result

        CMP     #inMenuBar,DØ
        BEQ     MenuBar             ;mouse down event in menu bar

        CMP     #inSysWindow,DØ
        BEQ     SysEvent            ;mouse down event in system window

        CMP     #inContent,DØ
        BEQ     ApplWindow          ;mouse down event in application window
```

(continued)

Listing 8.4 (continued)

```
        CMP   #inGoAway,DØ
        BEQ   CloseWindow          ;mouse down event in GoAway box

        BRA   Event                ;not a place this program monitors

; ---------- Mouse down event in system window ----------
SysEvent
        PEA   EventRecord(A5)                    ;address to event record on stack
        MOVE.L      WhichWindowPtr(A5),-(SP)     ;window posting event
        _SystemClick               ;system does all the work

        BRA   Event                ;get another event

; ---------- Mouse down event in menu bar ----------
MenuBar
        CLR.L -(SP)                ;space for menu ID and menu item
        MOVE.L      EventRecord+evtMouse(A5),-(SP)     ;place where mouse button
went down
        _MenuSelect                ;find menu number and menu item

Selections
        MOVE.L  (SP)+,DØ           ;recover result
        MOVE  DØ,D1                ;D1 now has low-order word (menu item)
        SWAP  DØ                   ;menu ID now in low-order word of DØ

        MOVEM.L     DØ/D1,-(SP)          ;save registers
        CLR   -(SP)                ;selects all menus
        _HiLiteMenu                ;remove highlighting from menu
        MOVEM.L     (SP)+,DØ/D1

        CMP   #1,DØ                ;in Apple menu?
        BNE   Menu2
        BRA   AppleMenu            ;handle desk accessories

Menu2 CMP   #2,DØ                  ;in File menu?
        BNE   Menu3
        BRA   FileMenu

Menu3 CMP   #3,DØ                  ;in Edit menu?
        BNE   Menu4
        BRA   EditMenu

Menu4 CMP   #4,DØ                  ;in Window menu?
        BNE   Event                ;something weird happened...
        BRA   WindowEvent

---------- Handle desk accessories ----------
AppleMenu
        MOVE.L  AppleHandle(A5),-(SP)      ;menu handle on stack
        MOVE  D1,-(SP)             ;menu item on stack
        PEA   DeskAccName(A5)      ;space for desk accessory name
        _GetItem                   ;retrieve name of desk accessory

        CLR   -(SP)                ;space for reference number
        PEA   DeskAccName(A5)      ;point to desk accessory name
        _OpenDeskAcc               ;open the desk accessory
        MOVE  (SP)+,DØ             ;discard reference number result

        BRA   Event                                              (continued)
```

```
;------------------------------ Handle editing in desk accessories ---------------------------------
EditMenu
        SUBQ  #1,D1                     ;adjust item selected for SysEdit
        CLR   -(SP)                     ;space for problem result
        MOVE  D1,-(SP)                  ;adjusted item number goes on stack
        _SysEdit                        ;let system handle to edit
        MOVE  (SP)+,DØ                  ;get rid of result

        BRA   Event

;------------------------------------- Handle File Menu ------------------------------------------
FileMenu
        CMP   #1,D1                     ;Close the active window?
        BEQ   WindowClose

        CMP   #2,D1                     ;Quit?
        BNE   Event

        RTS                             ;This returns to the Finder

WindowClose
        CLR.L -(SP)                     ;space for pointer to active window
        _FrontWindow                    ;get pointer
        MOVE.L (SP)+,A6                 ;save pointer

        MOVE.L A6,-(SP)                 ;put pointer back on stack
        _CloseWindow                    ;close the window

        SUBQ  #1,D7                     ;decrement window counter
        BNE   Fix
        MOVE.L FileHandle(A5),-(SP)
        MOVE  #1,-(SP)
        _DisableItem                    ;if no windows present, disable Close

Fix     CMP.L Window1Ptr(A5),A6         ;identify which window was closed
        BNE   Fix2
        MOVE  #1,D1
        BRA   ReEnable

Fix2    CMP.L Window2Ptr(A5),A6
        BNE   Fix3
        MOVE  #2,D1
        BRA   ReEnable

Fix3    CMP.L Window3Ptr(A5),A6
        BNE   Fix4
        MOVE  #3,D1
        BRA   ReEnable

Fix4    CMP.L Window4Ptr(A5),A6
        BNE   Fix5
        MOVE  #4,D1
        BRA   ReEnable

Fix5    CMP.L Window5Ptr(A5),A6
        BNE   Fix6
        MOVE  #5,D1
        BRA   ReEnable
```

(continued)

Listing 8.4 (continued)

```
Fix6    MOVE  #6,D1

ReEnable
        MOVE.L      WindowHandle(A5),-(SP)      ;handle to menu
        MOVE  D1,-(SP)                          ;window #
        _EnableItem                             ;turn the menu item back on

        BRA   Event

;------------------------------------ Handle Window Menu ----------------------------------------
WindowEvent
        MOVE  D1,-(SP)                          ;save register contents
        MOVE.L WindowHandle(A5),-(SP)
        MOVE  D1,-(SP)                          ;window number same as menu item #
        _DisableItem                            ;turn off this window
        MOVE  (SP)+,D1

        CMP   #1,D1                             ;window 1?
        BNE   Window2
        CLR.L -(SP)                             ;space for window handle
        MOVE  #1,-(SP)                          ;window ID
        PEA   Window1Strg(A5)                   ;pointer to window record
        MOVE.L #-1,-(SP)                        ;put window in front
        _GetNewWindow                           ;create the window
        MOVE.L (SP)+,Window1Ptr(A5)             ;retrieve the pointer
        BRA   WindowCount

Window2 CMP   #2,D1                             ;repeat for all windows
        BNE   Window3
        CLR.L -(SP)
        MOVE  #2,-(SP)
        PEA   Window2Strg(A5)
        MOVE.L      #-1,-(SP)
        _GetNewWindow
        MOVE.L      (SP)+,Window2Ptr(A5)
        BRA   WindowCount

Window3 CMP   #3,D1
        BNE   Window4
        CLR.L -(SP)
        MOVE  #3,-(SP)
        PEA   Window3Strg(A5)
        MOVE.L      #-1,-(SP)
        _GetNewWindow
        MOVE.L      (SP)+,Window3Ptr(A5)
        BRA   WindowCount

Window4 CMP   #4,D1
        BNE   Window5
        CLR.L -(SP)
        MOVE  #4,-(SP)
        PEA   Window4Strg(A5)
        MOVE.L      #-1,-(SP)
        _GetNewWindow
        MOVE.L      (SP)+,Window4Ptr(A5)
        BRA   WindowCount
```

(continued)

```
Window5     CMP   #5,D1
        BNE   Window6
        CLR.L -(SP)
        MOVE  #5,-(SP)
        PEA   Window5Strg(A5)
        MOVE.L        #-1,-(SP)
        _GetNewWindow
        MOVE.L        (SP)+,Window5Ptr(A5)
        BRA   WindowCount

Window6     CLR.L -(SP)
        MOVE  #6,-(SP)
        PEA   Window6Strg(A5)
        MOVE.L        #-1,-(SP)
        _GetNewWindow
        MOVE.L        (SP)+,Window6Ptr(A5)

WindowCount
        ADDQ  #1,D7                     ;count number of windows on screen
        CMP   #1,D7
        BNE   Done

        MOVE.L FileHandle(A5),-(SP)     ;handle to window menu
        MOVE  #1,-(SP)
        _EnableItem                     ;if first window, enable Close

Done    BRA   Event
; ---------- Handle mouse down in application window ----------
ApplWindow
        MOVE.L WhichWindowPtr(A5),-(SP)
        _SelectWindow               ;bring window to front & make active

        BRA   Event

; ---------- Handle mouse down in goAway box ----------
CloseWindow
        CLR.B -(SP)                             ;space for boolean result
        MOVE.L WhichWindowPtr(A5),-(SP)         ;window posting event
        MOVE.L EventRecord+evtMouse(A5),-(SP)   ;point of event
        _TrackGoAway                            ;monitor goAway box

        MOVE.B        (SP)+,DØ                  ;get result
        CMP   #Ø,DØ                             ;did user change mind?
        BEQ   Event                             ;don't close
        BRA   WindowClose                       ;close window just like menu selection

;---------- Data structures ----------

AppleHandle   DS.L  1           ;menu handles
EditHandle    DS.L  1
FileHandle    DS.L  1
WindowHandle  DS.L  1

Window1Ptr    DS.L  1           ;window pointers
Window2Ptr    DS.L  1
Window3Ptr    DS.L  1
Window4Ptr    DS.L  1
Window5Ptr    DS.L  1
Window6Ptr    DS.L  1
```

(continued)

Listing 8.4 (continued)

```
Window1Strg  DS    windowSize    ;storage for window records
Window2Strg  DS    windowSize
Window3Strg  DS    windowSize
Window4Strg  DS    windowSize
Window5Strg  DS    windowSize
Window6Strg  DS    windowSize

WhichWindowPtr     DS.L  1            ;for FindWindow result
DeskAccName  DS    16                 ;for desk accessory name

EventRecord  DS.B  16
```

Listing 8.5 Resource File for WindowPlay

```
WindowPlay.Rsrc

TYPE MENU
 ,1                                   ;; Apple menu
\14

 ,2                                   ;; File menu
File
(Close
Quit/Q

 ,3                                   ;; Edit menu
Edit
Undo/Z
(-
Cut/X
Copy/C
Paste/V
Clear

 ,4                                   ;; Window selection menu
Windows
documentProc
dBoxProc
plainDBox
altDBoxProc
noGrowDocProc
rDocProc

TYPE WIND
 ,1                                   ;; standard document window
Sample Window
4Ø 16Ø 3ØØ 48Ø
visible GoAway
Ø
Ø
```

(continued)

```
,2
No title                          ;; alert or modal dialog window
125 6Ø 275 18Ø
visible NoGoAway
1
Ø

,3
No title                          ;; plain document window
6Ø 9Ø 225 4ØØ
visible NoGoAway
2
Ø

,4
No title                          ;; plain document window with shadow
1ØØ 225 33Ø 35Ø
visible NoGoAway
3
Ø

,5
Sample Window                     ;; standard document window without size box
175 11Ø 25Ø 3ØØ
visible GoAway
4
Ø

,6
Sample                            ;; round cornered window for desk accessories
4Ø 4Ø 3ØØ 14Ø
visible GoAway
16
Ø
```

WindowPlay supports four menus: a standard Apple menu for the desk accessories, a File menu, an Edit menu (for the desk accessories only), and the application menu Windows that controls which windows appear on the screen.

The structure of WindowPlay is typical of a Macintosh assembly language program. The set-up process involves:

1. Initialization of all ToolBox and operating system managers
2. Opening the resource file
3. Reading menu templates from the resource file and creating the menu bar
4. Entering an event loop

The event loop itself determines the structure of the remainder of the program. WindowPlay looks for mouse down and key down events. Since there is no text editing, key down events are meaningful only as keyboard equivalents for menu

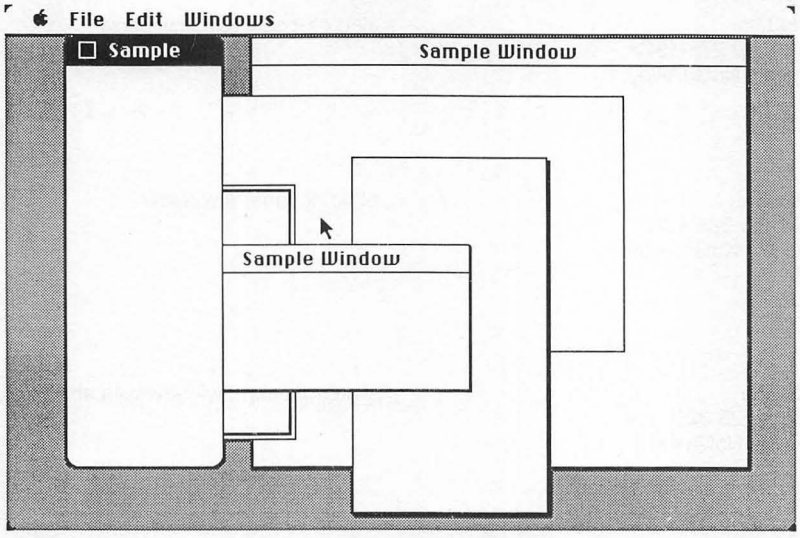


Figure 8.3 Sample Output from WindowPlay

selections. Menu selections represent either a request for a desk accessory, a request to return to the Finder, or a request to affect one of the windows displayed by the application.

When WindowPlay is launched, the screen is blank and the Close option of the File menu is dimmed. (It makes no sense to allow the user to close a window when no windows are visible.) WindowPlay keeps track of how many windows are displayed and always disables Close when the count drops to 0; it enables Close when the count rises to 1.

You will also notice that whenever a window is selected for display, its name in the Windows menu is disabled. This ensures that only one window of any given type will be displayed at any given time. When the window is closed, its name in the Windows menu is re-enabled.

Questions and Problems

1. Create binary event masks to select the following events:

   a. mouse down, mouse up
   b. mouse down, key down
   c. mouse down, key down, update, activate, disk insertion

2. Write an event loop that:

   A. retrieves events from the event queue with an event mask that selects all events
   B. checks for mouse down, key down, update, activate and disk insertion events
   C. branches to an appropriately named subroutine to handle each type of event

   Be sure to allocate any data structures your event loop will use.

3. Write an ordered list of the ToolBox and/or operating system routines that must be used to identify a user request for the note pad desk accessory. Indicate the information returned by each call. Assume that an event loop has already detected a mouse down event and that the Apple menu is Menu number 0.

4. Write a block of assembly language code to implement the procedure you outlined in problem 3. Use the event record field names defined in Chapter 8. Allocate any other data structures your code will use.

5. Write an ordered list of the ToolBox and/or operating system routines that must be used to identify a user request to scroll the text in a document window one page up. Indicate the information returned by each call. Assume that an event loop has already detected a mouse down event.

6. Write a block of assembly language code to implement the procedure you outlined in problem 5. Use the event record field names defined in Chapter 8. Allocate any other data structures your code will use.

7. Write an ordered list of the ToolBox and/or operating system routines that are needed to identify which menu item has been selected by a combination cloverleaf-alphanumeric key press. Indicate the information returned by each call. Assume that an event loop has already detected a key down event.

8. Write a block of assembly language code to implement the procedure you outlined in problem 7. Use the event record field names defined in Chapter 8. Allocate storage space for any other data structures your code will use.

9. Code and implement the following modifications to the program WindowPlay from Listings 8.4 and 8.5:

   A. Draw scroll bars and a grow icon in the standard document window. The scroll bars should be defined in the resource file.
   B. Trap for events in a title bar so that the three windows with title bars can be moved about the screen.
   C. Handle moving the three windows with title bars, including the scroll bars in the standard document window.
   D. Trap for events in a grow icon.
   E. Handle sizing the standard document window.

CHAPTER NINE

SCREEN AND KEYBOARD I/O: USING TEXTEDIT, ALERT AND DIALOG BOXES

Chapter Objectives

1. To understand the data structures that support Macintosh text editing
2. To learn to establish those data structures
3. To learn to manage windows that support text editing
4. To learn to implement text editing functions: entering text, deleting text, cut, paste, and copy
5. To learn to manage text characteristics such as font size and type
6. To learn to create the resource file templates that establish alerts and dialog boxes
7. To learn to use alerts and dialog boxes to control program actions

Entering, Displaying, and Editing Text

TextEdit is a collection of powerful ROM routines that permit the easy entry and editing of text. Text is written into a rectangle defined for that purpose. The rectangle may be an entire window or only part of a window.

To be precise, editing text requires two rectangles – a destination rectangle and a view rectangle. The destination rectangle establishes the bounds in which the text should be drawn; the view rectangle defines the area in which the text will be seen. Though both must be specified, they are usually identical. Destination and view rectangles are defined in the *local* coordinates of the grafport in which the text will appear. In other words, in order to enter or edit text, the window that contains the destination and view rectangles must be the current grafport (set with the **SetPort** routine).

Information about the editing environment is kept in an *edit record*. An edit record contains, in part, the coordinates of the destination and view rectangles, font and text justification information, the current selection range, the length of the text, a handle to where the text is stored, the number of lines in the text, and positions of line starts within the text. The text itself is stored as a packed array of characters (i.e., each ASCII character code occupies only one byte).

The structure of a text edit record is:

```
TeRec = RECORD
        destRect:     Rect;      the destination rectangle
        viewRect:     Rect;      the view rectangle
        selRect:      Rect;      boundaries of selection range
        lineHeight:   INTEGER;   height of a line of text
        fontAscent:   INTEGER;   number of pixels a font rises
        selPoint:     Point;     location of mouse button click
        selStart:     INTEGER;   start of selection range
        selEnd:       INTEGER;   end of selection range
        active:       INTEGER;   used internally – do not change
        wordBreak:    ProcPtr;   used to change how TextEdit
                                 views the end of a word
        clikLoop:     ProcPtr;   used to implement automatic
                                 scrolling
        clickTime:    LONGINT;   used internally – do not change
        clickLoc:     INTEGER;   used internally – do not change
        caretTime:    LONGINT;   used internally – do not change
        caretState:   INTEGER;   used internally – do not change
        just:         INTEGER;   text justification
        teLength:     INTEGER;   text length in # of characters
        hText:        Handle;    handle to the text itself
        recalBack:    INTEGER;   used internally – do not change
        recalLines:   INTEGER;   used internally – do not change
        clikStuff:    INTEGER;   used internally – do not change
        crOnly:       INTEGER;   if negative, indicates that a new
                                 line should start only after a CR
        txFont:       INTEGER;   font ID number
        txFace:       Style;     text style (e.g., bold or italic)
        txMode:       INTEGER;   pen mode
        txSize:       INTEGER;   font size
```

```
inPort:      GrafPtr;      pointer to grafport
highHook:    ProcPtr;      used by low-level routines
caretHook:   ProcPtr;      used by low-level routines
nLines:      INTEGER;      number of lines of text
lineStarts   ARRAY [0..16000] of INTEGER
                           positions of starts of lines
```

As with the other types of records we've discussed, an application won't need to retrieve data from most fields of the edit record directly. There are, however, some exceptions. A program may, for example, need the length of the text or the handle which contains the pointer to the text itself. Printing characters from a text edit record requires knowing how many lines of text there are and where each line begins. Equates for field offsets into an edit record are part of the ToolBox equates file. For example, **teLength** refers to a file $3E bytes in from the beginning of an edit record. If ToolBox.D is INCLUDEd at the beginning of an application's source code, the offsets to all fields in the edit record are available to the program.

Before using any TextEdit routines, you must initialize the manager with **TEInit**. This procedure takes no parameters. It should appear at the top of an application, along with the other initializations; **TEInit** can be the last call in the initialization sequence. Because text manipulation also often involves manipulating font characteristics, the initialization sequence should also include a call to **InitFonts**, which initializes the Font Manager.

A complete initialization sequence, one that will be complete enough for most applications, appears as follows:

```
PEA          -4(A5)
_InitGraf                ;initialize QuickDraw
_InitFonts               ;initialize the Font Manager
_InitWindows             ;initialize the Window Manager
_InitMenus               ;initialize the Menu Manager
CLR.L   -(SP)
_InitDialogs             ;initialize the Dialog Manager (discussed
                         below)
_TEInit                  ;initialize TextEdit
_InitCursor              ;get arrow cursor
```

Use this block of code exactly as it appears. Because the various managers interact so closely, it is imperative that the initializations are performed in this order.

Data Structures for Text Edit

Windows for text editing should be defined in a resource file, just like any other window. They can then be created with **GetNewWindow**. Text edit windows can also be manipulated like other windows in terms of visibility and position on the

screen. Doing the editing, though, requires the destination and view rectangles mentioned above.

In most cases, the destination and view rectangles will cover an entire window. (The major exception is in dialog boxes, which will be discussed at the end of this chapter.) Therefore, to determine the coordinates of the destination and view rectangles, you need only figure out how many pixels the window encompasses. Consider, as an example, the Video Tape Index's text edit windows.

The Video Tape Index uses one text window for each field in the TapeArray record. (For database applications this tends to simplify the text handling.) The Producer window, for example, has global coordinates of 75, 240, 95, 415. These coordinates appear in the program's resource file. The height of the window is therefore 21 pixels (bottom − top + 1) and its width 176 pixels (right − left + 1). Since the view and destination rectangles will occupy the entire window, they could theoretically have coordinates of 0, 0, 21, 176. In practice, though, the rectangles should come in at least one pixel from the edges of the windows. Otherwise, it's possible that the first and last characters will not be displayed completely. Therefore, the destination and view rectangles for the Producer text window have coordinates of 1, 1, 19, 175. These coordinates are defined within the source code:

```
ProducerViewRect    DC    1,1,19,175
ProducerDestRect    DC    1,1,19,175
```

Storage must also be set aside for a handle to each text window's edit record. You need not reserve space for the edit record itself; this will be done by the system when the record is created. The handle to an edit record has the data type **TEHandle** and therefore requires a longword of space:

```
ProducerTextHandle      DC.L  0
```

or

```
ProducerTextHandle      DS.L  1
```

Allocating Text Edit Records

Text edit records are allocated by the routine **TENew**:

```
FUNCTION TENew (destRect, viewRect: Rect) : TEHandle;
```

The addresses of the destination and view rectangles are pushed onto the stack. A longword handle is returned.

The above function looks simple. There is something important, however, to be aware of when allocating edit records. An edit record includes the grafport of the

editing environment in its **inPort** field; the **TENew** routine will automatically absorb whatever grafport is current at the time the call to **TENew** is placed. Therefore, prior to allocating an edit record, the window for the destination and view rectangles must have been created. Immediately before calling **TENew, SetPort** must be used to make that window the current grafport.

The Video Tape Index defines all of its windows and only then creates text edit records. A typical code sequence, assuming the window has been defined and its pointer saved, is:

```
MOVE.L    ProducerWindowPtr,-(SP)
__SetPort                        ;window is current port
CLR.L     -(SP)                  ;space for edit record handle
PEA       ProducerDestRect
PEA       Producerviewrect
__TENew
LEA       NameTextHandle,A0      ;address for handle storage
MOVE.L    (SP)+,A0               ;retrieve the handle and store
```

Managing Text Edit Windows

Whenever a text edit window is activated (e.g., a mouse down event was recorded somewhere in a deactivate text edit window), an application generally responds by calling **SelectWindow**. As mentioned in Chapter 8, SelectWindow generates an activate event for the window selected and a deactivate event for the previously active window.

Activating and deactivating text edit windows is important, since these actions control the appearance and disappearance of the straight-line cursor. Therefore, whenever an application detects an activate event in a text edit window, the event should be handled, not ignored.

TextEdit provides two routines to do the activating and deactivating: **TeDeActivate** removes the straight-line cursor; **TEActivate** makes the straight-line cursor appear at the left-most position of the activated view rectangle. (It does not make the cursor blink.)

The same event type is returned for both activate and deactivate events. An application can distinguish between the two by checking the **Modify** field of the event record. For example:

```
MOVE  Modify,D0          ;retrieve Modify field
BTST  #activeFlag,D0     ;is activate bit set?
BEQ   DeActivate         ;bit is not set — event is deactivate
```

The instruction **BTST** (for Bit Test) is handy when you need to determine whether or not a specific bit has been set within a register. **activeFlag** is defined in the System equates file as 0, which corresponds to the bit position of the flag which

is set if an activate event really corresponds to activating a window, and cleared if it means the window was deactivated. **BTST** works by looking at the specified bit number in the specified register. If the bit is set, the zero flag in the status register will be set; if the bit is cleared, the zero flag will be cleared. Therefore, an activate event will set the zero flag and a deactivate event will clear it.

In an environment like the Video Tape Index where there is more than one text edit record, an application must also identify which of the text edit windows posted a given event. Remember that for activate events, the **Message** field of the event record will contain the pointer to the window posting the event. Therefore, you need only compare each window pointer in turn with **Message** to identify the correct window.

The actual activating and deactivating of text edit windows is very straightforward, requiring only the handle to the edit record:

PROCEDURE TEActivate (hTE: TEHandle);

PROCEDURE TEDeactivate (hTE: TEHandle);

Move the handle onto the stack and then call the routine.

The Video Tape Index program's subroutine for detecting which window has posted an activate event and properly handling that event, ActivateTextWindow, appears in Listing 9.1. The first step is to retrieve the pointer of the window involved from the event record. This occurs at (a) in Listing 9.1. The application also needs to determine whether the window should be activated or deactivated. Therefore, the modify word is also retrieved from the event record (b). As discussed above, the activate or deactivate decision is based on the value of bit 0 in the modify word. A **BTST** instruction (c) can be used to check the value of the appropriate bit, which is equated to the symbolic address of **activeFlag**. If **activeFlag** has been cleared, then the window should be deactivated (d). The application branches to a block of code that specifically handles deactivations (k).

Listing 9.1 Activating Text Edit Windows

```
        ActivateTextWindow
(a)         MOVE.L  Message,AØ          ;get pointer to window which posted event
(b)         MOVE    Modify,DØ
(c)         BTST    #activeFlag,DØ      ;activate bit set?
(d)         BEQ     DeActivate          ;if not set, window was deactivated

        Activate1
(e)         CMP.L   NameWindowPtr,AØ    ;name window event?
(f)         BNE     Activat 2
(g)         MOVE.L  NameTextHandle,-(SP)
(h)         _TEActivate
            BRA     Activate99

        Activate2
(i)         CMP.L   ProducerWindowPtr,AØ
            BNE     Activate3                                    (continued)
```

```
            MOVE.L  ProducerTextHandle,-(SP)
            _TEActivate
            BRA     Activate99

        Activate3
            CMP.L   DateWindowPtr,AØ
            BNE     Activate4
            MOVE.L  DateTextHandle,-(SP)
            _TEActivate
            BRA     Activate99

        Activate4
            CMP.L   RatingWindowPtr,AØ
            BNE     Activate5
            MOVE.L  RatingTextHandle,-(SP)
            _TEActivate
            BRA     Activate99

        Activate5
            CMP.L   NumberWindowPtr,AØ
            BNE     Activate6
            MOVE.L  NumberTextHandle,-(SP)
            _TEActivate
            BRA     Activate99

        Activate6
            CMP.L   AnnotationWindowPtr,AØ
            BNE     Activate98              ;not one of our text windows
            MOVE.L  AnnotationTextHandle,-(SP)
            _TEActivate

        Activate99
(j)         MOVE.L  Message,-(SP)           ;make this the current grafport
            _SetPort

        Activate98
            RTS

        DeActivate
(k)         CMP.L   NameWindowPtr,AØ
            BNE     DeActivate1
            MOVE.L  NameTextHandle,-(SP)
            _TeDeActivate
            RTS

        DeActivate1
            CMP.L   ProducerWindowPtr,AØ
            BNE     DeActivate2
            MOVE.L  ProducerTextHandle,-(SP)
            _TeDeActivate
            RTS

        DeActivate2
            CMP.L   DateWindowPtr,AØ
            BNE     DeActivate3
            MOVE.L  DateTextHandle,-(SP)
                    _TeDeActivate
            RTS
```

(continued)

Listing 9.1 (continued)

```
DeActivate3
        CMP.L  RatingWindowPtr,AØ
        BNE    DeActivate4
        MOVE.L  RatingTextHandle,-(SP)
        _TeDeActivate
        RTS

DeActivate4
        CMP.L  NumberWindowPtr,AØ
        BNE    DeActivate5
        MOVE.L  NumberTextHandle,-(SP)
        _TeDeActivate
        RTS

DeActivate5
        CMP.L  AnnotationWindowPtr,AØ
        BNE    DeActivate6              ;not a text window
        MOVE.L  AnnotationTextHandle,-(SP)
        _TeDeActivate
        RTS

DeActivate6
        RTS
```

Assuming that **activeFlag** has been set (the window should be activated), the application does not execute the branch at (d). Instead it continues processing with statement (e). This is where the code begins the somewhat tedious process of identifying exactly which text window posted the activate event. There is only one reliable way to do so. The pointer retrieved from the **message** field of the event record must be compared to the pointer for each text window used in the application. A match indicates that the proper window has been found. Why is this necessary? Because **TEActivate** requires the text edit handle associated with the window being activated; there is no way to activate the appropriate text edit window without knowing specifically which text edit handle should be placed on the stack. Therefore, the application, at (e), compares the pointer from **message** (stored in A0) with a pointer to one of the text edit windows. In this case, the program looks first at the window for the tape name, but the order in which the windows are processed is nonetheless arbitrary.

If a match between the two pointers is not found (f), the program must branch to check the next window (i). On the other hand, if the two pointers are the same, then the application can proceed to activate the window. Statement (g) places the appropriate text edit handle on the stack. The window is then activated with a call to **TEActivate** (h).

One final step remains in the activation process: the newly activated window must be made the current grafport. Otherwise, no drawing can be performed in the window. Therefore, a call to **SetPort** is performed at (i).

The entire procedure is repeated for each text edit window.

Deactivating the text edit windows, beginning at (k), is more or less the same as activating. The window involved must be identified by comparing its pointer to the pointer from **message** so that its text edit handle can be placed on the stack. The handle is placed on the stack followed by a call to **TeDeActivate**. Once the window is deactivated, the application can return to the main program, since no call to **SetPort** is required.

Getting a Blinking Cursor

The blinking cursor in a text edit window is controlled by **TEIdle**. Like the **SystemTask** routine that updates desk accessories, **TEIdle** must be called repeatedly. It should be a part of each event loop in an application. Like the activate and deactivate procedures, **TEIdle** requires only the handle to the edit record of the text edit window where the cursor should blink (i.e., this must be the handle of the currently active text edit window):

```
PROCEDURE TEIdle (hTE: TEHandle);
```

The fact that **TEIdle** requires the handle of the currently active text window presents a problem for applications where there is more than one text edit window, any of which might be active while the same event loop is controlling program action. To solve this problem, **TEIdle** can be called with a sort of "generic" text edit handle. The Video Tape Index, for example, has allocated additional space for a text edit handle called **ActiveTextHandle**. Whenever a text edit window is selected, its handle is moved into **ActiveTextHandle**, which is then passed to **TEIdle**. Therefore, all calls to **TEIdle** appear as:

```
MOVE.L      ActiveTextHandle, -(SP)
__TEIdle
```

Moving the Cursor (Setting the Selection Range)

A selection range is what is highlighted in inverse video when you drag the mouse across a range of text or shift-click to indicate everything between the cursor and the click. A selection range can also be a single spot if it simply refers to the position of the blinking cursor.

Text edit records identify the selection range by counting the characters in the text, beginning from the left; the first position is numbered 0. The range can be set by an application's response to mouse actions or by the application itself.

If an application returns a mouse down event in an active text edit window, then the program can assume that the selection range needs to be moved. As you remember, a call to **FrontWindow** will return a pointer to the currently active

window. If this is the same as the pointer returned by **FindWindow**, then indeed the mouse down event occurred in the active window and the selection range should be adjusted.

TEClick takes care of positioning the selection range. It will move the straight-line cursor as well as highlight text and can handle extended selection ranges indicated by shift-click actions. **TEClick** needs to know where the mouse down event occurred, whether to process shift-click actions, and the text edit handle:

```
PROCEDURE TEClick (pt: Point; extend: BOOLEAN;
    hTE: TEHandle);
```

Point is from the event record. If **extend** is true, a shift-click will be processed; if extend is false, the cursor will simply be repositioned, regardless of whether the shift key was held down. Therefore, an application must check the **Modify** field of the event record prior to calling **TEClick** to determine what value to give the **extend** boolean. The final parameter is simply the handle to the text edit record whose window posted the mouse down event.

There is one catch here — the **Point** field from the event record returns the position of the mouse down event in global coordinates; **TEClick** requires that they be expressed in the local coordinates of the current grafport (i.e., those of the currently active text edit window). Therefore, before an application can call **TEClick**, the mouse coordinates must be converted to the local coordinate system.

As discussed previously, the QuickDraw routine **GlobalToLocal** will take care of the conversion:

```
PROCEDURE GlobalToLocal (VAR pt: Point);
```

Point is passed into the routine as global coordinates and is returned in local coordinates. (As you might expect, there is also a **LocalToGlobal** routine.)

The code for handling selection range movement using the mouse is therefore:

```
PEA         Point                ;push address so changed values can
                                 return
_GlobalToLocal
MOVE.L      Point,-(SP)          ;coordinates are now local
BTST        #shiftKey,Modify     ;was shift key pressed?
SNE         D0                   ;set true if shift key was held down
MOVE.B      D0,-(SP)             ;moving byte puts boolean in high order
                                 byte — system automatically pushes
                                 extra byte to keep stack pointer on
                                 even word boundary
MOVE.L      ActiveTextHandle,-(SP)
_TEClick
```

Note that the quantity **shiftKey** refers to the bit in the **Modify** field that is set when the shift key is held down during a mouse down or key down event.

The second way to control the selection range is to explicitly set it within the application itself. The routine **TESetSelect** will do just that:

```
PROCEDURE TESetSelect (selStart, selEnd: LONGINTEGER;
hTE: TEHandle);
```

selStart refers to the position to which the start of the selection range should be set. To set it to the first position, it should take a value of 0 since character positions are, as mentioned above, numbered from the left beginning with 0. **selEnd** refers to the character position which should be the right-most edge of the selection range. The routine also requires the handle to the text edit record.

Why might an application need to set its own selection range? Consider the situation where an application must clear all the text from a text edit record without deleting the record itself since it will be used again. It makes sense to select all the text and then "cut" it out. (Implementing "cut" is discussed below.) The start of the selection range would therefore be set to 0 and its end to the length of the text or the last possible character position allowed by the view and destination rectangles. If the end of the selection range given in the procedure call is beyond the last character actually present, it will be modified to correspond to the position of that last character. To select all the text in the Producer text edit record (a 20 character field), the Video Tape Index uses:

```
MOVE.L      #0, – (SP)      ;starting position
MOVE.L      #20, – (SP)     ;ending position
MOVE.L      ProducerTextHandle, – (SP)
__TESetSelect
```

If you look at the environment in which the Video Tape Index does this selection range assignment (see Listing 9.3, discussed later in this chapter), you'll notice that the sequence of events includes first selecting the window and then setting the grafport. TextEdit routines are very sensitive about grafports. To be safe, whenever preparing to call a TextEdit routine, be certain to set the correct grafport prior to making the call to TextEdit.

Inserting Characters into Text Edit Records

Just as selection ranges can be manipulated by the mouse or explicitly from within an application, characters can also be accepted from the keyboard or inserted into a text edit record by an application itself.

If an application detects a key down event without an accompanying press of the cloverleaf key, then the key press represents a character to be inserted into a

text edit record and displayed on the screen. The routine which actually inserts the character is **TEKey**:

```
PROCEDURE TEKey (key: CHAR; hTE: TEHandle);
```

The character that was pressed is available in the low-order word of the event record's **Message** field (i.e., **Message + 2**, just as used when identifying the key pressed in conjunction with the cloverleaf key). The second parameter is a handle to the currently active text edit record. **TEKey** inserts the key pressed into the text edit record and displays the character on the screen. It also removes characters that are deleted by the backspace key. To call it, use something like:

```
MOVE        Message+2,-(SP)     ;character that was pressed
MOVE.L      ActiveTextHandle,-(SP)
_TEKey
```

An application can do its own text insertion and display with **TEInsert**:

```
PROCEDURE TEInsert (text: Ptr; length: LONGINT;
   hTE: TEHandle);
```

The text specified by **text** (a pointer to where the text to be inserted is stored) will be inserted into the text edit record and drawn on the screen to the left of the current selection range. The **length** parameter contains the number of characters to be inserted.

The Video Tape Index uses this technique to display a record which has been retrieved using any of its three search strategies: printing all records sequentially; doing a binary search on a tape name; doing a sequential search on producer, date, rating, or tape number. The subroutine that performs the display, DisplayOneRecord, appears in Listing 9.2.

The subroutine first removes any previous text stored in the text edit windows (a). This procedure (Listing 9.3) is discussed in detail later in this chapter. The next three statements, beginning with (b), take the number for the record being displayed (stored in **RecordCounter**) and compute a byte offset into **TapeArray**. This offset locates the start of the record whose data will be inserted into the text edit records.

Each text edit record must be handled separately. Since **TEInsert** displays characters as well as inserting them into the text edit record, the first step is to make the appropriate text edit window the current grafport with a call to **SetPort**. This occurs at (c) for the tape name window only.

The subroutine then prepares for the call to **TEInsert**. The first parameter is the starting address of the text that is to be inserted into the text edit record. That address is the sum of three things: the starting address of **TapeArray** (d), the byte offset into **TapeArray** that locates the start of the record (e), and an offset into the record for the field whose contents are being inserted.

Listing 9.2 Inserting Text Directly into Text Edit Records

```
        DisplayOneRecord
(a)             JSR     DisplayWindows          ;clears out text edit records (Listing 9.3)
(b)             LEA     RecordCounter,AØ
                MOVE    (AØ),D5
                MULU    #64,D5

                MOVE.L  NameWindowPtr,-(SP)
(c)             _SetPort
(d)             LEA     TapeArray(A5),AØ
(e)             ADD     D5,AØ
(f)             MOVE.L  AØ,-(SP)                ;pointer to text
(g)             MOVE.L  #3Ø,-(SP)               ;# of characters to get
(h)             MOVE.L  NameTextHandle,-(SP)    ;edit record which will get characters
(i)             _TEInsert                       ;incorporate text into record

                MOVE.L  ProducerWindowPtr,-(SP)
                _SetPort
                LEA     TapeArray(A5),AØ
                ADD     D5,AØ
(j)             ADD.L   #oProducer,AØ
                MOVE.L  AØ,-(SP)
                MOVE.L  #2Ø,-(SP)
                MOVE.L  ProducerTextHandle,-(SP)
                _TEInsert

                MOVE.L  DateWindowPtr,-(SP)
                _SetPort
                LEA     TapeArray(A5),AØ
                ADD     D5,AØ
                ADD.L   #oReleaseDate,AØ
                MOVE.L  AØ,-(SP)
                MOVE.L  #4,-(SP)
                MOVE.L  DateTextHandle,-(SP)
                _TEInsert

                MOVE.L  RatingWindowPtr,-(SP)
                _SetPort
                LEA     TapeArray(A5),AØ
                ADD     D5,AØ
                ADD.L   #oRating,AØ
                MOVE.L  AØ,-(SP)
                MOVE.L  #4,-(SP)
                MOVE.L  RatingTextHandle,-(SP)
                _TEInsert

                MOVE.L  NumberWindowPtr,-(SP)
                _SetPort
                LEA     TapeArray(A5),AØ
                ADD     D5,AØ
                ADD.L   #oTapeNumber,AØ
                MOVE.L  AØ,-(SP)
                MOVE.L  #4,-(SP)
                MOVE.L  NumberTextHandle,-(SP)
                _TEInsert

                RTS
```

The name of the tape has an offset of 0, since it is the first field in the record and therefore needn't be considered when dealing with the tape name. Note, however, that for the other fields, the offset is included in the address computation. For example, look at statement (j), which adds the offset for the producer's name to the address in A0.

Once the starting address of the source text is computed, it is pushed onto the stack (f). That address is followed by the number of bytes which should be inserted (g) and the handle to the appropriate text edit record (h). The process is completed by calling **TEInsert** (i).

This sequence of events is repeated for each text edit window except the annotation window. Since annotations are kept on disk in a direct access file and only brought into memory as needed, annotation display is handled separately.

Editing Text: Cut, Copy, Paste, and Delete (Clear)

Those text editing functions for which the Macintosh is famous are surprisingly easy to implement. Cut, copy, paste, and delete (called "clear" in the Edit menu) each base their actions on the current selection range of a given text edit record. As discussed above, the placement of that selection range is controlled by either **TEClick** or **TESetSelect**.

If an application detects the "cut" command (through either a cloverleaf-X key press or a mouse down event in the Edit menu), it should call **TECut**:

PROCEDURE TECut (hTE: TEHandle);

The text in the current selection range will be deleted from the text edit record and copied to the Clipboard. The text will be removed from the screen and the rest of the text adjusted to compensate for the characters that were deleted.

If an application needs to remove text without copying it to the Clipboard, it can use **TEDelete** instead of **TECut**:

PROCEDURE TEDelete (hTE: TEHandle);

On the other hand, to get text onto the Clipboard without deleting it from the text edit record, use **TECopy**:

PROCEDURE TECopy (hTE: TEHandle);

Pasting from the Clipboard into a text edit record is similarly straightforward:

PROCEDURE TEPaste (hTE: TEHandle);

TEPaste takes whatever is on the Clipboard and inserts it into the text edit record just before the current insertion point. The screen display is adjusted to compensate for the new text. Pasting does not, by the way, disturb the contents of the

Clipboard. Only a Cut or Copy operation will do that. An application, therefore, can repeatedly paste the same text into a text edit record until such time as another Cut or Copy is executed.

The Video Tape Index uses the Cut function to clear out its text edit records. Whenever it becomes necessary to remove all characters from both the text entry windows and the text edit records, the program executes the following sequence of steps:

1. Select a window (**SelectWindow**)
2. Make it the current grafport (**SetPort**)
3. Select the selection range to the maximum number of characters that will be stored in this text edit record (**TESetSelect**)
4. Cut the text (**TECut**)

The procedure outlined above is used in the Video Tape Index's subroutine DisplayWindows (Listing 9.3). DisplayWindows selects each text edit window in turn, which brings it in front of the main window. It also cuts out any text that might be stored in the text edit records, so that the windows are empty when they appear. As with the other subroutines that deal with the text edit records, DisplayWindows must handle each text edit window separately, repeating the same sequence for every window. DisplayWindows returns with the tape name window active.

The first step is to select the window (a) and to then make it the current grafport (b). At that point, any existing text in the text edit record must be removed . In order to make **TECut** operate on all characters that are present, the subroutine first sets the selection range to encompass the maximum numbers of characters that can appear in the specific field. It begins the selection range at the first character position (c) and ends it at the last possible character position (d). Note that this will not cause any problems if there are less than the maximum number of characters in the text edit record, since **TESetSelect** will automatically adjust the ending position to the last character actually present. After placing the appropriate text edit handle on the stack (e), a call is made to **TESetSelect** (f). The contents of the text edit record can then be removed with **TECut** (g).

The steps illustrated by statements (a) through (g) are repeated for each of the text edit windows. If you are looking at Listing 9.3, however, you will see that a number of other things happen in DisplayWindows. These are the direct result of the calls made to **SelectWindow**.

SelectWindow not only brings a window to the front, but it also highlights that window. For the name, producer, rating, date, and number windows, highlighting is unimportant since their windows are simply outlined rectangles. But the annotation window is a standard document window with a title bar. **SelectWindow** will highlight it and leave it highlighted. Since the annotation window will not be the active window when DisplayWindows returns, it should not be highlighted. Therefore, the three statements beginning at (h) issue a call to **HiliteWindow** to remove the highlighting.

Listing 9.3 Setting a Text Edit Selection Range from within an Application

```
DisplayWindows
        MOVE.L  AnnotationWindowPtr,-(SP)
(a)     _SelectWindow
        MOVE.L  AnnotationWindowPtr,-(SP)
(b)     _SetPort
(c)     MOVE.L  #Ø,-(SP)
(d)     MOVE.L  #255,-(SP)
(e)     MOVE.L  AnnotationTextHandle,-(SP)
(f)     _TESetSelect            ;select all the text in the window
        MOVE.L  AnnotationTextHandle,-(SP)
(g)     _TECut                  ;cut out text from previous use

        MOVE.L  AnnotationWindowPtr,-(SP)
        SF      -(SP)
(h)     _HiliteWindow           ;get rid of highlighting in this window

        MOVE.L  NumberWindowPtr,-(SP)
        _SelectWindow
        MOVE.L  NumberWindowPtr,-(SP)
        _SetPort
        MOVE.L  #Ø,-(SP)
        MOVE.L  2Ø,-(SP)
        MOVE.L  NumberTextHandle,-(SP)
        _TESetSelect
        MOVE.L  NumberTextHandle,-(SP)
        _TECut

        MOVE.L  RatingWindowPtr,-(SP)
        _SelectWindow
        MOVE.L  RatingWindowPtr,-(SP)
        _SetPort
        MOVE.L  #Ø,-(SP)
        MOVE.L  #4,-(SP)
        MOVE.L  RatingTextHandle,-(SP)
        _TESetSelect
        MOVE.L  RatingTextHandle,-(SP)
        _TECut

        MOVE.L  DateWindowPtr,-(SP)
        _SelectWindow
        MOVE.L  DateWindowPtr,-(SP)
        _SetPort
        MOVE.L  #Ø,-(SP)
        MOVE.L  #5,-(SP)
        MOVE.L  DateTextHandle,-(SP)
        _TESetSelect
        MOVE.L  DateTextHandle,-(SP)
        _TECut

        MOVE.L  ProducerWindowPtr,-(SP)
        _SelectWindow
        MOVE.L  ProducerWindowPtr,-(SP)
        _SetPort
        MOVE.L  #Ø,-(SP)
        MOVE.L  #22,-(SP)
        MOVE.L  ProducerTextHandle,-(SP)
```

(continued)

```
                _TESetSelect
                MOVE.L  ProducerTextHandle,-(SP)
                _TECut

(i)             MOVE.L  $ØØØØØ1ØØ,DØ          ;mask to remove activate events
(j)             _FlushEvents

                MOVE.L  NameWindowPtr,-(SP)
                _SelectWindow                  ;name window is activated at start
                MOVE.L  NameWindowPtr,-(SP)
                _SetPort
                MOVE.L  #Ø,-(SP)
                MOVE.L  #32,-(SP)
                MOVE.L  NameTextHandle,-(SP)
                _TESetSelect
                MOVE.L  NameTextHandle,-(SP)
                _TECut

(k)             LEA     ActiveTextHandle,AØ
                MOVE.L  NameTextHandle,(AØ)    ;for TEIdle

                RTS
```

SelectWindow also generates two activate events each time it is called: one for the window being activated and one for the window being deactivated. The activate events from DisplayWindows are in some sense spurious; they do not correspond to any real need to activate or deactivate text edit windows. Their presence will confuse an event loop. Therefore, before dealing with the tape name window, which will be active when the subroutine ends, those extra activate events should be removed. A special mask is created to identify only activate events (i) and then used for a call to **FlushEvents** (j). This will remove those activate events before they can be processed by an event loop.

Since the tape name window will be active when DisplayWindows returns, **TEIdle** should have the handle to the name text edit record. Therefore, the name text edit handle is loaded into the generic text handle just before the subroutine finishes (j).

There is, by the way, an alternative way to delete the text in a text edit record – simply dispose of the entire record. The routine **TEDispose** (it requires only the handle to the text edit record as a parameter) removes the text edit record from memory. It would certainly be possible to dispose and then reallocate the text edit records each time the Video Tape Index finished with a given record. Doing so, however, requires more code than emptying the text edit record by cutting out its entire contents.

Displaying Static Text

In some cases it may be necessary to display text that won't be changed. For example, the Video Tape Index prints the name of the field to the left of each text edit window (see Figure 9.1). These prompts are essential; otherwise the user will

have no idea what information should be entered in each text window. Nonetheless, there is no need to change those prompts once they are printed.

The prompts for the TapeArray fields are printed on the main window. They could have been printed with **DrawString**, the ToolBox routine used in the Sample program to display text. To use **DrawString** an application must first move the cursor to the coordinates where printing should begin. **DrawString** then prints the characters, moving the cursor from left to right. This can be somewhat awkward, especially when the text needs to be justified (e.g., note that the Video Tape Index prompts are printed in a proportional type font which is lined up along the right hand side).

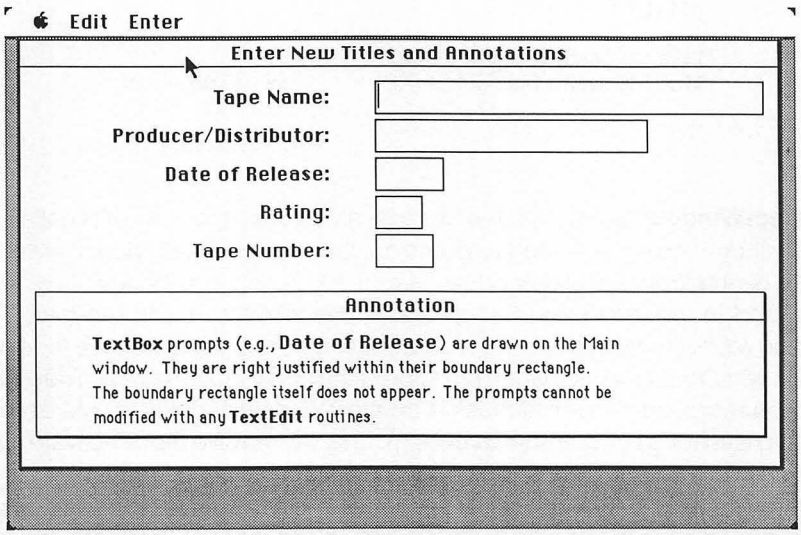


Figure 9.1 Displaying Static Text

TextEdit provides an alternative for printing static text with the **TextBox** routine. **TextBox** prints a string of text inside a rectangle expressed in the local coordinates of the current grafport. The rectangle has no visible borders, nor is any text edit record created. The routine also allows an application to specify text justification within the rectangle (left, right, or centered). The format of the call is:

PROCEDURE TextBox (text: Ptr; length: LONGINTEGER;
box: Rect; just: INTEGER)

As with anything else that requires placing coordinates on the Macintosh screen, using **textBox** requires a bit of planning. For example, since the Video Tape Index will print its prompts on the main window, the coordinates of the

rectangles in which the prompts will be printed must be expressed in terms of that main window (upper left-hand corner becomes 0,0 and lower right-hand corner becomes 240,490). To keep things simple, the windows for each prompt are the same size (11 pixels high and 191 pixels wide). The height is dictated by the size of the text; if a window is to display 12-point text, it must be a minimum of 10 pixels high. The width obviously depends on the maximum number of characters that will be printed. Establishing the exact placement of each rectangle nonetheless requires a bit of trial and error.

The parameter **just** is an integer that indicates how the text should be justified within its rectangle. A value of 0 will left-justify the text, 1 will center it, and −1 will right-justify. **length** is the number of characters to print, and **text** is a pointer to the text to be printed.

Consider as an example the code that displays the prompt for the Date text entry window:

```
PEA       StringConstant      ;pointer to string
MOVE.L    #17,-(SP)           ;number of characters to print
PEA       DatePromptBox       ;rectangle where text should go
MOVE      #-1,-(SP)           ;right justify the text
__TextBox
```

Two things must have occurred before the above code will function properly. First, the main window must be the current grafport (through a call to **SetPort**). Secondly, the rectangle **DatePromptBox** must have been defined. For example:

```
DatePromptBox  DC  62,10,82,200
```

It is also important to be sure that the string passed to **TextBox** has the data type Str255 (i.e., its first byte is a length byte). The easiest way to do so is to allocate space for the string with **DC**. For example:

```
StringConstant  DC  'Date of Release'
```

The subroutine that displays the Video Tape Index's prompts, DisplayPrompts, appears in Listing 9.4. DisplayPrompts first establishes the font that should be used when the prompts are drawn (a). Setting the text font is discussed a bit further on in this chapter. Then, the **TextBox** sequence is repeated for each of the text edit windows that occupy plain document boxes (i.e., all but the annotation window). The text of the prompts have all been established as constants with **DC**, ensuring that they will be assembled with a length byte. The first step (b), is to push a pointer to the title string onto the stack. That pointer is followed by the number of characters in the string (c), a pointer to the rectangle in which the text should be printed (d), and the text justification (d). The text is actually printed with the call to **TextBox** (e).

Listing 9.4 Using TextBox to Display Static Text

```
DisplayPrompts
        MOVE  #sysFont,-(SP)
(a)     _TextFont

(b)     PEA     NameTitle               ;text to print
(c)     MOVE.L  #11,-(SP)               ;number of characters to print
(d)     PEA     NamePromptBox           ;rectangle where text should be printed
(e)     MOVE    #-1,-(SP)               ;to right justify text
        _TextBox

        PEA     ProducerTitle
        MOVE.L  #22,-(SP)
        PEA     ProducerPromptBox
        MOVE    #-1,-(SP)
        _TextBox

        PEA     DateTitle
        MOVE.L  #17,-(SP)
        PEA     DatePromptBox
        MOVE    #-1,-(SP)
        _TextBox

        PEA     RatingTitle
        MOVE.L  #8,-(SP)
        PEA     RatingPromptBox
        MOVE    #-1,-(SP)
        _TextBox

        PEA     NumberTitle
        MOVE.L  #13,-(SP)
        PEA     NumberPromptBox
        MOVE    #-1,-(SP)
        _TextBox

        RTS


NamePromptBox       DC      12,1Ø,32,2ØØ
NameTitle           DC      'Tape Name:'
ProducerPromptBox   DC      37,1Ø,57,2ØØ
ProducerTitle       DC      'Producer/Distributor:'
DatePromptBox       DC      62,1Ø,82,2ØØ
DateTitle           DC      'Date of Release:'
RatingPromptBox     DC      87,1Ø,1Ø7,2ØØ
RatingTitle         DC      'Rating:'
NumberPromptBox     DC      112,1Ø,132,2ØØ
NumberTitle         DC      'Tape Number:'
```

Updating Text Edit Windows

TextEdit has its own routine for updating text edit windows. Whenever an update event is detected in a text edit window, an application should execute the following sequence of steps:

1. Call **BeginUpdate**
2. Call **EraseRect** (this ensures that when the window is deactivated, the cursor will disappear)
3. Call the special TextEdit routine **TEUpdate** (discussed below)
4. Call **EndUpdate**

TEUpdate redraws the text specified by a rectangle parameter:

PROCEDURE TEUpdate (rUpdate: Rect; hTE: TEHandle);

Generally, the text edit window's view rectangle is used for the **rUpdate** parameter. It is also important to remember that the text edit window referred to by **TEHandle** must be the current grafport in order for **TEUpdate** to work properly.

The Event Manager will return update events only for an active window. If an application has windows which are visible but not active, any changes in their contents will not be reported. For example, consider the Video Tape Index's text entry screen (e.g., Figure 9.1). Only one text entry window is active at any given time, yet it is possible to use a desk accessory that will overlay, and therefore erase portions of, windows that are not active. Therefore, it may not always suffice to update just the window reporting the update event.

The Video Tape Index handles updating text windows with the subroutine UpdateTextWindows (Listing 9.5). Whenever an update event is detected, the program erases and redraws the contents of all windows.

The main window, because it is not a text edit window, is handled a bit differently from the text edit windows. As with all updates, the process begins with a call to **BeginUpdate** (a). To ensure that all routines which affect the screen will function properly, it is then made the current grafport using **SetPort** (b). UpdateTextWindows then erases the main window's contents (**EraseRect** at (c)). The window's contents are redrawn by the subroutine DisplayPrompts from Listing 9.3 (d). As mentioned earlier, it is usually easier to erase and completely redraw a window's contents than it is to merely redraw the specific portion that has been disturbed by some other program action. The update is completed by calling **EndUpdate** (e).

Updates for the text edit windows begin in the same manner as updates to the main window – calling **BeginUpdate** (f), setting the grafport (g), and erasing the window (h). Redrawing the window's contents, however, is where the difference lies. **TEUpdate** will take care of redrawing the text. That routine requires that the text window's view rectangle (i) and its text handle (j) be placed on the stack before making the call (k). As usual, the update ends with **EndUpdate** (l).

Listing 9.5 Updating Multiple Windows

```
        UpdateTextWindows
                MOVE.L      MainWindowPtr,-(SP)
(a)             _BeginUpdate
                MOVE.L      MainWindowPtr,-(SP)
(b)             _SetPort
                PEA         MainWindowRect
(c)             _EraseRect
(d)             JSR         DisplayPrompts      ;re-draw window's contents
                MOVE.L      MainWindowPtr,-(SP)
(e)             _EndUpdate

                MOVE.L      NameWindowPtr,-(SP)
(f)             _BeginUpdate
                MOVE.L      NameWindowPtr,-(SP)
(g)             _SetPort
                PEA         NameViewRect
(h)             _EraseRect
(i)             PEA         NameViewRect
(j)             MOVE.L      NameTextHandle,-(SP)
(k)             _TEUpdate
                MOVE.L      NameWindowPtr,-(SP)
(l)             _EndUpdate

                MOVE.L      ProducerWindowPtr,-(SP)
                _BeginUpdate
                MOVE.L      ProducerWindowPtr,-(SP)
                _SetPort
                PEA         ProducerViewRect
                _EraseRect
                PEA         ProducerViewRect
                MOVE.L      ProducerTextHandle,-(SP)
                _TEUpdate
                MOVE.L      ProducerWindowPtr,-(SP)
                _EndUpdate

                MOVE.L      DateWindowPtr,-(SP)
                _BeginUpdate
                MOVE.L      DateWindowPtr,-(SP)
                _SetPort
                PEA         DateViewRect
                _EraseRect
                PEA         DateViewRect
                MOVE.L      DateTextHandle,-(SP)
                _TEUpdate
                MOVE.L      DateWindowPtr,-(SP)
                _EndUpdate
```

(continued)

```
MOVE.L      RatingWindowPtr,-(SP)
_BeginUpdate
MOVE.L      RatingWindowPtr,-(SP)
_SetPort
PEA         RatingViewRect
_Erase Rect
PEA         RatingViewRect
MOVE.L      RatingTextHandle,-(SP)
_TEUpdate
MOVE.L      RatingWindowPtr,-(SP)
_EndUpdate

MOVE.L      NumberWindowPtr,-(SP)
_BeginUpdate
MOVE.L      NumberWindowPtr,-(SP)
_SetPort
PEA         NumberViewRect
_EraseRect
PEA         NumberViewRect
MOVE.L      NumberTextHandle,-(SP)
_TEUpdate
MOVE.L      NumberWindowPtr,-(SP)
_EndUpdate

MOVE.L      AnnotationWindowPtr,-(SP)
_BeginUpdate
MOVE.L      AnnotationWindowPtr,-(SP)
_SetPort
PEA         AnnotationViewRect
_EraseRect
PEA         AnnotationViewRect
MOVE.L      AnnotationTextHandle,-(SP)
_TEUpdate
MOVE.L      AnnotationWindowPtr,-(SP)
_EndUpdate

RTS
```

Changing Fonts and Font Characteristics

One of the things that always excites new users about the Macintosh is its ability to manipulate multiple fonts with varying characteristics within a single text window. The three routines that manage those features are part of QuickDraw.

TextFont takes care of setting the font itself:

PROCEDURE TextFont (font: INTEGER);

Each font is identified by a font number. Equates for the standard release fonts are included in the QuickDraw equates file. The system font (Chicago), for example, has an ID of 0, while NewYork is 2 and London is 6. The address assigned to the standard release fonts appear in Table 9.1.

Table 9.1 Symbolic Addresses Assigned to Standard Release Fonts

Symbolic Address/ Font Name	Font Number
sysFont (Chicago)	Ø
applFont (Geneva)	1
newYork	2
geneva	3
monaco	4
venice	5
london	6
athens	7
sanFran	8
toronto	9
cairo	1Ø
losangel	11

To change the font, push the font ID number onto the stack and call the routine:

```
MOVE   #venice, – (SP)        ;pushes a 5
__TextFont
```

It is important to remember that **TextFont** only affects the current grafport and must therefore be repeated whenever the grafport changes to another window.

The style of a font (boldface, italic, underlined, outlined, shadowed, etc.) is controlled by **TextFace**:

```
PROCEDURE TextFace (face: Style);
```

The actual style of the font is determine by the style word that is supplied as a parameter to the routine. Bits in the style word represent one type of text face (see Figure 9.2). For example, if bit 0 is set, text will be displayed in boldface. If bit 2 is set, the text will be underlined. If both bits 0 and 2 are set, the text will be both boldface and underlined. To create bold and underlined text, use:

```
MOVE          #5, – (SP)      ;the 5 = 0000 0000 0000 0101
__TextFace
```

To return to normal text, use a style word of 0.

Like **TextFont**, **TextFace** also affects only the current grafport.

TextSize manipulates the size of the text in the current grafport:

```
PROCEDURE TextSize (size: INTEGER);
```

The size of the text is expressed in points, just seen in standard Style menus. Though an application can select virtually any size for any font, the text will look

best if it is expressed in a size that exists in the system. The following instructions will establish a text size of 14 points:

```
MOVE        #14,-(SP)
__TextSize
```

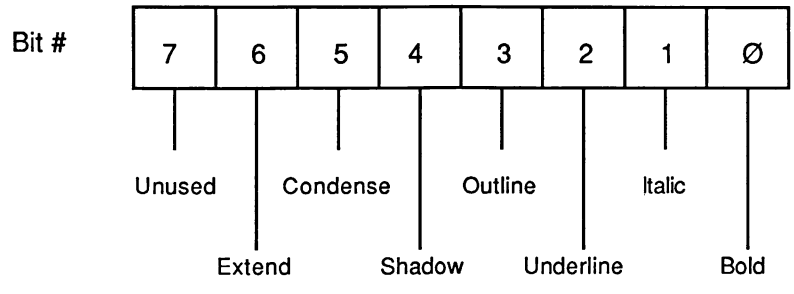
Text justification is handled by the routine **TESetJust**:

```
PROCEDURE TESetJust (just: INTEGER; h: TEHandle);
```

just is one of the three numbers used to specify justification for **TextBox**: 0 to left-justify, 1 for centered text, and −1 for right-justification. **h** is a handle to a text edit record containing the text to be justified. For example, to center text you might code:

```
MOVE        #0,-(SP)
MOVE.L      SomeTextHandle(A5),-(SP)
__TESetJust
```

TESetJust does not affect the text as it is displayed on the screen, only as it is stored in the text edit record. Therefore, to change the justification of the text on the screen, execute a complete update sequence that will erase the text edit window and redraw its contents with the new justification immediately after calling **TESetJust**.



To select any font style, set the appropriate bit in the style word. The styles are additive. For example, to get outlined boldface text set bits Ø and 2.

Figure 9.2 The Style Word Used by TextFont

Scrolling Text

Applications which permit the entry of large text documents will need to scroll text within text entry windows. Scrolling activities are implemented whenever the user clicks the mouse button somewhere in a scroll bar, or when the text being entered goes below the bottom edge of the view rectangle.

How far the text should be scrolled depends on what initiated the scrolling action. A single click in an up or down arrow will scroll the text one line. A click in a right or left arrow will scroll the text a character or two. A click in a page up or page down region will move text one "page" (generally one window full). On the other hand, if the user drags the thumb of a scroll bar, the amount to scroll will be proportional to the movement of the thumb.

Scrolling is implemented by a single TextEdit routine:

PROCEDURE TEScroll (dh,dv: INTEGER; hTE: TEHandle);

dh and **dv** are expressed in pixels. They specify how far the text should be scrolled. If both values are positive, **dh** refers to the number of pixels to scroll to the right and **dv** refers to the number of pixels to scroll down. If the values are negative, **dh** indicates the number of pixels to scroll left and **dv** the number of pixels to scroll up.

The height, in pixels, of a single line of text is contained in the text edit record in the field **lineHeight**. This parameter always reflects the current spacing (e.g., single or double spaced). Therefore, once an application determines the number of lines to scroll up or down, the number of pixels can be obtained by multiplying the number of lines to scroll by the number of pixels per line. For example, the following code will scroll text three lines down:

```
MOVE      #3,NumLines(A5)          ;# of lines to scroll

MOVE.L    TextEditHandle,A0        ;handle to TE record
MOVE.L    (A0),A0                  ;get pointer
MOVE      lineHeight(A0),D0        ;retrieve height of line
MULU      NumLines(A5),D0          ;total number of pixels

MOVE      #0,-(SP)                 ;don't move to the right
MOVE      D0,-(SP)                 ;pixels down
MOVE.L    TextEditHandle,-(SP)     ;handle to TE record
_TEScroll
;application must now update the text edit window
```

In terms of figuring out which way to scroll, remember that when a user clicks the up arrow of a vertical scroll bar, the text should move *down*. By the same token, a click in the down arrow will scroll the text *up*. The same is true of thumb movement — if the thumb moves up, the text should move down; if the thumb moves down, the text should move up.

How far does text move when a thumb is dragged? Consider the situation where a scroll bar has a minimum of 0 and a maximum of 10. If the thumb is moved to the middle of the scroll bar, it will have a value of 5. The text should therefore be scrolled to the middle of document, regardless of the length of the document. If the thumb has a value of 2, the text should be scrolled 20% from the beginning of the document.

Left to right scrolling is usually more rigidly controlled than up and down scrolling. Most text processing applications assign a fixed maximum width to a document. For example, Microsoft Word limits the user to an 8 1/2-inch-wide page, even though margins can be set at will. ThinkTank 512 also limits the user to an 8-1/2-inch line. Therefore, the amount of scrolling that a single click in a left or right arrow will produce does not depend on the size of the font in use, but is a fixed interval based on the maximum width of the document. Dragging the thumb of the horizontal scroll bar is also proportional to the maximum fixed width of the document.

Controlling Program Actions with Alert and Dialog Boxes

Dialog boxes appear whenever a program needs information from the user in order to proceed. Alert boxes generally appear to warn the user that an error has occurred or that the potential to commit some error exists.

As discussed in Chapter 1, there are two types of dialog boxes — modal and modeless. Modal dialog boxes restrict the user to working within the dialog box. For example, consider the dialog box that appears when you select the **PRINT** option from a standard File menu (Figure 9.3). Until you either click the OK button with the mouse or hit the ENTER key, the only actions possible are changing the print parameters displayed by the dialog box.

Modeless dialog boxes are more like regular document windows. Their presence on the screen does not prevent the user from performing other activities. The most common example of a modeless dialog box is the window that appears when **FIND** is selected from a Search menu (Figure 1.12). The user can work in the **FIND** box, deactivate it by clicking on another visible window, work in another active window, and later reactivate the dialog box without ever removing it from the screen.

Alert boxes are more like modal dialog boxes. They, too, freeze program action until the user responds to the alert. But while modal dialog boxes are used whenever the program needs information, alert boxes signal errors or warnings.

Dialog and alert boxes are handled by the Dialog Manager. To properly set up an application for calls to the Dialog Manager, include a call to **InitDialogs** in the initialization portion of the program. **InitDialogs** takes one parameter — a pointer

to whatever routine should be started whenever a system error occurs and the system must be restarted. The pointer should either restart the current application or be 0:

```
CLR.L -(SP)          ;no restart procedure
_InitDialogs
```

The call to **InitDialogs** can be the last initialization in the sequence.

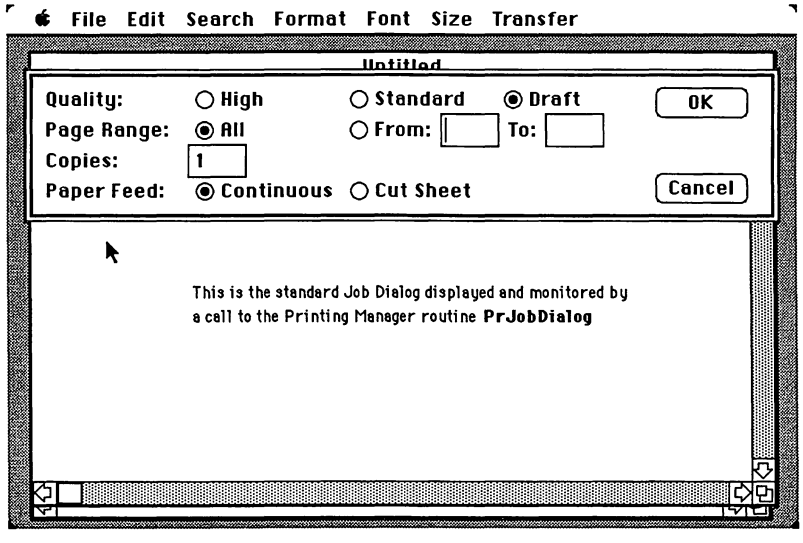


Figure 9.3 Standard Job Dialog

Defining Dialog and Alert Boxes

Dialog and alert boxes, like other windows, are defined in resource files. Though there are routines for defining them completely within an application, it is many times easier to use a resource file. Like other windows, the boundaries of dialog and alert boxes are rectangles expressed in global coordinates. In many cases, dialog boxes appear centered on the screen just below the menu bar; this is the position in which the standard Macintosh user interface guidelines expects them to appear.

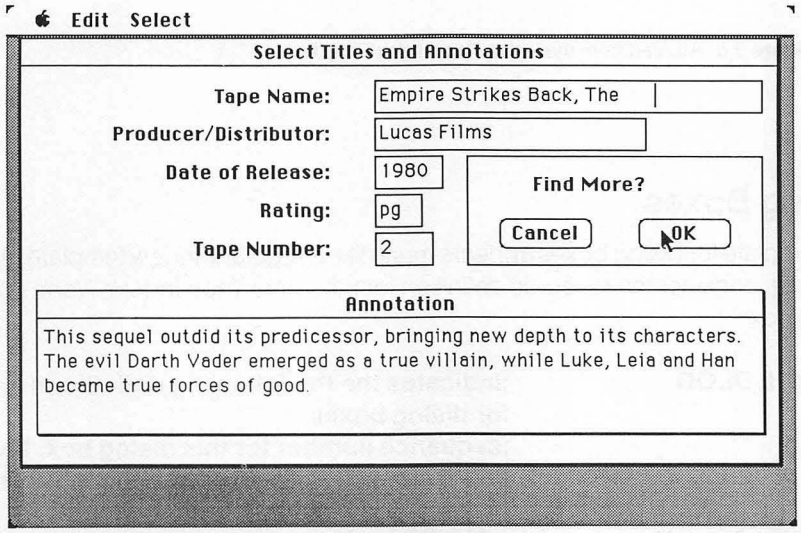
The Video Tape Index uses modal dialog boxes to control the progress of a search. Since only one record can be displayed at any one time, there must be

some mechanism to "freeze" the program, leaving that record on the screen until the user is ready to proceed. Therefore, rather than overlaying the text windows, the dialog boxes appear in the lower right-hand corner of the screen, just above the annotation window (see Figure 9.4).

Note that this technique of using modal dialog boxes to freeze program execution until the user is ready to go on is very much like using a dummy input sequence in a Pascal program. The Pascal statements:

```
write ('Hit <CR> to continue:');
readln (Dummy);
```

have the same effect as using a modal dialog box, since in either case the program will not resume execution until the user responds.



The "Find More?" dialog box freezes program action until the user clicks the mouse button with the cursor in either the OK or Cancel button.

Figure 9.4 Using a Dialog Box to Freeze Program Action

The Video Tape Index uses an alert box whenever a search has been chosen from a menu but no search criteria has been entered. This box also appears in the lower right-hand side of the screen above the annotation window (see Figure 9.5).

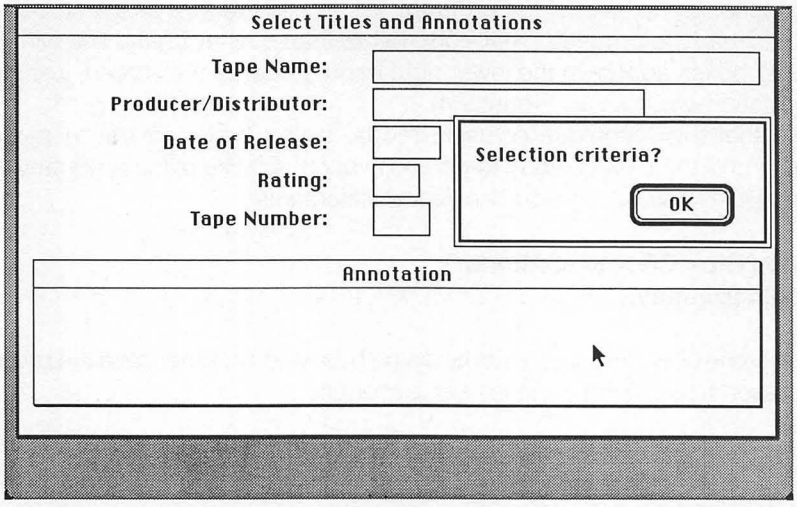


Figure 9.5 An Alert from the Video Tape Index Program

Dialog Boxes

The template for dialog boxes appears much like a regular window template. As an example, consider the resource definition for the Video Tape Index's *None Found* dialog box:

```
TYPE DLOG                ;indicates the the following definitions are
                          for dialog boxes
  ,1                     ;sequence number for this dialog box. Must
                          be unique within the resource type (i.e., no
                          other dialog box can have this number)
"None Found"             ;place for any message you like
100 300 170 490          ;coordinates of the box's boundary rectangle
Visible NoGoAway         ;same as for regular window definitions
2                        ;number corresponding to type of window
0                        ;reference value (always use 0)
1                        ;reference number to item list where box's
                          contents are defined (see below for details)
```

Rules that apply to other resource definitions hold for dialog boxes as well. For example, the sequence number must be preceded by a space and a comma. The number indicating the type of window should be selected from those available for regular window definitions.

Alert Boxes

Alert boxes have their own resource template:

```
TYPE ALRT          ;indicates that an alert box follows
  ,4               ;unique sequence number within all alerts
100 300 170 490    ;boundary rectangle
4                  ;reference number to item list where box's
                   contents are defined
7765               ; "stages" word (in hex)
```

The only unusual thing about an alert box definition is the stages word. This number, expressed in hexadecimal, controls what will happen each time the alert is invoked. It means that if the user continues to make the same error, the consequences can vary. Alerts can be instructed to beep the Mac's speaker one or more times, cause the menu bar to flash, display or not display the box itself, and change which button within the box will be the default button (i.e., the button that is selected when the user presses ENTER or RETURN).

Each alert has four stages; if an alert is called more than four times, it will simply repeat whatever actions are specified by the fourth stage. Each stage is controlled by four bits within the stages word:

Bits	**0 - 3**	**stage one**
	4 - 7	**stage two**
	8 - 11	**stage three**
	12 - 15	**stage four**

Within the four bits allocated to each stage, the highest-order bit refers to the item number of the default button minus 1 (the item number is the position of the item [usually a button] within the item list; item lists are discussed below). By convention, the first item in the list is always the OK button. It appears in the stages word as a 0. If a CANCEL button is present, it will be the second item in the item list and therefore is indicated as a 1 in the status word. The next lower-order bit is set if the alert box is to be drawn and cleared if it should not be drawn. The two lowest-order bits refer to how many times the speaker should be beeped (0 to 3).

To create a stages word, first design it in binary and then translate it to hexadecimal. If we convert the Video Tape Index's stages word to binary, we can see exactly what actions it instructs the Mac to take when the alert is invoked:

$7765 = %0111 0111 0110 0101

In all four stages, the highest-order (left-most) bit is 0. That indicates that the default item will always be the OK button. (As you will see below in the discussion of item lists, the OK button is the first item in the item list.) The second bit from the left is always 1. Therefore, the box will be displayed at all four stages. The difference between the four stages is in the number of times the speaker will sound. At stage

one it will beep once, at stage two twice, and three times at stages three and four. Note that if the value of the sound bits is 0, the speaker will not sound at all but the menu bar will flash.

Item Lists

The items which appear in alert and dialog boxes are also best defined in a resource file. They are linked to the appropriate box by the item list number within the alert or dialog box definition. Therefore, each alert and dialog box must assign a unique number to its item list; the Mac can't tell the difference between lists that belong to dialog boxes and those that belong to alerts.

A number of special items can appear in dialog and alert boxes. The phrase that should be used to identify the item in a resource file appears in boldface:

1. Buttons [**button**] (the hot-dog shaped buttons)
2. Check boxes [**checkbox**]
3. Radio buttons [**radiobutton**] (the round buttons)
4. Static text [**staticText**] (text that is simply displayed on the screen; it cannot be edited)
5. Edit text [**editText**] (text that can be edited; available only in dialog boxes)

Note that both static text and edit text items are limited to 241 characters.

Buttons and check boxes are controls. You can manage them directly through routines in the Control Manager, but when they are part of alert and dialog boxes, the Dialog Manager will make the calls to the Control Manager for you.

The item list for dialog box will appear as follows. This one is for the Video Tape Index's *None Found* dialog box:

```
TYPE DILT                ;indicates that item lists follow
  ,1                     ;same as item list reference number
                         in the dialog box's definition
2                        ;number of items in the list

button                   ;type of item
40 110 60 170            ;boundary rectangle for the item,
                         expressed in local coordinates of the
                         dialog box
OK                       ;content of the item

staticText               ;type of item
10 41 30 149             ;coordinates to enclose the text
None Found               ;text to be printed
```

Note that the location of each item in the dialog or alert box is indicated by a boundary rectangle. That rectangle is expressed in the local coordinates of the specific dialog or alert box.

The item number to which we referred earlier simply corresponds to an item's physical position in the item list. The first item that appears (in this case, the OK button) is item #1; the second item that appears (the text "None Found") is item #2.

For dialog boxes, the default item (the one that is selected when the user presses ENTER or RETURN) is always the first item in the list. As mentioned above, the stages word determines whether the first or second item will be the default for alerts.

The complete resource file templates for the Video Tape Index's alerts and dialog boxes are reprinted in Listing 9.6. The important thing to notice about these definitions is how the item lists are connected to the appropriate alert or dialog box by matching the number of the item list with the item list parameter in the alert or dialog box template.

Listing 9.6 Resource Templates for the Video Tape Index's Alerts and Dialog Boxes

```
TYPE DLOG                                   ;; dialog box definitions follow
,1                                          ;; sequence number
Dialog box for "None Found" condition       ;; comment line
1ØØ 3ØØ 17Ø 49Ø                             ;; boundary rectangle
Visibile NoGoAway                           ;; box is visible & has no GoAway Box
2                                           ;; window type (plainDBox)
Ø                                           ;; no reference value
1                                           ;; item list is #1

,2                                          ;; sequence number
Dialog box for "One Found/Find More?" condition
1ØØ 3ØØ 17Ø 49Ø
Visible NoGoAway
2
Ø
2                                           ;; item list is #2

,3                                          ;; sequence number
Dialog box for "One Found" condition
1ØØ 3ØØ 17Ø 49Ø
Visible NoGoAway
2
Ø
3                                           ;; item list is #3

TYPE ALRT                                   ;; alert definitions follow
,4                                          ;; sequence number
1ØØ 3ØØ 17Ø 49Ø
4                                           ;; item list is #4
7765                                        ;; stages word

,5                                          ;; sequence number
5Ø 14Ø 12Ø 39Ø
5                                           ;; item list is #5
4444

,6                                          ;; sequence number
5Ø 14Ø 12Ø 39Ø
6                                           ;; item list is #6
5555
```

(continued)

Listing 9.6 (continued)

```
TYPE DITL                          ;; item lists for dialog boxes and alerts
,1                                 ;; items for "None Found" dialog box
2                                  ;; 2 items in the list

button                             ;; push button
4Ø 11Ø 6Ø 17Ø                      ;; boundary rectangle
OK                                 ;; contents

staticText                         ;; static text item
1Ø 41 3Ø 149                       ;; boundary rectangle

None Found                         ;; text to be displayed

,2                                 ;; item list for "Find More?" dialog box
3                                  ;; 3 items in list

button
4Ø 11Ø 6Ø 17Ø
OK

button
4Ø 2Ø 6Ø 8Ø
Cancel

staticText
1Ø 41 3Ø 149
Find More?

,3                                 ;; item list for "Find & Wait" dialog box
1                                  ;; 1 item in list

button
4Ø 11Ø 6Ø 17Ø
OK

,4                                 ;; item list for "No selection" alert
2                                  ;; 2 items in list

button
4Ø 11Ø 6Ø 17Ø
OK

staticText
1Ø 5 3Ø 185
Selection criteria?

,5                                 ;; item list for "Printer" alert
2

button
4Ø 18Ø 6Ø 24Ø
OK

staticText
1Ø 1Ø 3Ø 24Ø
Turn on printer. Press "Enter".
```

(continued)

```
,6                                          ;; item list for "File error" alert
2

button
4Ø 18Ø 6Ø 24Ø
OK

staticText
1Ø 1Ø 3Ø 24Ø
Unexpected file error!
```

Data Structures for Alert and Dialog Boxes

Dialog and alert boxes require only two data structures: a block of storage to hold the dialog window record (one will do if an application will never have more than one dialog box or alert on the screen at any given time), and a place to put a pointer to the dialog or alert window (this is returned by the routine that creates the box):

```
DialogWindRec     DS     dWindLen
DialogWindPtr     DS.L   1
```

The parameter **dWindLen** refers to the number of words in a dialog window record and is defined in the ToolBox equates file.

Creating and Disposing of Dialog Boxes

Unlike other windows, dialog boxes are usually created only when they are needed. They also are not hidden or made invisible when an application no longer needs them; rather, they are completely removed from the system. Re-use of the same dialog box during the same program run requires re-creation of the dialog box. Though modal dialog boxes can be managed like other windows (using **HideWindow, ShowWindow, BringToFront**, etc.), they generally are not, since they are used infrequently and their presence occupies memory the Mac can use for other purposes. Modeless dialog boxes are handled like other windows until the user clicks the GoAway box to close them, at which point they are deleted.

The ToolBox routine **GetNewDialog** will create and display a dialog box:

```
FUNCTION GetNewDialog (dialogID: INTEGER;
   dStorage: Ptr; behind: WindowPtr) : DialogPtr;
```

The first parameter, **dialogID**, refers to the sequence number given to the dialog box in the resource file. (Don't confuse this sequence number with the number of the dialog box's item list; though the two numbers are often the same for convenience, they need not be.) **dStorage** is a pointer to the area set aside to store the dialog window record.

behind has the same function as the **behind** parameter in the **GetNewWindow** routine; it determines the placement of the dialog box with respect to the other windows in the screen. A value of −1 will place the dialog box in front of all others.

The result of **GetNewDialog** is a pointer to the dialog window. It is essential to save this pointer if any Window Manager routines are going to be used on this dialog window.

To create its *None Found* dialog box, the Video Tape Index uses this code:

```
CLR.L     -(SP)                    ;space for dialog window
                                   pointer
MOVE      #1,-(SP)                 ;this is dialog box 1
PEA       DialogWindRec(A5)        ;pointer to dialog window record
                                   storage
MOVE.L    #-1,-(SP)                ;put dialog box in front
__GetNewDialog
MOVE.L    (SP)+,DialogWindPtr(A5)
                                   ;recover the window pointer
MOVE.L    DialogWindPtr(A5),-(SP)
__SetPort                          ;make dialog box the current
                                   ;grafport
```

The final step in this sequence is an important one. The dialog box must be made the current grafport so that activities within the box will be properly recorded.

Disposal of a dialog box is taken care of by **CloseDialog**:

```
PROCEDURE CloseDialog (theDialog: DialogPtr);
```

Move the dialog's window pointer onto the stack and call the routine:

```
MOVE.L      DialogWindPtr(A5),-(SP)
__CloseDialog
```

This will not only remove the dialog box from the screen, but will dispose of all data structures associated with the box.

Managing Modal Dialog Box Actions

There is no need to return to an application's event loop to monitor events relating to modal dialog boxes. The ToolBox routine **ModalDialog** performs all

necessary event trapping. **ModalDialog** polls the event manager by calling **GetNextEvent**. It also makes repeated calls to **SystemTask** to make sure that desk accessories are properly updated. If a mouse down event occurs outside the dialog box, the speaker will beep.

The Pascal format for **ModalDialog** is:

```
PROCEDURE ModalDialog (filterProc: ProcPtr;
    VAR itemHit: INTEGER);
```

filterProc refers a pointer to a function that determines how **ModalDialog** should interpret events from the event queue. A value of 0 for the filter procedure pointer will cause **ModalDialog** to default to the standard filter procedure. The standard filter procedure returns the value 1 for **itemHit** whenever the user hits the ENTER or RETURN keys. Assuming that the dialog box's OK button is the first item in the item list, then the standard filter procedure will allow the user to select OK with the ENTER or RETURN keys. This usage is consistent with the standard Macintosh user interface.

Using **ModalDialog** to monitor for an OK requires only a simple loop:

```
Loop    MOVE.L   #0,-(SP)          ;standard filter procedure
        PEA      WhatItem(A5)      ;place to accept number of item
                                   that was pressed
        _ModalDialog
        MOVE     WhatItem(A5),D0
        CMP      #okButton,D0      ;does WhatItem = 1?
        BNE      Loop
```

The constant **okButton** is defined in the ToolBox equates file.

If other actions are possible, then the loop must continue to check item numbers and take the appropriate action. This process is directly analogous to identifying which item was selected from a menu.

Note that events in modeless dialog boxes are handled like those in other windows. An application's event loop must monitor any modeless dialog boxes that are present along with system and application windows.

Creating and Managing Alert Boxes

A single ToolBox routine handles creating alert boxes and monitoring events until either the ENTER or RETURN key is pressed or a mouse down event occurs in the box. That same routine also takes care of disposing of the box when it is no longer needed. Note that if an application needs something other than an OK or a CANCEL reaction to some condition, then an alert box is probably not the correct way to control the situation; use a dialog box instead.

The routine that takes care of alert boxes is simply called **Alert**:

```
FUNCTION Alert (alertID: INTEGER; filterProc: ProcPtr) :
    INTEGER;
```

alertID is the sequence number of the alert box's definition in the resource file. **filterProc** is a pointer to a procedure that indicates how **Alert** should select events from the event queue. As with **ModalDialog**, using a 0 will select the standard filter procedure (pressing ENTER or RETURN selects the default button just as if the user clicked on it with the mouse).

Alert returns a result that corresponds the position in the item list of the item that was selected. If an alert box has only an OK button, then **Alert**'s result can be disregarded. Nonetheless, the result must be removed from the stack. If the box has box OK and CANCEL buttons, then the application must examine the result to determine which button was selected and what action to take.

The Video Tape Index uses one of its three alert boxes (Figure 9.5) to indicate that a search request was made before selection criteria was entered. Therefore, the box only contains some static text and an OK button (the box merely freezes program action until the user is ready to continue). A "no selection criteria" condition (indicated by a length of 0 in the text edit record for the field on which the chosen search is to be based) initiates the following actions:

```
CLR       -(SP)        ;space for alert item result
MOVE      #4,-(SP)     ;alert box sequence number
MOVE.L    #0,-(SP)     ;use standard filter procedure
_Alert
MOVE      (SP)+,D0     ;retrieve result to keep stack pointer
                       in good order
```

Note that the result of **Alert** is not checked in this case, since the only button present is the OK button.

Questions and Problems

1. Assume that a window has been defined with a boundary rectangle of 10, 10, 335, 500. Write a block of code that will define a text edit record that uses the entire window. Allocate any necessary constants and data structures, including needed rectangles. Be sure to retrieve the text edit handle from the stack.

2. A. What sequence of events generates an activate event for a text edit window?
   B. Under what circumstances should the window be deactivated?
   C. Under what circumstances should it be activated?

3. Write an ordered list of the ToolBox and/or operating system calls needed to activate a text edit window. Indicate the information returned by each call. Assume that an event loop has already detected an activate event.

4. Write the assembly language code to implement the procedure outlined in problem 2. Remember to distinguish between the need to activate or deactivate a window. Use the event record field names as defined in Chapter 8. Allocate any other data structures your code will use.

5. A user has pressed the cloverleaf and X keys together (the keyboard equivalent of selecting "cut" from the Edit menu). Write an ordered list of ToolBox and/or operating system calls needed to process the cut operation. Assume that an event loop has already detected a key down event. Indicate the information returned by each call.

6. Write the assembly language code to implement the cut operation outlined in problem 5. Assume that the Edit menu is menu #2. Use the event record field names as defined in Chapter 8. Allocate any other data structures your code will use.

7. Describe the differences between the following ToolBox routines, each of which displays text:

   a. DrawChar
   b. DrawString
   c. TEKey
   d. TEInsert
   e. TextBox

8. Write resource file templates to define a dialog box that will appear across the top quarter of the screen. The box is approximately 4" wide and 3" high. The items in the box are:

   A. a static text item (the actual text is up to you)
   B. an edit text item to hold one line of text
   C. an OK button
   D. a Cancel button

   Choose the boundary rectangle for the dialog box and decide on placement of the items within it.

9. Write a block of assembly language code to create and monitor user actions in the dialog box defined in problem 8. Close the dialog box when the user clicks the mouse button in the OK or Cancel buttons, or presses the Enter or Return key. Allocate any data structures the code will require.

10. Write resource file templates to define an alert that will appear centered on the screen. It should be approximately 2" high and 3" wide. The items in the box are a line of static text of your choosing and an OK button. Select an appropriate boundary rectangle for the alert and decide on placement of the two items. The Mac should beep once the first time the alert is invoked, twice the second time, and three times the third and fourth times. The box should always be displayed; the OK button is always the default button.

11. Write a block of assembly language code to create and monitor user actions in the alert defined in problem 10. Close the alert box when the user clicks the mouse button in the OK button, or presses the Enter or Return key. Allocate any data structure the code will require.

CHAPTER TEN

PRINTING

Chapter Objectives

1. To understand the difference between draft and spooled printing
2. To learn the sequence of Printing Manager routines that control the printing process
3. To learn to position and produce images on a printed page

Introduction

Like most other aspects of writing a Macintosh application in assembly language, printing requires a great deal of planning. An application must not only figure out where to place text and graphics on the page, but must also determine parameters such as the space between lines (determined by the size of the font). Nonetheless, the printing process is rather "cookbook"; the basic steps are the same for all applications.

The Macintosh supports two types of printing – draft printing and spool printing. In draft printing, a document is printed directly, line by line, as text is sent to the Printing Manager. It is a very fast way to print, but is generally only suitable for printing text, since graphics requires the ability to move the cursor freely about the page. (This kind of movement is often referred to as *direct cursor addressing*.) Spool printing creates a disk file that contains an image of an entire document.

Since the print file is a direct access file, graphics images that require random cursor movement can be stored. Once a spooled print file is complete, it can then be printed line by line in a separate step.

The actual results of draft and spool printing are not the same, even though the same program code may be used to produce both kinds of output. For example, compare Figures 10.1 (draft printing) and 10.2 (spool printing). Both were created with exactly the same program statements. The only difference is the choice the user made when selecting the type of printing. Draft printing will not necessarily look exactly like what is seen on the screen. To duplicate screen displays exactly, use spool printing.

Spool printing does have some drawbacks. First of all, it is slower than draft printing. Secondly, "imaging" the print file to print it requires a great deal of memory. In many cases, it becomes necessary to swap much of the application program out of memory before beginning the print operation. Therefore, the program must be segmented. (Such operations are handled by the Segment Loader.) Program segmentation is a conceptually complex operation requiring intimate knowledge of where storage space has been allocated in RAM and how to perform memory management with the Memory Manager. It is an advanced operation that you should attempt only when you are comfortable with the concepts presented in this book. Details can be found in *Inside Macintosh*.

Spool printing also uses up a great deal of disk space to store the print file. Consider what happens with MacWrite: if you have a 512K Mac you can store as many as 80 pages of text in RAM, but you can only spool a document of 27 pages, assuming that there is nothing on the startup disk but the MacWrite program file and a system folder. If, though, you switch the print mode from standard to draft, the Printing Manager will not attempt to create a print file on disk, but will print directly from RAM, allowing you to print the entire 80 pages. The drawback to switching to draft printing is that it limits the type fonts and type styles that can be used.

Accessing the Printing Manager

The routines that comprise the Printing Manager are not in ROM; they are stored on disk. The Macintosh can therefore support a variety of printers. The discussion that follows, though, assumes that printing will be done on the Imagewriter printer.

Since Printing Manager routines are not in ROM, they are not called with the usual trap mechanism (i.e., an underbar followed by the name of the routine). Instead, they are external subroutines and are therefore invoked with a **JSR**.

Figure 10.1 Video Tapes (Draft Printing)

Video Tapes

Title	Producer	Date	Ratg	Numb
Empire Strikes Back, The	Lucas Films	1980	pg	2

This sequel outdid its predicessor, bringing new depth to its characters. The evil Darth Vader emerged as a true villain, while Luke, Leia and Han became true forces of good.

Return of the Jedi	Lucas Films	1983	pg	3

Tied up all the loose ends created in the first two films and provided a satisfactory ending to this middle trilogy (Lucas says there will be six more films).

Search for Spock, The	Paramount	1984	pg	6

Gives Spock a new beginning but leaves the rest of the crew in jeapardy, since the Enterprise was destroyed and the crew as mutineers

Star Trek: The Movie	Paramount	1978	g	4

A valiant effort to recapture the magic of the television series. Unfortunately, it fell short of expectations.

Star Wars	Lucas Films	1977	pg	1

This landmark film raised our expectations with regard to what science fiction films should be. It set a new standard for special effects.

Printing requires two special files. To print with the Imagewriter, the Imagewriter file must be part of the system folder on the startup disk. This file is a resource file containing information that describes the printer. By replacing the file with one that describes another printer, an application can produce printed output on other kinds of printers.

Figure 10.2 Video Tapes (Spool Printing)

Video Tapes

Title	Producer	Date	Ratg	Numb
Empire Strikes Back, The	Lucas Films	1980	pg	2

This sequel outdid its predicessor, bringing new depth to its characters. The evil Darth Vader emerged as a true villain, while Luke, Leia and Han became true forces of good.

Return of the Jedi	Lucas Films	1983	pg	3

Tied up all the loose ends created in the first two films and provided a satisfactory ending to this middle trilogy (Lucas says there will be six more films).

Search for Spock, The	Paramount	1984	pg	6

Gives Spock a new beginning but leaves the rest of the crew in jeapardy, since the Enterprise was destroyed and the crew as mutineers

Star Trek: The Movie	Paramount	1978	g	4

A valiant effort to recapture the magic of the television series. Unfortunately, it fell short of expectations.

Star Wars	Lucas Films	1977	pg	1

This landmark film raised our expectations with regard to what science fiction films should be. It set a new standard for special effects.

The second file, PrLink.Rel, must be linked to the application's object code. PrLink.Rel (you will find it on MDS2 in the Sample Programs folder along with the Printing Sample program) contains the machine language version of the Printing Manager routines that are not a part of the application itself.

Setting up the Linker Control File for an application that supports printing is only marginally more complex than what was created for the Sample program. For example, a Linker Control File to handle the Video Tape Index appears as:

```
Tapes.Rel
PrLink.Rel

$
```

Data Structures for Printing

Each printing job uses a rather complex data structure known as a print record. It is made up of a few single parameters and a number of subrecords. Equates for the field names are in the file PrEqu.Txt, which should be INCLUDEd in your source code.

The fields in a printing record are filled in three ways:

1. An application can store information directly into the record.
2. The Printing Manager routine **PrintDefault** can be used to fill in default information.
3. The user can change information in some fields by making selections from the standard Style and Job dialogs (Figures 10.3a and 10.3b).

The top-level structure of a **print record** appears as:

```
TPrint = RECORD
    iPrVersion:  INTEGER;     Printing Manager version
    prInfo:      TPrInfo;     subrecord for printer information
    rPaper:      Rect;        boundary coordinates of printer paper
    prStl:       TPrStl;      subrecord for style information
    prInfoPT:    TPrInfo;     copy of printer information subrecord
    prXInfo:     TPrXInfo:    subrecord for band information
    prJob:       TPrJob;      subrecord for job information
    printX:      ARRAY [1..19] of INTEGER;
                              used internally
END;
```

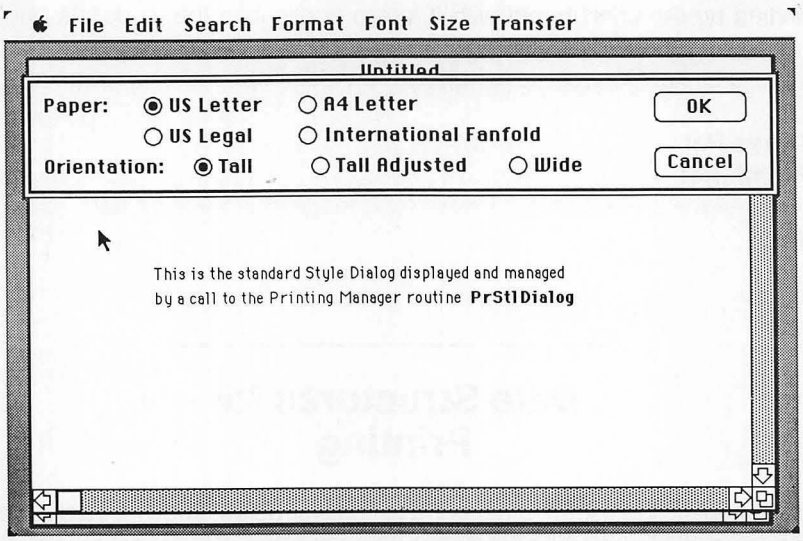


Figure 10.3(a) Standard Style Dialog

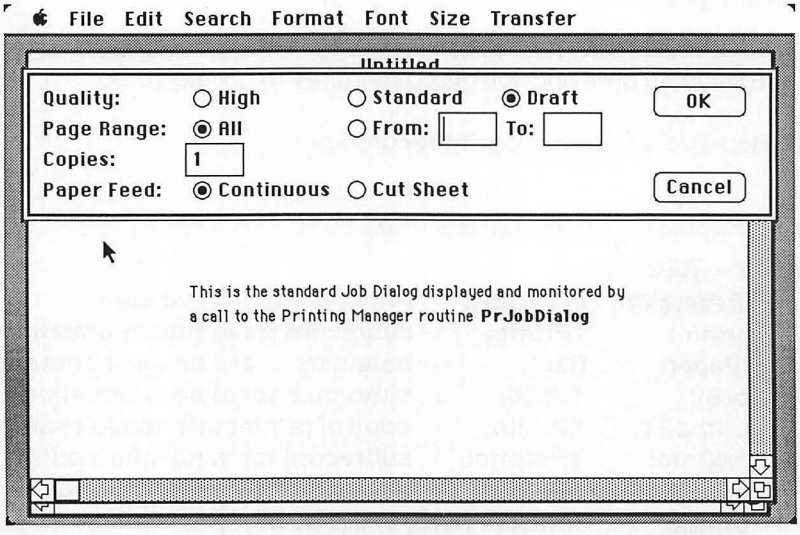


Figure 10.3(b) Standard Job Dialog

The data types which begin with **T** are pointers to subrecords. Actually, each subrecord is allocated sequentially. For example, the printer information subrecord begins two bytes from the beginning of the printer record and occupies the next 14 bytes (see below for details). The rectangle which describes the boundaries of the printer paper occupies the next eight bytes, from byte 16 through byte 23. The style information subrecord follows immediately, beginning with byte 24.

The **printer information subrecord** contains information about the printer being used in this particular printing job:

```
TPrInfo = RECORD
    iDev:       INTEGER;    information about the printer driver
    iVRes:      INTEGER;    vertical resolution of printer
    iHRes:      INTEGER;    horizontal resolution of printer
    rPage:      Rect;       boundaries of actual printing surface
END;
```

These parameters are filled when an application initializes the Printing Manager. The last three can be changed by the user through the standard Style dialog.

Generally, the only field of the printer information subrecord that an application will use directly is **rPage**, a rectangle that describes the coordinates of the actual surface available for printing. Its top left coordinates are always 0,0. It is somewhat smaller than **rPaper**, which contains the coordinates of the physical printer paper. This means that the top left coordinates of **rPaper** will be negative.

The printer information subrecord is duplicated in the print record. The copy is used internally by the Printing Manager during the printing process.

The **style information subrecord** contains parameters that further describe the paper being used:

```
TPrStl = RECORD
    wDev:       TWord;      used internally
    iPageV:     INTEGER;    height of printer paper
    iPageH:     INTEGER;    width of printer paper
    bPort:      SignedByte; port to which printer is connected
    feed:       TFeed;      type of paper (e.g., cut sheet or pin
                            feed)
END;
```

iPageV and **iPageH** refer to the physical dimensions of the printer paper, expressed in 120ths of an inch. They are set when the user makes choices from the standard Style dialog. **bPort** indicates whether the printer being used is connected to the printer or the modem port.

The final parameter, **feed**, is set from the standard Job dialog. The user chooses either continuous or single sheet. If single-sheet is selected, the Printing Manager will automatically pause between pages so the user can insert paper.

Parameters that describe a specific printing job are found in the **job information subrecord**:

```
TPrJob = RECORD
    iFstPage:    INTEGER;      first page to print
    iLstPage:    INTEGER;      last page to print
    iCopies:     INTEGER;      number of copies to print
    bJDocLoop:   SignedByte;   0 if draft, 1 if spoiled
    fFromUser:   BOOLEAN;      source of printing request
    pIdleProc:   ProcPtr;      pointer to background procedure
    pFileName:   TPStr80;      name of spool file
    iFileVol:    INTEGER;      volume reference number
    bFileVers:   SignedByte;   version of spool file
    bJobX:       SignedByte;   unused
END;
```

Some of these parameters are set through the standard Job dialog. Others should be stored directly to the printer record.

iFstPage, iLstPage, and **iCopies** are selected by the user from the standard Job dialog. For spool printing, the system will automatically check the **iCopies** field and print the correct number of copies. When an application does draft printing, however, the application must check **iCopies** and implement multiple copy printing within its own code.

bJDocLoop is also set by the user from the standard Job dialog. During calls to routines that actually create printed images, regardless of whether an application is doing draft or spool printing, the system will check **bJDocLoop** and direct the material being printed to the appropriate output device. The application must then explicitly examine the contents of **bJDocLoop** to decide whether to print a spool file.

fFromUser indicates the source of the printing request. If the **fFromUser** byte is set true, then the request came from within the application; if the byte is clear, then the printing request came from the Finder. This parameter is set by the system.

Creating a document that can be printed from the Finder requires special preparation. The Finder must be able to identify which application created the document in order to launch that application to perform the print activity. The Finder looks at the document to examine its *creator type*, a unique four-character sequence that identifies an application. If the Finder can't find an application with a matching type, it displays the alert box "An application can't be found to open this document." Creator types are assigned by Macintosh Technical Support so they will be unique across all Macintosh applications.

pIdleProc is a pointer to the routine that should execute in the background of the printing task. This is based on the idea that printing is a fairly slow operation; printer output happens at significantly slower speeds than activities which happen completely in main memory. Therefore, the CPU will have some idle time while it waits for a printer operation to finish. The background procedure can be anything

appropriate. If the **pIdleProc** is set to 0, the Mac will run its default background procedure. This routine periodically checks the keyboard to see if the cloverleaf-period has been pressed to interrupt printing.

pFileName is a pointer to the name of the spool file. By default the Printing Manager fills this field with a pointer to "Print File." If an application will have more than one spool file on disk at any given time, then this parameter can be changed by storing directly to the print record. A spool file name contains no more than 80 characters; the first byte of the string must be a length byte.

iFileVol identifies the physical disk volume on which a spool file is stored. **bFileVers** refers to the version number of the spool file. Volumes and file versions are discussed in more detail in Chapter 11.

The final subrecord is the **band information subrecord**. In this context, the term *band* refers to a strip cut from a page. It takes an enormous amount of memory to print from a spool file, far more than will fit in memory at a single time. Therefore, a page to be printed is broken up into a series of strips called bands. The bands can run from right to left, left to right, top to bottom, or bottom to top. Bands can then be brought into memory one at a time and printed individually. An application will rarely need to access the individual fields of the band information subrecord. Its parameters are set by the Printing Manager.

Programming Technique – Packing an Equates File

Offsets for all fields in a print record are assigned symbolic addresses in the file PrEqu.Txt. However, unlike the other equates files, there is no packed version of the printer equates on MDS2. Packed symbol files are identified by the **.D** extension. They are created from text files, like PrEqu.Txt, by the application PackSyms. Packing an equates file will speed up the assembly process and will also save disk and memory space.

Packing an equates file is a two step process. First, the text version of the equates file is assembled into a symbol file with an extension of **.Sym**. Then the symbol file is packed by PackSyms.

The creation of a symbol file is controlled by the assembler directive **.DUMP**. **.DUMP** places all equates in the current program into a file with the **.Sym** extension. For example, assembling this code will create the file **PrEqu.Sym**:

```
INCLUDE     PrEqu.Txt     ;get the text of the equates file
.DUMP       PrEqu         ;create the symbol file
```

The two-line file above should be saved with the name **PrEqu.Asm**. It can then be assembled. Note that the program does not have to be linked or run to create **PrEqu.Sym**; assembling is enough.

To do the actual packing, run the PackSyms program that comes on MDS1. Choose the "Select input" option from the File menu and double click on the name of the file that should be packed, in this case **PrEqu.Sym**. **PrEqu.Sym** will be packed, but not automatically saved as **PrEqu.D**. When the packing of the file is completed, you can either select another file to pack by choosing "Select input" again, or you can save all files that have been packed during the current run. Choose "Select output" from the File menu to save the packed file. The system will display a file name — the name of the last file packed with a **.D** extension. Either confirm the file name by hitting the Enter key or enter another filename.

Establishing Print Records

Space for a print record is allocated in the application heap. That means that an application doesn't need to set aside a location for the entire 120 byte record but merely a handle to that location. The handle to the print record is created with a Memory Manager routine, **NewHandle**;

```
FUNCTION NewHandle (logicalSize:Size) : Handle;
```

NewHandle is an operating system routine. It takes one parameter — the number of bytes of storage that should be allocated — that is placed in D0. It returns a handle to that storage area in A0. Assuming that PrEqu.txt has been INCLUDEd in the source code, the constant **iPrintSize** contains the size of a print record. To set aside space for a print record, then:

```
MOVE.L      #iPrintSize,D0
_NewHandle
MOVE.L      A0,PrintRecordHandle(A5)      ;save handle
```

A word of caution is in order here with regard to storage space while using the Printing Manager. It is true that it is good practice to place the storage for all locations to which an application will write in the applications globals area (i.e., they should be allocated with **DS** rather than **DC**). Nevertheless, the Printing Manager has a bad habit of altering values stored in the applications globals area. To put it bluntly, it trashes storage locations that it has no business touching. If you find that a particular value is mysteriously changed after a call to a Printing Manager routine, allocate its storage with **DC**. Though the examples in this chapter will use storage locations in the applications globals area, be aware that on occasion you may have to resort to writing to the code portion of an application.

The Sequence of Printing Manager Routines

A single printing activity is bounded by calls to routines that open and close the Printing Manager. The printing of one document is surrounded by calls to routines that open and close documents. Printing a single page is bounded by calls that open and close a page. This nested arrangement of procedure and function calls is diagrammed in Figure 10.4.

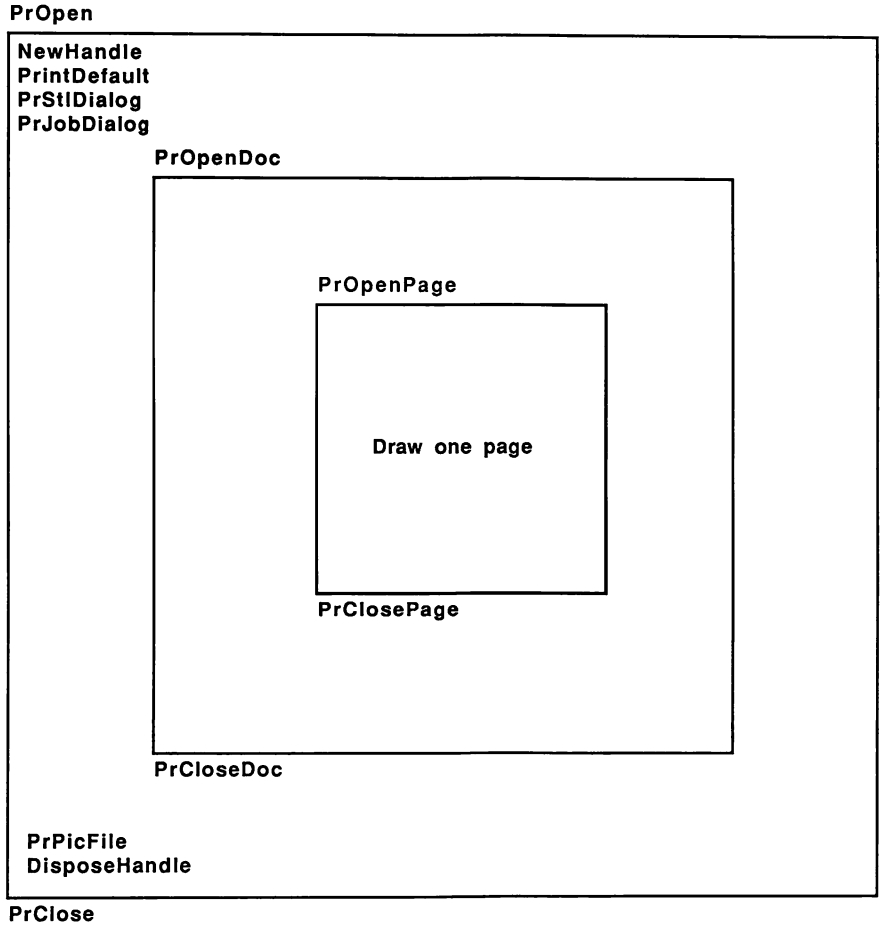


Figure 10.4 Nested Printing Manager Calls

In general, an application will organize a printing activity in the following order:

1. Open the Printing Manager (**PrOpen**)
2. Allocate a print record (**NewHandle**)
3. Fill the print record with default information (**PrintDefault**)
4. Present standard Style dialog to user to fill in more information (**PrStlDialog**)
5. Present standard Job dialog to user in to finish collecting print record parameters (**PrJobDialog**)
6. Open a document (**PrOpenDoc**)
7. Open a page (**PrOpenPage**)
8. Print the page
9. Close a page (**PrClosePage**)
10. Repeat steps 7 through 9 until all pages in the document have been printed
11. Close the document (**PrCloseDoc**)
12. If spool printing was done, image and print the spool file (**PrPicFile**)
13. Repeat steps 6 through 12 until all documents have been printed
14. Free the storage used by the print record (**DisposHandle**)
15. Close the Printing Manager (**PrClose**)

Those Printing Manager routines that return result codes do so in D0. A value of 0 indicates no error. The only other error unique to the Printing Manager is −108, which indicates that there wasn't enough heap space to complete the requested operation. All other errors generated by calls to Printing Manager routines are represented by Resource Manager result codes (see Table 10.1).

Table 10.1 Resource Manager Result Codes Returned by Printing Manager Routines

Hex Code	Decimal Code	Meaning
Ø	Ø	No error
FFFFFF4C	-18Ø*	Not enough memory to image and print spool file
FFFFFF4Ø	-192	Resource not found (generally means something is wrong with the printer resource file)
FFFFFF3F	-193	Printer resource file is missing

*This is a Printing Manager result code, not a Resource Manager result code.

Opening and Closing the Printing Manager

An application should call **PrOpen** and **PrClose** only once – at the very beginning and very end of printing activity. Neither routine takes any parameters and both are therefore called by a simple:

```
JSR  PrOpen
```

or

```
JSR  PrClose.
```

PrOpen opens both the printer driver and the printer resource file. **PrOpen** will do nothing, however, if either of the two things are missing or there is a problem with the printer resource file. A value of 0 in D0 indicates that the call to **PrOpen** was successful. Otherwise, the routine returns one of the Resource Manager error codes.

Collecting Information for the Print Record

The first step in assembling the necessary information to complete a printing operation is to fill the fields of the print record with the default values for the parameters. These are stored in the printer resource file. They include the last selections made from the standard Style and Job dialog boxes. **PrintDefault** needs only the handle to the print record:

```
PROCEDURE PrintDefault (hPrint: THPrint);
```

As with all other Printing Manager routines, the parameter is placed on the stack and the routine called with a **JSR**:

```
MOVE.L      PrintRecordHandle(A5), – (SP)
JSR         PrintDefault
```

Once the print record has been filled with the default information, the user has the opportunity to change it through the standard Style and Job dialogs. Both dialog boxes are predefined within the Printing Manager and do not need to be included in an application's resource file.

Usually, the Style dialog box is presented first:

FUNCTION PrStlDialog (hPrint: THPrint) : BOOLEAN;

The function displays the dialog box and returns a boolean result indicating whether the user closed the dialog box with the ENTER button (a value of true) or the CANCEL button (a value of false). If the function result is true, any changes made by the user will be reflected in the print record.

The code to display the Style dialog box might be:

```
CLR         -(SP)          ;space for boolean result
MOVE.L      PrintRecordHandle(A5),-(SP)
JSR         PrStlDialog
```

The standard Job dialog is handled in precisely the same way as the Style dialog. It, too, is a function that returns a boolean result:

FUNCTION PrJobDialog (hPrint:THPrint) : BOOLEAN;

Any changes made by either **PrStlDialog** or **PrJobDialog** are reflected not only in the print record in RAM, but in the printer resource file as well. The next time an application attempts to print from this same disk, it will be presented with the new values as default values.

Opening and Closing a Document

Macintosh printing actually involves opening a special kind of grafport — called a *printer port* — in which text and graphics images are drawn. The exact nature of the printing port depends on whether the user selected draft or spool printing. Nonetheless, it is **PrOpenDoc** that establishes the printing port and makes it the current grafport:

FUNCTION PrOpenDoc (hPrint: THPrint; pPrPort : TPPrPort;
pIOBuf:Ptr) : TPPrPort;

hPrint is the handle to the print record. **pPrPort** is a pointer to storage for the printer port. If this parameter is 0, the Printing Manager will allocate a new printer port and return a handle to it as the function's result. An application does not need to explicitly set aside storage for a printer port; only space for its pointer (one longinteger location) is required.

plOBuf is important for spool printing. It is a pointer to a portion of memory that should be used as temporary storage when creating a spool file. (I/O buffers are discussed in detail in Chapter 11.) Normally, it is not necessary to supply an explicit I/O buffer for spooling; the value of **plOBuf** will be 0, telling the system to use the volume's I/O buffer.

To open a printing port:

```
CLR.L       -(SP)                   ;space for printer port pointer
MOVE.L      PrintRecordHandle(A5),-(SP)
CLR.L       -(SP)                   ;new printer port will be created
CLR.L       -(SP)                   ;use the volume I/O buffer
JSR         PrOpenDoc               ;call the routine
MOVE.L      (SP)+,PrPortPtr(A5)     ;recover printer port pointer
```

PrCloseDoc terminates a printing task. If draft printing, it sends a form feed to the printer. If spool printing, it closes the spool file. If the spooling was unsuccessful, it closes and then deletes the spool file. To call the routine, an application needs only the pointer to the printer port:

```
PROCEDURE PrCloseDoc (pPrPort: TPPrPort);
```

Printing a Single Page

The real work in programming Macintosh printing activities comes in laying out the printed page. Each page begins with a call to **PrOpenPage**:

```
PROCEDURE PrOpenPage (pPrPort:TPPrPort;
    pPageFrame: TPRect);
```

pPrPort is nothing more than the pointer to the printer port that was returned by **PrOpenDoc. pPageFrame** is a rectangle that describes boundaries within which QuickDraw images will be drawn. When a spool file is printed, this rectangle will be scaled to fit onto the printer paper. The easiest way to handle **pPageFrame** is to set it to 0. In that case, the Printing Manager will use the page rectangle (**rpage**) from the printer records as the page frame. The page will then not be scaled when it is printed.

PrOpenPage checks the page range parameters in the print record (**iFstPage,iLstPage**). If the page to be printed doesn't fall within that range, no printing will be performed.

The actual printing on a page is handled by QuickDraw. An application can draw to the printer port using any QuickDraw routines, just as it would to the screen. Remember that **PrOpenDoc** makes the printer port the current grafport.

That means that any calls to QuickDraw routines that draw something will affect the printer port until it is closed by **PrCloseDoc**. Graphics printing (always spooled) will use the coordinates of the **rPage** rectangle to ensure that printed images are within the boundaries of the page.

Printing straight text, especially if draft printing is possible, requires a somewhat different method for establishing spacing between lines and determining when a page has been filled. When printing, it is not possible to use TextEdit to space and justify characters; text is printed with either **DrawChar, DrawString,** or **DrawText**. The latter routine is the easiest to use if the text to be printed is stored in a text edit record. **DrawString** is convenient when the text is not stored in main memory in the format in which it will be printed.

The position on the page at which text should be printed is set with **MoveTo**, the QuickDraw routine that handles cursor placement. An application must therefore carefully compute the size of the font being used to determine how far apart lines of text must be.

Information about the size of characters in a font can be retrieved with the QuickDraw routine **GetFontInfo**:

```
PROCEDURE GetFontInfo(VAR info: FontInfo);
```

This procedure returns an eight-byte record, a pointer to which should be placed on the stack before calling the routine:

```
PEA       FontInfoStorage(A5)
_GetFontInfo
```

GetFontInfo provides four parameters about the font for the current grafport, each expressed in terms of pixels: ascent (how many pixels letters like "h" rise), descent (how many pixels letters like "y" descend below the line), maximum character width, and the number of pixels between the descent of one line and the ascent of the next line below it (known as "leading"). The **FontInfo** record structure is:

```
FontInfo = RECORD
        ascent:         INTEGER;
        descent:        INTEGER;
        widMax:         INTEGER;
        leading:        INTEGER;
END;
```

Offsets into the **FontInfo** record are available in the QuickDraw equates file, which should be INCLUDEd at the beginning of the source code.

The height of a line is the sum of ascent, descent, and leading:

```
MOVE  FontInfoStorage+ascent(A5),D4
ADD   FontInfoStorage+descent(A5),D4
ADD   FontInfoStorage+leading(A5),D4
```

D4 contains the height, in pixels, of a single line of text in whatever font is set for the current grafport. In this case, the current grafport is the printer port. Assuming that D3 is used to hold the vertical position of the pen (read "pen" as *cursor* or *print head*, if you like), then D3 will be incremented by the quantity in D4 every time a line is printed.

One other parameter is necessary for text printing — the coordinate, in pixels, of the bottom of the page. This will be compared to the current vertical position (stored, in this example, in D3) to determine if a full page has been printed. The coordinate of the bottom can be retrieved from the print record:

```
MOVE.L    PrintRecordHandle(A5),A0        ;get handle
MOVE.L    (A0),A0                         ;get pointer
MOVE      prInfo+rPage+bottom(A0),D6      ;get bottom
```

How does this work? The first step retrieves the handle to print record. The second de-references the handle to get the pointer to the record. At this stage in the process, the actual address of the start of the print record is in A0. The third step uses Address Register Indirect with Offset addressing to locate one precise piece of information. **prinfo** and **rPage** are constants defined in the printer equates file. **prInfo** stands for the number of bytes the printer information subrecord is offset from the beginning of the print record. **rPage** is an offset within the printer information subrecord. **rPage** is a rectangle; it has four components — top, left, bottom, right — that are defined in the QuickDraw equates file. **bottom**, therefore, refers to the third field in the rectangle, **rPage**. To compute the address for the **MOVE**, the Macintosh adds the three constants to obtain the offset and then adds that quantity to the contents of A0.

Since some characters do descend below the printing line, it is wise to subtract the descent from the bottom coordinate to ensure that characters that do descend will be completely printed:

```
SUB   FontInfoStorage+descent(A5),D6
```

The initial vertical position for printing text is not 0; it is down the height of a single line from the top of the printing page. Therefore, assuming that D3 is being used to hold the vertical position of the pen, it should be initialized to the height of a line before any printing activity begins:

```
MOVE  D4,D3
```

Moving the Pen

Printing or drawing, whether on the screen or on paper, is only possible if you have control over where the display activity will begin. The QuickDraw routine **MoveTo** positions Mac's pen anywhere within a grafport. Remember that a printing port is a special kind of grafport and that once a printer port has been

opened, any calls to QuickDraw routines that affect output (e.g., drawing or moving the pen) will affect the printed page.

To use **MoveTo**, an application must supply the horizontal and vertical coordinates, in pixels, of the new pen position:

PROCEDURE MoveTo (h,v: INTEGER);

h is the horizontal coordinate; **v** is the vertical coordinate.

In spool printing, there is virtually no limit to how the pen can be moved, since writing to the spool file allows random access. When draft printing, however, be aware of the abilities of the specific printer being used. Some printers, like the Imagewriter, can move the platten backwards; that is, it is possible to pass the Imagewriter a vertical coordinate less than the most recent vertical coordinate. Many printers, however, are not only unable to move the platten backwards, but are unable to backspace; that is, they cannot accept a horizontal coordinate less than the most recent horizontal coordinate.

Though the Imagewriter can do more or less random print head movement, sending print images directly to the printer in that manner will significantly slow down the printing process. Therefore, draft printing is really not suitable for a printing activity that includes graphics.

Printing Text with DrawString

DrawString is a QuickDraw routine that will print text from left to right, beginning at the current position of the pen. Like the other QuickDraw routines that print characters, it does no formatting. In other words, the application must decide how many characters will fit on a single printed line.

Calling **DrawString** requires only a pointer to the text of the string:

PROCEDURE DrawString (s: Str255);

It is important to realize that the data type of the string (Str 255) requires that the first byte in the string be a length byte. The system checks that length byte to determine the number of characters to print.

The Video Tape Index program uses **DrawString** to print information about a single video tape. The data for that print line is found in the TapeArray in RAM and must therefore be reformatted before it is printed.

About 100 characters of 12-point type will fit across a 8 1/2" piece of paper. Therefore, the Video Tape Index sets up a 102-character print string. The first byte will be a length byte; the last byte is an extra byte appended to keep the total length of the string even. The strategy to assemble and print a single line of data is therefore:

1. Fill print line with blanks

2. Move each field from its storage location in TapeArray to its proper position in the print string
3. Set font characteristics (**TextFont, TextFace, TextSize**)
4. Move the pen (**MoveTo**)
5. Draw the string (**DrawString**)
6. Increment the register that holds the vertical position of the pen

The code for this procedure appears in Listing 10.1. The subroutine ClearPrintLine (a) fills the print string with blanks. It uses a pre-defined string of 102 blanks (stored as PrintLineMask) which is simply moved to the print string with **BlockMove** (b). ClearPrintLine also installs a length byte in the print string (c).

Listing 10.1 Printing One Record from TapeArray

```
(a)     ClearPrintLine                          ;fill print line with blanks
                LEA     PrintLineMask,AØ
                LEA     PrintLine(A5),A1
                MOVE    #1Ø2,DØ
(b)             _BlockMove

(c)             MOVE.B  #1ØØ,PrintLine(A5)      ;set length of print line

                RTS

(d)     PrintOneRecord
(e)             JSR     ClearPrintLine
                LEA     TapeArray(A5),A2

                MOVE.L  D7,-(SP)                ;save record counter
                MOVE    D7,D5
(f)             JSR     ComputeAddress2 ;address returned in A4 (see Listing 5.1 or 6.1)
                MOVE.L  (SP)+,D7                ;restore record counter

(g)             MOVE.L  A4,AØ                   ;start of record
(h)             LEA     PrintLine+12(A5),A1
(i)             MOVE    #3Ø,DØ
(j)             _BlockMove                      ;moves TapeName

                MOVE.L  A4,AØ
                ADD.L   #oProducer,AØ
                LEA     PrintLine+44(A5),A1
                MOVE    #2Ø,DØ
                _BlockMove                      ;moves Producer

                MOVE.L  A4,AØ
                ADD.L   #oReleaseDate,AØ
                LEA     PrintLine+66(A5),A1
                MOVE    #4,DØ
                _BlockMove                      ;moves Date
```

(continued)

Listing 10.1 (continued)

```
                MOVE.L  A4,AØ
(k)             ADD.L   #oRating,AØ
                LEA     PrintLine+72(A5),A1
                MOVE    #4,DØ
                _BlockMove                      ;moves Rating

                MOVE.L  A4,AØ
                ADD.L   #oTapeNumber,AØ
                LEA     PrintLine+78(A5),A1
                MOVE    #4,DØ
                _BlockMove                      ;moves Tape Number

(l)             MOVE    #Ø,-(SP)
(m)             MOVE    D3,-(SP)
(n)             _MoveTo
                MOVEM.L D1/D2/D7,-(SP)
(o)             PEA     PrintLine(A5)
(p)             _DrawString
                MOVEM.L (SP)+,D1/D2/D7

                ADD     D4,D3
(q)
                RTS
```

Actual printing of a single line is handled by PrintOneRecord, beginning at (d). On input, the number of the **TapeArray** record to be printed is stored in register D7. PrintOneRecord begins by calling ClearPrintLine (e) to erase the previous contents of the print string and reset the length byte. Then it assembles the data from **TapeArray** into their proper positions in the print line.

To do so, PrintOneRecord must first compute the main memory address of the particular record being printed. Subroutines to compute such addresses already exist as part of the straight-insertion sort (see Listing 5.1 or 6.1) and therefore can simply be called rather than rewritten (f). Using the address returned by ComputeAddress2, PrintOneRecord then moves one field at a time with repeated calls to **BlockMove**. The starting address of the field being moved is loaded into A0 (g), the starting position for the field in the print string into A1 (h), and the length of the field into D0 (i). The transfer is completed with the operating system call (j).

Steps (g) through (j) are repeated for each field. Note, however, that there is an extra step required for all fields but the first one. The offset of the field in the record must be added to the starting address of the record. For example, at (k) PrintOneLine adds the offset of the Rating field. The offsets have been equated to symbolic addresses for ease of use.

The actual printing process begins at (l) with the set-up sequence to move the pen. The horizontal coordinate is moved onto the stack; it's value is 0 since printing

should begin at the far left-hand side of the page. The vertical coordinate follows it (m); it's value is stored in D3 while the page is being printed. A call to **MoveTo** actually moves the pen (n). To draw the print string, a pointer to the string is pushed onto the stack (o) followed by the call to **DrawString** (p).

Only one task remains. The register containing the vertical print coordinate, D3, must be incremented by the height of a single print line to prepare for printing the next line. Therefore, the contents of D4 (the register set aside to contain the height of a print line) are added to D3 (q). PrintOneLine can then return to the part of the program that called it.

There is an alternative to using one string to print an entire line: rather than moving the text to be printed into a single place, each string can be drawn individually. In this case, the strategy is:

1. Set font characteristics (**TextFont, TextFace, TextSize**)
2. Move the pen to the beginning horizontal and vertical position of the line (**MoveTo**)
3. Draw the first string (**DrawString**)
4. Set font characteristics if desired (**TextFont, TextFace, TextSize**)
5. Move the pen horizontally (using the same vertical coordinate) to the position of the next set of characters on the line (**MoveTo**)
6. Draw the string (**DrawString**)
7. Repeat steps 4 through 6 until the entire line is printed

The advantage to this second strategy is that you can vary the font characteristics of the text across the line, something which is not possible when the entire print line is a single string.

Printing Text with DrawText

DrawText prints an entire line of text from a specified storage location in RAM. It differs somewhat from **DrawString**. When using **DrawString**, an application pushes a pointer to the text onto the stack; the length of the string is imbedded in the string itself. **DrawText** requires a pointer to the starting location of an entire block of text, an offset into that block, and the number of bytes to print:

```
PROCEDURE DrawText (textBuf:QDPtr;firstByte,byteCount:
    INTEGER);
```

It is therefore best suited to printing text that is stored in a text edit record.

Since **DrawString** does not do any text formatting, it does not know where TextEdit marked the end of lines. Therefore, an application must use two pieces of

information from the text edit record to control the printing operations – the total number of lines in the text and the character positions of the line starts.

The strategy to print text from a text edit record is:

1. Get handle to the text edit record (**TEGetText**)
2. De-reference handle to get a pointer to the text
3. Retrieve total number of lines in the text
4. Initialize a line counter
5. Check to see if the counter contains the number of the last line. If so, jump to step 11.
6. Retrieve starting position of current line
7. Retrieve starting position of next line
8. Subtract starting position of current line from starting position of next line to obtain number of characters in current line
9. Print the line (**DrawText**)
10. Increment the line counter. Jump to step 5.
11. Retrieve total number of characters
12. Subtract starting position of last line from total number of characters +1 to obtain number of characters in last line
13. Print the line (**DrawText**).

The Video Tape Index's implementation of this procedure to print annotations appears in Listing 10.2. The code that begins with EnoughRoom is initiated after the program determines that there is enough room left on the page to print the entire annotation.

The first step is to call PrintOneLine to print the data from **TapeArray** that applies to the tape in question (a). A blank line must then appear between the **TapeArray** data and the first line of the annotation. Getting a blank line is straightforward – the register holding the vertical position of the pen (D3) is simply incremented by the height of a single line (held in D4) without printing any text (b).

Printing the annotation requires a loop that uses the total number of lines in the annotation as a target value. Therefore, before the actual printing can begin, the program must retrieve the number of lines from the text edit record. The three statements beginning at (c) get the handle to the text edit record and de-reference it to obtain a pointer to the record. The number of lines in the text is then stored in D0 (d). D1 is initialized to act as a line counter (e).

As indicated in the printing procedure described above, the last line in the text must be handled separately from all other lines. The first activity in the printing loop must therefore be a "look ahead" to determine if the last line has been reached. The line counter is incremented by 1 (f) and compared to the total number of lines in the

text (g). If the two values are equal, the program branches out of the loop to print the last line (h). Assuming that the last line has not been reached, the line counter is decremented to restore the correct line number (i).

Listing 10.2 Printing an Annotation that is Stored in a TextEdit Record

```
        EnoughRoom
                MOVEM.L     D2/D7,-(SP)
(a)             JSR         PrintOneRecord          ;(Listing 1Ø.1)
(b)             ADD         D4,D3                   ;get a blank line
                MOVEM.L     (SP)+,D2/D7

(c)             LEA         AnnotationTextHandle,A2
                MOVE.L      (A2),A2
                MOVE.L      (A2),A2
(d)             MOVE        teNLines(A2),DØ         ;get number of lines again
(e)             MOVE        #Ø,D1

        AnotherLine
                MOVEM.L     D2/D4,-(SP)
(f)             ADDQ        #1,D1                   ;look at next line
(g)             CMP         D1,DØ                   ;at last line?
(h)             BEQ         LastLine
(i)             SUBQ        #1,D1                   ;restore current line #
                MOVE        #2,D4
(j)             MULU        D1,D4                   ;line starts are stored as integers
(k)             MOVE        teLines(A2,D4),D2       ;line start of this line
                ADDQ        #2,D4
(l)             MOVE        teLines(A2,D4),D5       ;start of next line
(m)             SUB         D2,D5                   ;D5 has number of bytes

(n)             CLR.L       -(SP)
(o)             MOVE.L          AnnotationTextHandle,-(SP)
(p)             _TEGetText                          ;get handle to annotation text
                MOVE.L      (SP)+,A6                ;retrieve handle
(q)             MOVE.L      (A6),A6                 ;de-reference to get pointer

(r)             MOVE        #2Ø,-(SP)           ;annotation is indented 2Ø pixels
(s)             MOVE        D3,-(SP)
(t)             _MoveTo

                MOVEM.L     DØ/D1/D7/A2/A6,-(SP)
(u)             MOVE.L      A6,-(SP)                ;pointer to text
(v)             MOVE        D2,-(SP)                ;starting position
(w)             MOVE        D5,-(SP)                ;number of bytes to print
(x)             _DrawText
                MOVEM.L     (SP)+,DØ/D1/D7/A2/A6
                MOVEM.L     (SP)+,D2/D4
(y)             ADDQ        #1,D1                   ;increment line counter
(z)             ADD         D4,D3                   ;space to next line
(aa)            BRA         AnotherLine

        LastLine
                SUBQ        #1,D1                   ;restore current line #
                MOVEM.L     D1/D3/D7/A2/A6,-(SP)
                MULU        #2,D1
```

(continued)

Listing 10.2 (continued)

```
(bb)        MOVE        teLines(A2,D1),D5       ;start of last line

(cc)        MOVE        #257,DØ                 ;total characters + 1
            SUB         D5,DØ                   ;characters left to print

            MOVE        #2Ø,-(SP)
            MOVE        D3,-(SP)
            _MoveTo

            MOVE.L      A6,-(SP)
            MOVE        D5,-(SP)
            MOVE        DØ,-(SP)
            _DrawText
            MOVEM.L     (SP)+,D1/D3/D7/A2/A6
            MOVEM.L     (SP)+,D2/D4

(dd)        ADD         D4,D3                   ;one blank line
            ADD         D4,D3                   ;another blank line
```

The next task is to prepare for the call to **DrawText** which will be used to print a single line. **DrawText** needs to know the starting address of the text, a byte offset into that text where printing should start, and the total number of characters to print.

The positions within the text where new lines start are stored in the text edit record as integers. The start of the first line is stored immediately after the total number of lines in the text. Therefore, the starting position of the line being printed can be found by:

1. Multiplying the line number by 2 to account for the line starts being stored as integers (j)

2. Adding that result to the starting address of the text edit record and the offset for the number of lines, **telines** (k).

Statement (k) stores the line start in D0.

In order to figure out the number of characters in the line, the program also needs the line start of the following line (l). Then it subtracts the starting position of the current line from the starting position of the next line to obtain the number of characters in the current line (m).

The final piece of data needed by **DrawText** is the starting address of the text itself. **TEGetText** will return a handle to the text in a text edit record. The program

calls it by clearing space on the stack for the handle result (n), pushing the handle to the text edit record on the stack (o), and then calling the routine (p). Once the result is pulled from the stack it must be de-referenced to obtain a pointer (q).

Before actually printing, the pen must be moved. Since the annotation is indented from the left-hand margin of the page, the horizontal position is not 0, but 20, an arbitrary indentation chosen merely because it looks nice on the page (r). The vertical coordinate is again taken from register D3, which stores the vertical position while a page is printed (s). **MoveTo** takes care of positioning the pen (t).

The set-up for the call to **DrawText** requires pushing the pointer to the text onto the stack (u), followed by the starting position in the text (v), and the total number of bytes to print (w). The call actually draws the text (x).

The program then increments the line counter (y) and the vertical position of the pen (z). This completes printing one line of the annotation. Therefore, the program must branch to print another line (aa).

Printing the last line is only slightly different from printing the other lines. The difference lies in determining how many characters are in the line. For the last line, there is no "next" line. The total number of characters in the last line is equal to the starting position of the last line (bb) subtracted from the total number of characters in the text plus 1 (cc). The remainder of the procedure is exactly the same.

Once the annotation is printed, the final task is to print two blank lines beneath it. This is accomplished by simply incrementing the vertical position of the pen twice (dd).

Finishing a page

Generally, an application will decide to finish printing a page when the vertical pen coordinate is greater than or equal to the bottom of the page coordinate, or when the entire document has been printed. (The Video Tape Index closes a page when all records from TapeArray have been printed, even though an entire physical page may not be filled.) When that occurs, a call to **PrClosePage** is necessary. If the application is draft printing, the call will eject the current page and, if printing from single sheets, will prompt the user to insert another sheet. If the application is spool printing, the call will simply close the printer port for the page being printed.

Calling **PrClosePage** needs only a pointer to the printer port as a parameter:

```
PROCEDURE PrClosePage (pPrPort: TPPrPort);
```

At this point, the application must decide whether there are more pages to print or whether the document should be closed.

Imaging and Printing Spool Files

As far as the Macintosh is concerned, the term *imaging* refers to the process of taking the picture of a printed page that is stored in a spool file and turning it into an array of dots of the right size and shape. That array can then be sent to the printer one band at a time, so the printer can easily print the page from the top down.

Assuming that there is sufficient memory to hold the image of a single band from a page of the spool file, imaging and printing the file is a simple process – it requires only a call to **PrPicFile**. This routine takes care of breaking the spool file into bands for printing, bringing the bands into memory one by one, and printing them.

The format of **PrPicFile** is:

```
PROCEDURE PrPicFile (hPrint: THPrint; pPrPort: TPPrPort:
    pIOBuf: Ptr; pDevBuf: Ptr; VAR prStatus: TPrStatus);
```

The first parameter, **hPrint**, is the handle to the print record. The second parameter, **pPrPort**, looks, at first, to be the same as the printer port used to create the spool file, but it is not. The printer port created by **PrOpenDoc** was closed by the call to **PrCloseDoc**. **PrPicFile** requires its own printer port. A value of 0 for **pPrPort** will instruct the system to allocate its own printer port.

pIOBuf is a pointer to the area in memory which should be used to hold information as it is read from the disk. Though application may set aside its own area, generally it's just as easy to pass a 0 for this parameter, allowing the system to use the disk volume's buffer for this purpose. **pDevBuf** is also a pointer. It locates an area known as the "band buffer" that is used to hold data to be printed. Passing a 0 for **pDevBuf** will cause the system to allocate the buffer on the heap.

The variable parameter **PrStatus** is a pointer to a printer status record. The printer status record monitors the activity of the system while it is printing from a spool file. The structure of a status record is:

```
TPrStatus = RECORD
        iTotPages:      INTEGER;    total number of pages
        iCurPage:       INTEGER;    page being printed
        iTotCopies:     INTEGER;    number of copies to print
        iCurCopy:       INTEGER;    copy being printed
        iTotBands:      INTEGER;    number of bands per page
        iCurBand:       INTEGER;    band being printed
        fPgDirty:       BOOLEAN;    TRUE if page is being printed
        fImaging:       BOOLEAN;    TRUE if page is being imaged
        hPrint:         THPrint;    handle to print record
        pPrPort:        TPPrPort;   pointer to printing port
        hPic:           PicHandle;  used internally – do not change
END;
```

An application must allocate space for the entire printer status record:

```
PrinterStatusRec DS.B  iPrStatSize  ;where iPrStatSize is
                                    equated to the total number
                                    of bytes in a printer
                                    status record
```

The printer status record is generally most useful to applications that are running their own background procedure. The background procedure can repeatedly check the fields of the printer status record to determine the status of the printing process. If an application relies on the default background procedure, the printer status record is of minimal importance.

The code to image and print a spool file from the Video Tape Index program appears as follows:

```
MOVE.L   PrintRecordHandle(AS), -(SP)   ;put handle on stack
CLR.L    -(SP)                          ;system allocates it own
                                        printing port
CLR.L    -(SP)                          ;system uses volume I/O
                                        buffer
CLR.L    -(SP)                          ;system uses it own
                                        band buffer
PEA      PrinterStatusRec(A5)           ;push address
JSR      PrPicFile                      ;image and print
```

Completing the Printing Task

When an application has finished printing, regardless of whether it has draft printed or imaged and printed a spool file, there is no longer any need to retain the print record on the heap. The storage held by the print record should therefore be released through a call to **DisposHandle**:

```
PROCEDURE DisposHandle (h: Handle);
```

The handle to the print record must be in A0 before calling the routine:

```
MOVE.L     PrintRecordHandle(AS),A0  ;get the handle
__DisposHandle                       ;release the heap storage
```

The final step is, as discussed earlier in this chapter, to call **PrClose** to close the Printing Manager.

Putting it All Together — BannerPrint

BannerPrint is a demonstration program that prints large upper-case letters sideways on 8 1/2 x 11 computer paper. To create a banner, the sheets of paper must be separated and then taped together to hide the gaps between the pages. Source code for BannerPrint appears in Listing 10.3; its resource file can be found in Listing 10.4.

BannerPrint creates a small text edit window in which the user can enter upper-case letters and spaces. The standard editing functions are supported in that window. The banner can be draft or spool printed; which method is used is determined by the user's choice in the standard job dialog box.

The large letters are stored as strings in the code portion of the program (i.e., they are defined as constants). There are certainly other ways to specify how the letters should be printed, but this particular method was chosen because it is easy to type in from a printed listing; you can see the shape of the letters on the screen as you work. Note that while each string has its own **DC** directive, it doesn't have a unique name. The symbolic address **Letters** refers to the entire block of letter templates.

While each line of a letter is exactly 30 characters long, all the letters are not made up of the same number of lines (i.e., "I" has only four lines, "W" and "M" have 16, and all the rest have 12). That means that the program must have some way of locating the start of a letter within the **Letters** block. BannerPrint uses a technique known as a "jump table."

The jump table (stored under the symbolic address **JumpTable**) itself consists of 26 numbers. Each corresponds to the number of bytes the start of a letter template is offset from the address assigned to **Letters**. Therefore, if the program knows the ordinal position of a character in the alphabet, it can look in the jump table to discover how far beyond **Letters** it should begin. The ordinal position a character is determined by comparing it against the letters in the alphabet; those letters are stored as **OrdinalList**.

BannerPrint must also have a way to determine when all the lines of a particular character have been printed; since the number of lines per character vary, it can't simply count lines printed. Instead, the program looks ahead to the next line. If the first non-blank character in the next line is different from the character being printed, then the character must be complete.

To keep it relatively short, BannerPrint was written without a number of checks that would catch user errors. It does not, for example, trap the situation where the user enters a character other than an upper-case letter or a space. It also does not prompt the user to ready the printer. For suggestions on what you can do to make the program "bullet-proof," see Problem 10.

Listing 10.3 BannerPrint

```
        Include MacTraps.D
        Include ToolEqu.D
        Include SysEqu.D
        Include PrEqu.Txt
        Include QuickEqu.D

        PEA     -4(A5)
        _InitGraf'
        _InitFonts
        MOVE.L #$0000FFFF,D0
        _FlushEvents
        _InitWindows
        _InitMenus
        CLR.L  -(SP)
        _InitDialogs
        _TEInit
        _InitCursor

        CLR     -(SP)
        PEA     'MAL.files:BannerPrint.Rsrc'
        _OpenResFile                    ;open resource file
        MOVE    (SP)+,D0                ;discard unused result

;------------------------- Set up menus -------------------------------
        CLR.L  -(SP)                    ;space for handle
        MOVE   #1,-(SP)                 ;menu ID
        _GetRMenu                       ;get Apple menu template
        MOVE.L (SP)+,AppleHandle(A5)            ;retrieve & store handle

        MOVE.L AppleHandle(A5),-(SP)            ;put handle back on stack
        MOVE.L #'DRVR',-(SP)            ;resource type for desk accessories
        _AddResMenu                     ;get desk accessories

        MOVE.L AppleHandle(A5),-(SP)
        CLR     -(SP)                   ;put the menu after all others
        _InsertMenu                     ;put menu in menu list

        CLR.L  -(SP)                    ;repeat procedure for other menus
        MOVE   #2,-(SP)
        _GetRMenu
        MOVE.L (SP)+,FileHandle(A5)

        MOVE.L FileHandle(A5),-(SP)
        CLR     -(SP)
        _InsertMenu

        CLR.L  -(SP)
        MOVE   #3,-(SP)
        _GetRMenu
        MOVE.L (SP)+,EditHandle(A5)

        MOVE.L EditHandle(A5),-(SP)
```

(continued)

Listing 10.3 (continued)

```
        CLR     -(SP)
        _InsertMenu

        _DrawMenuBar

; ------------------------ Event loop starts here ------------------------
        MOVE    #0,WindowFlag(A5)                       ;will be set if window is
                                                         present

Event   _SystemTask                             ;update desk accessories

        MOVE    WindowFlag(A5),D0               ;text edit window open?
        BEQ     NoWindow
        MOVE.L TextHandle(A5),-(SP)
        _TEIdle

NoWindow
        CLR     -(SP)                           ;space for boolean result
        MOVE    #-1,-(SP)                       ;mask to select all events
        PEA     EventRecord(A5)                         ;pointer to event record
        _GetNextEvent

        MOVE    (SP)+,D0                        ;retrieve boolean result
        BEQ     Event                           ;no event

        MOVE    EventRecord(A5),D0              ;get event type

        CMP     #mButDwnEvt,D0                          ;mouse down event?
        BEQ     MouseEvent

        CMP     #keyDwnEvt,D0                   ;key down event?
        BEQ     KeyEvent

        CMP     #upDatEvt,D0
        BEQ     Update

        BRA     Event

;-------------------------- Handle key down events ----------------------
KeyEvent
        MOVE    EventRecord+evtMeta(A5),D0
        BTST.L #cmdKey,D0                       ;command key pressed?
        BNE     KeyboardEquivalent

        MOVE    EventRecord+evtMessage+2(A5),-(SP)      ;character pressed
        MOVE.L TextHandle(A5),-(SP)
        _TEKey                                  ;insert character

        BRA     Event

KeyboardEquivalent
        CLR.L   -(SP)                           ;place for menu ID & item number
        MOVE    EventREcord+evtMessage+2(A5),-(SP)      ;character
        _MenuKey

        BRA     Selections                      ;process with mouse down selection
```

(continued)

```
; ---------------------- Update the text window --------------------
Update
        MOVE.L CharWindPtr(A5),-(SP)
        _BeginUpdate

        MOVE.L CharWindPtr(A5),-(SP)
        _SetPort

        PEA    ViewRect(A5)
        MOVE.L TextHandle(A5),-(SP)
        _TEUpdate

        MOVE.L CharWindPtr(A5),-(SP)
        _EndUpdate

        BRA    Event
; ---------------------- Handle mouse down events ------------------------
MouseEvent
        CLR    -(SP)                        ;space for "what" result
        MOVE.L EventRecord+evtMouse(A5),-(SP)   ;place where event occurred
        PEA    WhichWindowPtr(A5)           ;window affected goes here
        _FindWindow                         ;get exact location of event
        MOVE   (SP)+,D0                     ;recover result

        CMP    #inMenuBar,D0                ;in menu bar?
        BEQ    MenuBar

        CMP    #inSysWindow,D0                    ;desk accessory?
        BEQ    SysEvent

        CMP    #inContent,D0                ;in the text edit window?
        BEQ    ApplWindow

        CMP    #inGoAway,D0                 ;close the window?
        BEQ    GoAwayBox

        BRA    Event                        ;not an event this program handles

; -------------------- Handle events in system windows ------------------
SysEvent
        PEA    EventRecord(A5)
        MOVE.L WhichWindowPtr(A5),-(SP)   ;window posting event
        _SystemClick                        ;let system handle it

        BRA    Event

;-------------------- Handle events in content area of window -------------
ApplWindow
        PEA    EventRecord+evtMouse(A5)   ;place where event occurred
        _GlobalToLocal                            ;make local

        MOVE.L EventRecord+evtMouse(A5),-(SP)    ;coordinates now local
        MOVE   EventRecord+evtMeta(A5),D0
        BTST.L #shiftKey,D0                 ;extended selection?
        SNE    D0
        MOVE.B D0,-(SP)                     ;extend or not extend
```

(continued)

Listing 10.3 (continued)

```
        MOVE.L TextHandle(A5),-(SP)
        _TEClick                        ;establish the selection range

        BRA    Event

; ------------------- Handle events in the menu bar -----------------------
MenuBar
        CLR.L  -(SP)                    ;space for menu ID and menu item
        MOVE.L EventRecord+evtMouse(A5),-(SP)  ;place where event occurred
        _MenuSelect                     ;find menu ID and menu item

Selections
        MOVE.L (SP)+,D7                 ;recover result
        MOVE   D7,D6                    ;D6 now has menu item
        SWAP   D7                       ;low-order word has menu ID

        CLR    -(SP)                    ;selects all menus
        _HiLiteMenu                     ;remove highlighting from menu

        CMP    #1,D7                    ;apple menu?
        BEQ    AppleMenu

        CMP    #2,D7                    ;file menu?
        BEQ    FileMenu

        CMP    #3,D7                    ;edit menu?
        BEQ    EditMenu

        BRA    Event

;------------------------ Handle desk accessories -------------------------
AppleMenu
        MOVE.L AppleHandle(A5),-(SP)
        MOVE   D6,-(SP)                 ;menu item
        PEA    DeskAccName(A5)                  ;space for desk accessory name
        _GetItem

        CLR    -(SP)                    ;space for reference number
        PEA    DeskAccName(A5)                  ;item name
        _OpenDeskAcc
        MOVE   (SP)+,D0                 ;discard result

        BRA    Event

; ------------------------ Handle editing --------------------------------
EditMenu
        SUBQ   #1,D6                    ;adjust item selected for SysEdit
        CLR    -(SP)                    ;space for result
        MOVE   D6,-(SP)                 ;adjusted item number
        _SysEdit

        MOVE   (SP)+,D0                 ;get result
        BNE    Event                    ;system handled edit

        ADDQ   #1,D6                    ;restore item number
        CMP    #3,D6                    ;cut?
```

(continued)

```
        BNE     EditMenu2
        MOVE.L TextHandle(A5),-(SP)
        _TECut
        BRA     Event

EditMenu2
        CMP     #4,D6                   ;copy?
        BNE     EditMenu3
        MOVE.L TextHandle(A5),-(SP)
        _TECopy
        BRA     Event

EditMenu3
        CMP     #5,D6                   ;paste?
        BNE     EditMenu4
        MOVE.L TextHandle(A5),-(SP)
        _TEPaste
        BRA     Event

EditMenu4
        CMP     #6,D6                   ;clear?
        BNE     Event
        MOVE.L TextHandle(A5),-(SP)
        _TEDelete
        BRA     Event

;------------------- Handle File Menu ---------------------------------
FileMenu
        CMP     #1,D6                   ;New window?
        BEQ     NewWindow

        CMP     #2,D6                   ;Close the window
        BEQ     CloseWindow

        CMP     #3,D6                   ;Print the banner
        BEQ     Print

        CMP     #4,D6                   ;Quit
        BNE     Event
        RTS                             ;return to Finder

; ------------------ Open a new window with text edit record --------------
NewWindow
        CLR.L   -(SP)                   ;space for window pointer
        MOVE    #1,-(SP)                ;window ID
        PEA     CharWindStrg(A5)        ;window storage
        MOVE.L #-1,-(SP)                ;put window in front
        _GetNewWindow
        MOVE.L (SP)+,CharWindPtr(A5)            ;get pointer

        MOVE.L CharWindPtr(A5),-(SP)
        _SetPort                        ;make this the current grafport

        CLR.L   -(SP)                   ;space for text edit handle
        PEA     DestRect                ;destination rectangle
        PEA     ViewRect                ;view rectangle
```

(continued)

Listing 10.3 (continued)

```
        _TENew                          ;establish text edit record
        MOVE.L (SP)+,TextHandle(A5)             ;get text handle

        MOVE   #1,WindowFlag(A5)        ;set window flag

        MOVE.L TextHandle(A5),-(SP)
        _TEActivate                     ;activate the text window

        BRA    Event

; -------------------- Close a window --------------------------------
GoAwayBox
        CLR.B  -(SP)                    ;space for boolean result
        MOVE.L WhichWindowPtr(A5),-(SP) ;window pointer
        MOVE.L EventRecord+evtMouse(A5),-(SP)   ;point of event
        _TrackGoAway                    ;monitor GoAway box

        MOVE.B (SP)+,D0                 ;get result
        BEQ    Event                    ;don't close

CloseWindow
        MOVE.L TextHandle(A5),-(SP)
        _TEDispose                      ;close text edit record

        MOVE.L CharWindPtr(A5),-(SP)
        _CloseWindow                    ;close the window

        MOVE   #0,WindowFlag(A5)        ;clear window flag

        BRA    Event

; -------------------------- Print the banner ----------------------
Print
        JSR    PrOpen                   ;open printing manager
        MOVE.L #iPrintSize,D0                   ;size of print record
        _NewHandle                      ;space on heap for printer record
        MOVE.L A0,PrRecHandle(A5)       ;save handle

        MOVE.L PrRecHandle(A5),-(SP)
        JSR    PrintDefault             ;fill record with default info

        CLR    -(SP)                    ;space for boolean result
        MOVE.L PrRecHandle(A5),-(SP)
        JSR    PrJobDialog              ;draft or spooled?
        MOVE   (SP)+,D0
        BEQ    Event                    ;user canceled

        CLR.L  -(SP)                    ;space for pointer to printer port
        MOVE.L PrRecHandle(A5),-(SP)
        CLR.L  -(SP)                    ;system will allocate port
        CLR.L  -(SP)                    ;use system I/O buffer
        JSR    prOpenDoc
        MOVE.L (SP)+,PrPortPtr(A5)      ;get the pointer

        MOVE   #monaco,-(SP)
        _TextFont                       ;set the font
```

(continued)

```
        MOVE   #12,-(SP)
        _TextSize                       ;set the size

        PEA    FontInfoStrg(A5)
        _GetFontInfo                    ;get size of font
        MOVE   FontInfoStrg+ascent(A5),D4
        ADD    FontInfoStrg+descent(A5),D4
        ADD    FontInfoStrg+leading(A5),D4      ;height of line
        MOVE.L PrRecHandle(A5),A0
        MOVE.L (A0),A0
        MOVE   prInfo+rPage+bottom(A0),PageBottom(A5)  ;bottom of page

        MOVE.L TextHandle(A5),A0        ;handle to text edit record
        MOVE.L (A0),A0                        ;de-reference to get pointer
        MOVE   teLength(A0),D7                ;number of characters
        MOVE.L teTextH(A0),A0                 ;handle to text
        MOVE.L (A0),A0                        ;pointer to text
        MOVE   #0,D0                    ;initialize index register/character
counter

NewPage
        JSR    StartAPage               ;begins new page at start of character
OuterLoop
        MOVE.B (A0,D0),D6               ;get one character
        MOVE   #0,D1                    ;another index register
        LEA    OrdinalList,A1                 ;address of alphabet

        CMP.B  #' ',D6                        ;is this a blank?
        BNE    Loop1
        MOVE   D4,D2
        MULU   #4,D2
        ADD    D2,D3
        BRA    Endings

Loop1   CMP.B  (A1,D1),D6               ;attempt to identify character
        BEQ    Found
        ADDQ   #1,D1
        BRA    Loop1                    ;character not found

Found   LEA    JumpTable,A1
        MULU   #2,D1                    ;offset into word-sized table
        MOVE   (A1,D1),D5               ;get offset into letter data

        LEA    Letters,A6               ;starting address of letter data

OneLine
        MOVEM.L      D0-D4/D6/D7/A0/A1/A6,-(SP)
        MOVE   #0,-(SP)                 ;horizontal coordinate
        MOVE   D3,-(SP)                 ;vertical coordinate
        _MoveTo                                 ;set the pen
        MOVEM.L      (SP)+,D0-D4/D6/D7/A0/A1/A6

        MOVEM.L      D0-D4/D6/D7/A0/A1/A6,-(SP)
        MOVE.L A6,-(SP)                 ;pointer to start of text
        MOVE   D5,-(SP)                 ;offset into block
        MOVE   #30,-(SP)                ;number of bytes in line
```

(continued)

Listing 10.3 (continued)

```
        _DrawText                           ;draw the line
        MOVEM.L     (SP)+,D0-D4/D6/D7/A0/A1/A6
        ADD     D4,D3                       ;increment vertical pointer
        CMP     PageBottom(A5),D3           ;at bottom of page?
        BLT     SamePage
        JSR     CloseAPage
        JSR     StartAPage                  ;begins new page in middle of character

SamePage
        ADD     #30,D5                      ;offset to next line

        MOVE    D5,A3
BlankCheck
        MOVE.B (A6,A3),D2                   ;get first character of next line
        CMP.B   #' ',D2                         ;is it a blank?
        BNE     CheckChar
        ADDQ    #1,A3                       ;increment index to skip over blank
        BRA     BlankCheck
CheckChar
        CMP.B   D2,D6                       ;has character changed?
        BEQ     OneLine                         ;no change

        ADD     D4,D3                       ;space between characters
        ADD     D4,D3

Endings
        ADDQ    #1,D0                       ;increment character counter
        CMP     PageBottom(A5),D3           ;at bottom of page?
        BLT     RoomLeft
        JSR     CloseAPage
        BRA     NewPage

RoomLeft
        CMP     D0,D7                       ;all characters printed?
        BNE     OuterLoop
        MOVE.L PrPortPtr(A5),-(SP)
        JSR     PrClosePage

        MOVE.L PrPortPtr(A5),-(SP)
        JSR     PrCloseDoc

        MOVE.L PrRecHandle(A5),A0
        MOVE.L (A0),A0
        MOVE.B prJob+bJDocLoop(A0),D0           ;draft or spooled?
        BEQ     DonePrinting

        MOVE.L PrRecHandle(A5),-(SP)
        CLR.L   -(SP)                       ;spooler uses its own printing port
        CLR.L   -(SP)                       ;spooler uses its own buffer
        CLR.L   -(SP)                       ;spooler uses its own device buffer
        PEA     PrStatusRec(A5)
        JSR     PrPicFile                   ;image and print spool file
```

(continued)

```
DonePrinting
        MOVE.L PrRecHandle(A5),A0
        _DisposHandle                   ;free space taken by print record

        JSR     PrClose                         ;close printing manager
        BRA     Update                  ;update window - it was covered by job
                                        ;dialog

StartAPage
        MOVEM.L D0/D4/D7/A0,-(SP)
        MOVE.L PrPortPtr(A5),-(SP)
        CLR.L   -(SP)                   ;no scaling
        JSR     prOpenPage              ;new page
        MOVEM.L         (SP)+,D0/D4/D7/A0

        MOVE    D4,D3                   ;initialize vertical coordinate
        RTS

CloseAPage
        MOVEM.L         D0/D4/D7/A0,-(SP)
        MOVE.L PrPortPtr(A5),-(SP)
        JSR     PrClosePage
        MOVEM.L         (SP)+,D0/D4/D7/A0
        RTS
;---------------------------------- Data Structures ----------------------
CharWindPtr   DS.L   1
CharWindStrg  DS     WindowSize

EventRecord   DS.B   16
WhichWindowPtr       DS.L   1
DeskAccName   DS     16
WindowFlag    DS     1

AppleHandle   DS.L   1
FileHandle    DS.L   1
EditHandle    DS.L   1
TextHandle    DS.L   1
PrRecHandle   DS.L   1
PrPortPtr     DS.L   1
FontInfoStrg  DS     4

PrStatusRec   DS.B   iPrStatSize
PageBottom    DS     1

ViewRect      DC     3,3,47,287
DestRect      DC     3,3,47,287

OrdinalList   DC.B   'ABCDEFGHIJKLMNOPQRSTUVWXYZ'

JumpTable     DC     0,360,720,1080,1440,1800,2160,2520,2880,3000,3360,3720,4080
              DC     4560,4920,5280,5640,6000,6360,6720,7080,7440,7800,8280,8640,
                     9000
```

(continued)

Listing 10.3 (continued)

```
Letters     DC.B        'AAAAAAAAAAAAAAA                    ' ;IMPORTANT NOTE!!!
            DC.B    'AAAAAAAAAAAAAAAAAAAA                ' ;All strings are 30
            DC.B    'AAAAAAAAAAAAAAAAAAAAAAAAAA          '' ;characters in length...
            DC.B    'AAAAAAAAAAAAAAAAAAAAAAAAAAAAAA      '
            DC.B    '          AAAAAAA     AAAAAAAAA'
            DC.B    '          AAAAAAA       AAAAAAA'
            DC.B    '          AAAAAAA       AAAAAAA'
            DC.B    '          AAAAAAA     AAAAAAAAA'
            DC.B    'AAAAAAAAAAAAAAAAAAAAAAAAAAAAAA      '
            DC.B    'AAAAAAAAAAAAAAAAAAAAAAAAAAAA        '
            DC.B    'AAAAAAAAAAAAAAAAAAA                 '
            DC.B    'AAAAAAAAAAAAAAA                     '

            DC.B    'BBBBBBBBBBBBBBBBBBBBBBBBBBBBBB'
            DC.B    'BBBBBBBBBBBBBBBBBBBBBBBBBBBBBB'
            DC.B    'BBBBBBBBBBBBBBBBBBBBBBBBBBBBBB'
            DC.B    'BBBBBBBBBBBBBBBBBBBBBBBBBBBBBB'
            DC.B    'BBBBBB      BBBBBBBB      BBBBBB'
            DC.B    'BBBBBB      BBBBBBBB      BBBBBB'
            DC.B    'BBBBBB      BBBBBBBB      BBBBBB'
            DC.B    'BBBBBB      BBBBBBBB      BBBBBB'
            DC.B    'BBBBBBB   BBBBBBBBBB    BBBBBBB'
            DC.B    ' BBBBBBBBBBBBBB  BBBBBBBBBBBBBB '
            DC.B    '  BBBBBBBBBB       BBBBBBBBBB   '
            DC.B    '    BBBBBB           BBBBBB     '

            DC.B    '   CCCCCCCCCCCCCCCCCCCCCCC     '
            DC.B    '  CCCCCCCCCCCCCCCCCCCCCCCCC    '
            DC.B    ' CCCCCCCCCCCCCCCCCCCCCCCCCCC   '
            DC.B    'CCCCCCCCCCCCCCCCCCCCCCCCCCCCC'
            DC.B    'CCCCCCCCCC           CCCCCCCCCC'
            DC.B    'CCCCCCCC               CCCCCCCC'
            DC.B    'CCCCCCCC               CCCCCCCC'
            DC.B    'CCCCCCCC               CCCCCCCC'
            DC.B    'CCCCCCCC               CCCCCCCC'
            DC.B    ' CCCCCCCCCCC       CCCCCCCCCC  '
            DC.B    '  CCCCCCCCCC       CCCCCCCCCC  '
            DC.B    '    CCCCCCCC       CCCCCCCC    '

            DC.B    'DDDDDDDDDDDDDDDDDDDDDDDDDDDDDD'
            DC.B    'DDDDDDDDDDDDDDDDDDDDDDDDDDDDDD'
            DC.B    'DDDDDDDDDDDDDDDDDDDDDDDDDDDDDD'
            DC.B    'DDDDDDDD               DDDDDDDD'
            DC.B    'DDDDDDDD               DDDDDDDD'
            DC.B    'DDDDDDDD               DDDDDDDD'
            DC.B    'DDDDDDDD               DDDDDDDD'
            DC.B    'DDDDDDDD               DDDDDDDD'
            DC.B    ' DDDDDDDD             DDDDDDDD '
            DC.B    '  DDDDDDDDDDDDDDDDDDDDDDDDDD   '
            DC.B    '    DDDDDDDDDDDDDDDDDDDDDD     '
            DC.B    '       DDDDDDDDDDDDDDDD        '
```

(continued)

```
DC.B   'EEEEEEEEEEEEEEEEEEEEEEEEEEEEEE'
DC.B   'EEEEEEEEEEEEEEEEEEEEEEEEEEEEEE'
DC.B   'EEEEEEEEEEEEEEEEEEEEEEEEEEEEEE'
DC.B   'EEEEEEEEEEEEEEEEEEEEEEEEEEEEEE'
DC.B   'EEEEEEEE    EEEEEE    EEEEEEEE'
DC.B   'EEEEEEEE    EEEEEE    EEEEEEEE'
DC.B   'EEEEEEEE    EEEEEE    EEEEEEEE'
DC.B   'EEEEEEEE    EEEEEE    EEEEEEEE'
DC.B   'EEEEEEEE              EEEEEEEE'
DC.B   'EEEEEEEE              EEEEEEEE'
DC.B   'EEEEEEEE              EEEEEEEE'
DC.B   'EEEEEEEE              EEEEEEEE'

DC.B   'FFFFFFFFFFFFFFFFFFFFFFFFFFFFFF'
DC.B   'FFFFFFFFFFFFFFFFFFFFFFFFFFFFFF'
DC.B   'FFFFFFFFFFFFFFFFFFFFFFFFFFFFFF'
DC.B   'FFFFFFFFFFFFFFFFFFFFFFFFFFFFFF'
DC.B   '            FFFFFF    FFFFFFFF'
DC.B   '            FFFFFF    FFFFFFFF'
DC.B   '            FFFFFF    FFFFFFFF'
DC.B   '            FFFFFF    FFFFFFFF'
DC.B   '                      FFFFFFFF'
DC.B   '                      FFFFFFFF'
DC.B   '                      FFFFFFFF'
DC.B   '                      FFFFFFFF'

DC.B   '   GGGGGGGGGGGGGGGGGGGGGGG    '
DC.B   '  GGGGGGGGGGGGGGGGGGGGGGGGG   '
DC.B   ' GGGGGGGGGGGGGGGGGGGGGGGGGGG  '
DC.B   'GGGGGGGGGGGGGGGGGGGGGGGGGGGGG'
DC.B   'GGGGGGGGGG          GGGGGGGGGG'
DC.B   'GGGGGGGG              GGGGGGGG'
DC.B   'GGGGGGGG  GGGG        GGGGGGGG'
DC.B   'GGGGGGGG  GGGG        GGGGGGGG'
DC.B   'GGGGGGGG  GGGG        GGGGGGGG'
DC.B   ' GGGGGGGGGGGGG    GGGGGGGGGG '
DC.B   '  GGGGGGGGGGG     GGGGGGGGG   '
DC.B   '    GGGGGGGGG     GGGGGGG     '

DC.B   'HHHHHHHHHHHHHHHHHHHHHHHHHHHHHH'
DC.B   'HHHHHHHHHHHHHHHHHHHHHHHHHHHHHH'
DC.B   'HHHHHHHHHHHHHHHHHHHHHHHHHHHHHH'
DC.B   'HHHHHHHHHHHHHHHHHHHHHHHHHHHHHH'
DC.B   '            HHHHHHHH          '
DC.B   '            HHHHHHHH          '
DC.B   '            HHHHHHHH          '
DC.B   '            HHHHHHHH          '
DC.B   'HHHHHHHHHHHHHHHHHHHHHHHHHHHHHH'
DC.B   'HHHHHHHHHHHHHHHHHHHHHHHHHHHHHH'
DC.B   'HHHHHHHHHHHHHHHHHHHHHHHHHHHHHH'
DC.B   'HHHHHHHHHHHHHHHHHHHHHHHHHHHHHH'

DC.B   '||||||||||||||||||||||||||||||'
DC.B   '||||||||||||||||||||||||||||||'
DC.B   '||||||||||||||||||||||||||||||'
DC.B   '||||||||||||||||||||||||||||||'
```

(continued)

Listing 10.3 (continued)

```
DC.B    '      JJJJJJJJ                  '
DC.B    '    JJJJJJJJJJ                  '
DC.B    '  JJJJJJJJJJJJ                  '
DC.B    ' JJJJJJJJJJJJ                   '
DC.B    'JJJJJJJJJJ                      '
DC.B    'JJJJJJJJ                        '
DC.B    'JJJJJJJJ                        '
DC.B    'JJJJJJJJ                        '
DC.B    'JJJJJJJJ                        '
DC.B    ' JJJJJJJJJJJJJJJJJJJJJJJJJJJJJJ'
DC.B    '    JJJJJJJJJJJJJJJJJJJJJJJJJJJJ'
DC.B    '      JJJJJJJJJJJJJJJJJJJJJJJJJJ'
DC.B    '        JJJJJJJJJJJJJJJJJJJJJJJJ'

DC.B    'KKKKKKKKKKKKKKKKKKKKKKKKKKKKKK'
DC.B    'KKKKKKKKKKKKKKKKKKKKKKKKKKKKKK'
DC.B    'KKKKKKKKKKKKKKKKKKKKKKKKKKKKKK'
DC.B    'KKKKKKKKKKKKKKKKKKKKKKKKKKKKKK'
DC.B    '          KKKKKKKKKKKKKK        '
DC.B    '        KKKKKKKKKKKKKKKK        '
DC.B    '     KKKKKKKKKK  KKKKKKKKKK     '
DC.B    '   KKKKKKKKKK      KKKKKKKKKK   '
DC.B    'KKKKKKKKKK           KKKKKKKKKK'
DC.B    'KKKKKKKKK             KKKKKKKKK'
DC.B    'KKKKKKKK               KKKKKKKK'
DC.B    'KKKKKK                   KKKKKK'

DC.B    'LLLLLLLLLLLLLLLLLLLLLLLLLLLLLL'
DC.B    'LLLLLLLLLLLLLLLLLLLLLLLLLLLLLL'
DC.B    'LLLLLLLLLLLLLLLLLLLLLLLLLLLLLL'
DC.B    'LLLLLLLLLLLLLLLLLLLLLLLLLLLLLL'
DC.B    'LLLLLLLL                        '
DC.B    'LLLLLLLL                        '
DC.B    'LLLLLLLL                        '
DC.B    'LLLLLLLL                        '
DC.B    'LLLLLLLL                        '
DC.B    'LLLLLLLL                        '
DC.B    'LLLLLLLL                        '
DC.B    'LLLLLLLL                        '

DC.B    'MMMMMMMMMMMMMMMMMMMMMMMMMMMMMM'
DC.B    'MMMMMMMMMMMMMMMMMMMMMMMMMMMMMM'
DC.B    'MMMMMMMMMMMMMMMMMMMMMMMMMMMMMM'
DC.B    'MMMMMMMMMMMMMMMMMMMMMMMMMMMMMM'
DC.B    '                    MMMMMMMMM   '
DC.B    '                  MMMMMMMMM     '
DC.B    '                MMMMMMMMM       '
DC.B    '              MMMMMMMMM         '
DC.B    '              MMMMMMMMM         '
DC.B    '                MMMMMMMMM       '
DC.B    '                  MMMMMMMMM     '
DC.B    '                    MMMMMMMMM   '
DC.B    'MMMMMMMMMMMMMMMMMMMMMMMMMMMMMM'
DC.B    'MMMMMMMMMMMMMMMMMMMMMMMMMMMMMM'
DC.B    'MMMMMMMMMMMMMMMMMMMMMMMMMMMMMM'
DC.B    'MMMMMMMMMMMMMMMMMMMMMMMMMMMMMM'
```

(continued)

```
DC.B   'NNNNNNNNNNNNNNNNNNNNNNNNNNNNNN'
DC.B   'NNNNNNNNNNNNNNNNNNNNNNNNNNNNNN'
DC.B   'NNNNNNNNNNNNNNNNNNNNNNNNNNNNNN'
DC.B   'NNNNNNNNNNNNNNNNNNNNNNNNNNNNNN'
DC.B   '                    NNNNNNNNN   '
DC.B   '                  NNNNNNNNN     '
DC.B   '                NNNNNNNNN       '
DC.B   '              NNNNNNNNN         '
DC.B   'NNNNNNNNNNNNNNNNNNNNNNNNNNNNNN'
DC.B   'NNNNNNNNNNNNNNNNNNNNNNNNNNNNNN'
DC.B   'NNNNNNNNNNNNNNNNNNNNNNNNNNNNNN'
DC.B   'NNNNNNNNNNNNNNNNNNNNNNNNNNNNNN'

DC.B   '    OOOOOOOOOOOOOOOOOOOO     '
DC.B   '  OOOOOOOOOOOOOOOOOOOOOOOO   '
DC.B   ' OOOOOOOOOOOOOOOOOOOOOOOOOO  '
DC.B   'OOOOOOOOOOOOOOOOOOOOOOOOOOOO'
DC.B   'OOOOOOOOO             OOOOOOOO'
DC.B   'OOOOOOOO               OOOOOOO'
DC.B   'OOOOOOOO               OOOOOOO'
DC.B   'OOOOOOOOOO           OOOOOOOOO'
DC.B   'OOOOOOOOOOOOOOOOOOOOOOOOOOOO'
DC.B   ' OOOOOOOOOOOOOOOOOOOOOOOOOO  '
DC.B   '  OOOOOOOOOOOOOOOOOOOOOOOO   '
DC.B   '    OOOOOOOOOOOOOOOOOOOO     '

DC.B   'PPPPPPPPPPPPPPPPPPPPPPPPPPPPPP'
DC.B   'PPPPPPPPPPPPPPPPPPPPPPPPPPPPPP'
DC.B   'PPPPPPPPPPPPPPPPPPPPPPPPPPPPPP'
DC.B   'PPPPPPPPPPPPPPPPPPPPPPPPPPPPPP'
DC.B   '          PPPPPP        PPPPPP'
DC.B   '          PPPPPP        PPPPPP'
DC.B   '          PPPPPP        PPPPPP'
DC.B   '          PPPPPP        PPPPPP'
DC.B   '           PPPPPP      PPPPPP '
DC.B   '           PPPPPPPPPPPPPPPP   '
DC.B   '            PPPPPPPPPPPPPP    '
DC.B   '              PPPPPPPPPP      '

DC.B   '    QQQQQQQQQQQQQQQQQQQQ     '
DC.B   '  QQQQQQQQQQQQQQQQQQQQQQQQ   '
DC.B   ' QQQQQQQQQQQQQQQQQQQQQQQQQQ  '
DC.B   'QQQQQQQQQQQQQQQQQQQQQQQQQQQQ'
DC.B   'QQQQQQQQQ             QQQQQQQQ'
DC.B   'QQQQQQQQ   QQQ         QQQQQQQ'
DC.B   'QQQQQQQQ  QQQ          QQQQQQQ'
DC.B   'QQQQQQQQQQQQ          QQQQQQQQ'
DC.B   'QQQQQQQQQQQQQQQQQQQQQQQQQQQQQQ'
DC.B   ' QQQQQQQQQQQQQQQQQQQQQQQQQQQQ  '
DC.B   '  QQQQQQQQQQQQQQQQQQQQQQQQ    '
DC.B   '    QQQQQQQQQQQQQQQQQQQQ      '
```

(continued)

Listing 10.3 (continued)

```
        DC.B    'RRRRRRRRRRRRRRRRRRRRRRRRRRRRRR'
        DC.B    'RRRRRRRRRRRRRRRRRRRRRRRRRRRRRR'
        DC.B    'RRRRRRRRRRRRRRRRRRRRRRRRRRRRRR'
        DC.B    'RRRRRRRRRRRRRRRRRRRRRRRRRRRRRR'
        DC.B    '          RRRRRR        RRRRRR'
        DC.B    '        RRRRRRRR        RRRRRR'
        DC.B    '      RRRRRRRRRR        RRRRRR'
        DC.B    '     RRRRRRRRRR         RRRRRR'
        DC.B    '  RRRRRRRRRRRRRR      RRRRRR  '
        DC.B    'RRRRRRRRR   RRRRRRRRRRRRRRR   '
        DC.B    'RRRRRRRR     RRRRRRRRRRRRR    '
        DC.B    'RRRRRR         RRRRRRRRRR     '

        DC.B    '   SSSSS       SSSSSSSSSS     '
        DC.B    '  SSSSS      SSSSSSSSSSSSS    '
        DC.B    ' SSSSS      SSSSSSSSSSSSSSS   '
        DC.B    'SSSSSS     SSSSSSSSSSSSSSSSS  '
        DC.B    'SSSSSS     SSSSSSS     SSSSSSS'
        DC.B    'SSSSSS     SSSSSS       SSSSSS'
        DC.B    'SSSSSS     SSSSSS       SSSSSS'
        DC.B    'SSSSSS     SSSSSS       SSSSSS'
        DC.B    ' SSSSSSSSSSSSSS         SSSSSS'
        DC.B    '  SSSSSSSSSSSS          SSSSS '
        DC.B    '    SSSSSSSS           SSSSS  '
        DC.B    '      SSSSS                   '

        DC.B    '                      TTTTTTTT'
        DC.B    '                      TTTTTTTT'
        DC.B    '                      TTTTTTTT'
        DC.B    '                      TTTTTTTT'
        DC.B    'TTTTTTTTTTTTTTTTTTTTTTTTTTTTTT'
        DC.B    'TTTTTTTTTTTTTTTTTTTTTTTTTTTTTT'
        DC.B    'TTTTTTTTTTTTTTTTTTTTTTTTTTTTTT'
        DC.B    'TTTTTTTTTTTTTTTTTTTTTTTTTTTTTT'
        DC.B    '                      TTTTTTTT'
        DC.B    '                      TTTTTTTT'
        DC.B    '                      TTTTTTTT'
        DC.B    '                      TTTTTTTT'

        DC.B    '     UUUUUUUUUUUUUUUUUUUUUUUUU'
        DC.B    '   UUUUUUUUUUUUUUUUUUUUUUUUUU'
        DC.B    ' UUUUUUUUUUUUUUUUUUUUUUUUUUU'
        DC.B    'UUUUUUUUUUUUUUUUUUUUUUUUUUUU'
        DC.B    'UUUUUUUUUUUUU                '
        DC.B    'UUUUUUUUUUU                  '
        DC.B    'UUUUUUUUUUU                  '
        DC.B    'UUUUUUUUUUUUU                '
        DC.B    'UUUUUUUUUUUUUUUUUUUUUUUUUUUU'
        DC.B    ' UUUUUUUUUUUUUUUUUUUUUUUUUU'
        DC.B    '   UUUUUUUUUUUUUUUUUUUUUUUU'
        DC.B    '     UUUUUUUUUUUUUUUUUUUUUU'
```

(continued)

```
DC.B   '                        UUUUUUUUUU'
DC.B   '                    UUUUUUUUUU    '
DC.B   '                UUUUUUUUUU        '
DC.B   '            UUUUUUUUUU            '
DC.B   '        UUUUUUUUUU                '
DC.B   'UUUUUUUUU                         '
DC.B   'UUUUUUUUU                         '
DC.B   '        UUUUUUUUUU                '
DC.B   '            UUUUUUUUUU            '
DC.B   '                UUUUUUUUUU        '
DC.B   '                    UUUUUUUUUU    '
DC.B   '                        UUUUUUUUUU'

DC.B   'WWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWW'
DC.B   'WWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWW'
DC.B   'WWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWW'
DC.B   'WWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWW'
DC.B   '  WWWWWWWWW                       '
DC.B   '    WWWWWWWWW                     '
DC.B   '      WWWWWWWWW                   '
DC.B   '        WWWWWWWWW                 '
DC.B   '        WWWWWWWWW                 '
DC.B   '      WWWWWWWWW                   '
DC.B   '    WWWWWWWWW                     '
DC.B   '  WWWWWWWWW                       '
DC.B   'WWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWW'
DC.B   'WWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWW'
DC.B   'WWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWW'
DC.B   'WWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWW'

DC.B   'XXXX                        XXXX'
DC.B   'XXXXXXXX                  XXXXXXX'
DC.B   'XXXXXXXXXXX             XXXXXXXXXX'
DC.B   '   XXXXXXXXXXXX XXXXXXXXXXX     '
DC.B   '      XXXXXXXXXXXXXXXXXX        '
DC.B   '          XXXXXXXXXX            '
DC.B   '          XXXXXXXXX             '
DC.B   '      XXXXXXXXXXXXXXXXXX        '
DC.B   '   XXXXXXXXXXXX XXXXXXXXXXX     '
DC.B   'XXXXXXXXXXX             XXXXXXXXXX'
DC.B   'XXXXXXXX                  XXXXXXX'
DC.B   'XXXX                        XXXX'

DC.B   '                            YYYY'
DC.B   '                          YYYYYYY'
DC.B   '                        YYYYYYYYYY'
DC.B   '                    YYYYYYYYYY    '
DC.B   'YYYYYYYYYYYYYYYYYYYYYYYYYY        '
DC.B   'YYYYYYYYYYYYYYYYYYYYYYYY          '
DC.B   'YYYYYYYYYYYYYYYYYYYYYY            '
DC.B   'YYYYYYYYYYYYYYYYYYYYYYYYYY        '
DC.B   '                    YYYYYYYYYY    '
DC.B   '                        YYYYYYYYYY'
DC.B   '                          YYYYYYY'
DC.B   '                            YYYY'
```

(continued)

Listing 10.3 (continued)

```
DC.B   'ZZZZZZZZ              ZZZZZZZZ'
DC.B   'ZZZZZZZZZZZ           ZZZZZZZZ'
DC.B   'ZZZZZZZZZZZZZZ        ZZZZZZZZ'
DC.B   'ZZZZZZZZZZZZZZZZZ     ZZZZZZZZ'
DC.B   'ZZZZZZZZZZZZZZZZZZZZ  ZZZZZZZZ'
DC.B   'ZZZZZZZZZZZZZZZZZZZZZZZZZZZZZZ'
DC.B   'ZZZZZZZZZZZZZZZZZZZZZZZZZZZZZZ'
DC.B   'ZZZZZZZZ  ZZZZZZZZZZZZZZZZZZZZ'
DC.B   'ZZZZZZZZ    ZZZZZZZZZZZZZZZZZ'
DC.B   'ZZZZZZZZ       ZZZZZZZZZZZZZZ'
DC.B   'ZZZZZZZZ          ZZZZZZZZZZZ'
DC.B   'ZZZZZZZZ             ZZZZZZZZ'
```

Listing 10.4 Resource File for BannerPrint

```
BannerPrint.Rsrc

TYPE MENU
 ,1
\14

 ,2
File
New/N
Close/W
Print/P
Quit/Q

 ,3
Edit
Undo/Z
(-
Cut/X
Copy/C
Paste/V
Clear

TYPE WIND
 ,1
Banner Text
5Ø 11Ø 1ØØ 4ØØ
Visible GoAway
Ø
Ø
```

Questions and Problems

1. When doing draft printing, the Printing Manager will print only one copy of a document, regardless of the contents of the **iCopies** field in the print record. Write assembly language code to control the printing of multiple draft copies. For the actual printing details, include:

   JSR PrintOneCopy

   in the body of your loop. Assume that print record has been allocated and has a handle stored as **PrRecHandle** in the applications globals area.

2. Write assembly language code to change the name of a spool file the Printing Manager will create from the default "Print File" to any other name of your choosing. Allocate any data structures your code will require. Assume the print record has been allocated and has a handle stored as **PrRecHandle** in the applications globals area.

3. Write pseudocode that describes the logic necessary to print a multi-page document. Indicate the details of drawing a single page by writing "Draw one page." (The purpose of this problem is to summarize the sequence of Printing Manager calls.) Use the names of Printing Manager routines as appropriate.

4. If you look carefully at Figure 10.2 (spooled output), you will notice that the line under the column headings stretches across the entire page. This occurs because the entire line is printed as one string.

   A. Suggest a strategy that would restrict the underlining to the column headings themselves, as it appears in Figure 10.1 (draft output).
   B. What difficulty does this present for the programmer? Hint: think in terms of what information is required to properly space the heading.

5. Assume that an array of data is stored in the applications globals area. A pointer to the starting location of the array has the symbolic address **BookStuff**. Each record is 80 bytes long. The fields within the array are defined by the following equates:

```
Title       EQU  0
Author      EQU  30
Publisher   EQU  50
Date        EQU  75
```

Write the assembly language code that draws one record from this array onto a printer port. Assume:

a. The print line will hold 100 characters.
b. The number of the record being printed is in D0.
c. All necessary Printing Manager calls have been made.
d. The current vertical pen position is in D1.
e. The height of the print line is in D2.

Format the lines so there is space between the fields even when each field contains the maximum number of characters.

6. Expand the code from problem 5 to print an entire page. As well as adding a loop to print repeated records from the array, include:

   a. A page number in the upper right-hand corner of the page (retrieve it from the printer record which is stored under **PrRecHandle**)
   b. A page heading of your choice centered on the page two lines below the page number
   c. A heading above each column, three lines below the page heading

   Assume that the page's bottom coordinate is stored in D3. All necessary printing manager calls have been made. The code need not check to see if all records in the array have been printed, but does need to check for the bottom of the page. Print the records single spaced.

7. Modify the code from problem 6 to set font characteristics as follows:

   a. The page number should be boldface.
   b. The page heading should be boldface and underlined.
   c. Column headings should be standard print and underlined.
   d. All headings should be printed using the system font (Chicago); the body of the page (the records themselves) should use the Geneva font.

8. Write a block of assembly language code that decides whether a user requested spooled or draft printing. Assume that the print record has a handle, **PrRecHandle**, stored in the applications globals area.

9. Expand the code from problem 8 to image and print the spool file.

10. As mentioned at the end of this chapter, the program BannerPrint is far from bullet-proof. As it appears in Listing 8.3, it has many holes into which a user could fall. Code and implement the following modifications to BannerPrint, each of which will isolate a user from his or her mistakes:

    A. Write an alert template to indicate that the user has entered something other than an upper-case letter or a space. Store the template in the

resource file (don't forget to recompile it with RMaker). Display the alert at the appropriate place in the program.

B. Write an alert template to get the user to turn on the printer. Store the template in the resource file. Display the alert at the appropriate place in the program. Printing should not begin until the user clicks OK to indicate that the printer is ready.
C. Add code to disable the New option from the File menu when a text edit window is created. Re-enable the New option when the window is closed. Disable the Close option when no window is present; enable it whenever a window is on the screen.
D. Add code to trap lower-case letters and transform them to upper-case before printing. In this case, the alert created in (a) should be displayed only if a character is not a letter or a space.

11. The appearance of the large letters produced by BannerPrint depend entirely on the type font and type size being used. The letters will be unrecognizable if the font is not mono-spaced (i.e., all characters are the same width), but that restriction nonetheless leaves a great deal of flexibility in font size and style. Code and implement the following enhancements to BannerPrint to give the user more choices:

    A. Create a Size menu that will allow the user to select the size of the type to be used for printing. A template for the menu should be placed in the resource file.
    B. Create a Style menu that will allow the user to select the style of type to be used for printing (e.g., plain text, boldface, outline, etc.).

    NOTE: changes in size and style should also be reflected in the text displayed in the text edit window.

CHAPTER ELEVEN

FILE I/O

Chapter Objectives

1. To understand the difference between sequential and direct file access
2. To understand the data structures needed to process Macintosh files
3. To learn to create, open, close, read from, and write to both sequential and direct access files
4. To learn to use the Standard File Package to obtain file names and locations for opening and saving files

Introduction

Disk file manipulation is handled by the File Manager. While the routines and their parameter blocks may at first seem rather forbidding, the process is actually much easier than it looks.

When programming in Pascal, you must choose between setting up a file for direct access (with fixed field lengths) or for sequential access (with variable field lengths). As far as the Macintosh is concerned, however, there are only direct access files. That does not mean that a file cannot be processed in a sequential manner.

That last sentence is not double-talk. The terms *direct access* and *sequential access* really refer to how a file is processed, not to any physical characteristics of

the file. Direct access means that records are accessed in random order; that capability usually requires that the records are of a fixed length. Sequential access simply means that the records are accessed in order, starting at the beginning of the file. Assuming that one character (generally a carriage return) signifies the end of a record, files written for only sequential access can have variable record lengths. On the Macintosh it is also possible to move backwards when doing sequential processing. Note also that there is no reason that a file with fixed record lengths (i.e., a file that will permit direct access) cannot be processed in a sequential manner. For simplicity, this chapter will often speak of "direct access" and "sequential" files; such terminology applies only to the manner in which the data in the file are read and written.

The Macintosh keeps track of its current position within a file with a pointer called the *mark*. The mark is always positioned just beyond the last character read or the last character written. In other words, the mark points to the next byte to be read or written. Direct access is therefore achieved by specifying where file operations should occur with respect to either the current position of the mark or the start of the file. The mark is moved whenever read or write activities are performed. There is also a File Manager routine that will set the mark anywhere within a file.

Because file operations are rather slow compared to RAM-based operations, the Macintosh provides the option for an application to execute file operations *asynchronously*. Asynchronous file calls permit the program to continue with other tasks while the file operation is in progress. *Synchronous* file operations force the application to wait for the file operation to finish before proceeding. Synchronous execution is the default mode; asynchronous execution can be specified by setting bit 10 of the routine trap word. This chapter assumes that all file operations are to be executed synchronously.

Macintosh files have two parts, known as *forks*. The *resource fork* contains resource definitions and the code of application programs; the *data fork* is used for storing data. Data files created by applications will usually use only the data fork. In fact, although it is possible to open a file's resource fork from the File Manager, the commonly used routines are directed toward the data fork. The discussion that follows applies only to a file's data fork.

The resource and data forks maintain their own marks. They also maintain their own logical and physical end-of-file pointers. A logical end-of-file pointer is always positioned immediately after the last byte in the file. Since file space is allocated in 1024-byte blocks, the physical end-of-file pointer will be positioned just after the byte which ends the nearest block of 1024 bytes.

Data Structures for File Operations

There are three categories of file manipulation routines: I/O routines, file information routines, and volume information routines. (In this context the term

volume usually refers to a single floppy disk; a volume may also be a partition on a hard drive.) Each group of routines has a lengthy parameter block. The address of the appropriate parameter block must be loaded into A0 before a File Manager routine is called.

The first eight parameters in the block are common to all File Manager routines:

```
ParamBlockRec = RECORD
    qLink:          QElemPtr;     next element in file queue
    qType:          INTEGER;      queue type
    ioTrap:         INTEGER;      routine trap
    ioCmAddr:       Ptr;          routine address
    ioCompletion:   ProcPtr;      completion procedure
    ioResult:       OSErr;        result code
    ioNamePtr:      StringPtr;    volume or file name
    ioVRefNum:      INTEGER;      volume reference number
                                  or drive number
```

qLink and **qType** refer to the system's file queue. Requests to the File Manager are queued, much like events are queued by the Event Manager. The File Manager, unless told otherwise, processes file activities in the order in which they were entered into the queue. **ioTrap** and **ioCmdAddr** relate to the particular routine being called. These four parameters are used solely by the File Manager and, for the most part, can be ignored.

ioCompletion is a pointer to a routine that should be initiated when an asynchronous file operation is completed. If there is no completion routine, **ioCompletion** should be set to 0. For synchronous calls, **ioCompletion** is automatically set to 0 and can therefore be ignored.

ioResult contains a File Manager result code (see Table 11.1). The result code also appears in D0 at the completion of all File Manager routines, which means that an assembly language application rarely needs to check this field of the parameter block.

Result codes do more than report errors; they provide important information about the condition of the file system. Consider, for example, the situation where an application needs to create a data file only if one doesn't already exist. The application can simply attempt to create the file. If a file by the same name already exists, the File Manager will return a result code of −48 ($FFFFFFD0). Therefore, a result code of 0 (no error) or −48 means that the application can proceed to open the file, since creating a file does not open it. Any other result code indicates that something unexpected has happened. The application can either interpret the code further (e.g., to determine if the disk is full) or abort the file request.

The contents of **ioNamePtr** depends on whether the routine being called is directed toward a single file or toward an entire volume. For routines that operate on volumes, it contains a pointer to the name of the volume. For file operations, the field contains a pointer to a file name. Note that a file name may be prefaced by a volume name. In that case, the volume name is separated from the file name by a colon. For example, **tape.index:Annotations** refers to the file called **Annotations** on a disk with the name **tape.index**.

Table 11.1 File Manager Result Codes

Hex Code	Decimal Code	Meaning
Ø	Ø	No error
FFFFFFDF	-33	File directory is full
FFFFFFDE	-34	Disk is full (no free 1Ø24 byte allocation blocks)
FFFFFFDD	-35	Requested volume is not on-line
FFFFFFDC	-36	Unspecific disk I/O error
FFFFFFDB	-37	File or volume name is bad
FFFFFFDA	-38	File is not open
FFFFFFD9	-39	End-of-file encountered when reading
FFFFFFD8	-4Ø	Application tried to put mark before start of file
FFFFFFD7	-41	No space left in system heap
FFFFFFD6	-42	Attempt to open more than 12 access paths
FFFFFFD5	-43	File can't be located
FFFFFFD4	-44	Volume is hardware locked
FFFFFFD3	-45	File is software locked
FFFFFFD2	-46	Volume is software locked
FFFFFFD1	-47	Some files are open
FFFFFFDØ	-48	Duplicate file name
FFFFFFCF	-49	Attempt to open more than one access path/file for writing
FFFFFFCE	-5Ø	No volume specified and there is no default volume
FFFFFFCD	-51	Access path number does not exist
FFFFFFCB	-53	Volume does not exist
FFFFFFCA	-54	Access path will not permit writing
FFFFFFC9	-53	Attempt to mount an already mounted volume
FFFFFFC8	-56	Drive number does not exist
FFFFFFC7	-57	Not at Macintosh volume
FFFFFFC7	-58	Illegal path reference number
FFFFFFC6	-59	Unsuccessful attempt to rename a file
FFFFFFC5	-6Ø	Volume must be reinitialized because master directory block is bad
FFFFFFC4	-61	Access path will not permit writing

ioVRefNum can contain either a reference number to a volume or the drive number that contains a particular volume. Generally, we use the drive number: 1 for the internal drive, 2 for the external drive.

Specific Fields for I/O Routines

Calls to I/O routines require nine fields in addition to the eight fields described above:

```
ioRefNum:    INTEGER;      path reference number
ioVersNum:   SignedByte;   version number
ioPermssn:   SignedByte;   read/write permission
ioMisc:      Ptr;          depends on the routine
ioBuffer     Ptr;          pointer to data buffer
```

ioReqCount	**LONGINT;**	**number of bytes to be transferred**
ioActCount	**LONGINT;**	**actual number of bytes transferred**
ioPosMode:	**INTEGER;**	**newline character and position of start of operation relative to the mark**
ioPosOffset:	**LONGINT;**	**offset from mark or beginning of file**

ioRefNum contains a file's *path reference number*. When a file is opened, the system creates an *access path* to that file. An access path is a description of how the system should get to a file. Twelve different access paths may be open at one time. Any given file can therefore support up to 12 access paths, though only one per file can be used for writing. Each access path has its own mark which moves independently of the marks in any other access paths to that file. The path reference number identifies which specific path should be used in a file operation. The path reference number is returned when a file is opened and passed to routines which read from and write to files.

ioVersNum was designed to allow the Finder to distinguish between two files with the same name on the same disk. In practice, though, the Finder ignores this parameter; the Resource Manager and Segment Loader won't work with files that have non-zero version numbers. Therefore, the version number should always be 0.

The Macintosh allows an application to specify what kinds of operations are permitted on a file; this is known as a file's read/write permission. It is stored in the parameter block in **ioPermssn**. The possible values for **ioPermssn** are:

0: the same as the access path's current permission

1: read only permission

2: write only permission

3: read and write permission

By restricting file activity to reading, for example, an application can protect files that should not be altered.

The contents of **ioMisc** varies with the specific File Manager routine.

ioBuffer is a pointer to an *I/O buffer*. An I/O buffer is an area in RAM from which data is written to the disk or into which data is read. Its size depends on how much data is to be transferred. An application does not necessarily need to set aside a special I/O buffer. For example, since the Video Tape Index program keeps the entire TapeArray in RAM in a single location while the application is running, that block of storage can double as the buffer for accepting the information when it is read from the disk at the beginning of program execution and when it is re-written just before the program ends.

On the other hand, if data are scattered in RAM, then they must be assembled into a single storage block before being written to disk. Reading that same data back into RAM will deposit them into one contiguous block. In that case, an application must allocate enough storage to hold all the data.

ioReqCount is the number of bytes that are to be transferred. That quantity is passed into read and write routines. **ioActCount** is returned by routines that transfer data; it contains the number of bytes actually read or written.

ioPosMode contains information to position the mark for data transfer operations and may also contain the ASCII code of a character that indicates the end of a record. The low-order byte of **ioPosMode** holds the position offset:

0: read and write operations should be at the current position of the mark (**ioPosOffset** is therefore ignored)

1: the offset contained in **ioPosOffset** is the offset, in bytes, from the beginning of the file

2: the offset contained in **ioPosOffset** is the offset, in bytes, from the end of the file

3: the offset contained in **ioPosOffset** is the offset, in bytes, from the current position of the mark.

The use of **ioPosOffset** depends on the value of **ioPosMode**. If **ioPosMode** is 0, the offset parameter is ignored. For an **ioPosMode** of 1, the offset will be added to the starting address of the file; the offset must be positive. When **ioPosMode** is either 2 or 3, the offset will be added to the end of the file or the mark, respectively; the offset may be either positive or negative.

Specific Fields for File Information Routines

The two routines that set and retrieve information about files require 16 parameters in addition to the first eight:

```
ioFRefNum:      INTEGER;      path reference number
ioFVersNum:     SignedByte;   version number
filler1:        SignedByte;   unused
ioFDirIndex:    INTEGER;      file number
ioFlAttrib:     SignedByte;   file attributes
ioFlVersNum:    SignedByte;   version number
ioFlFndrInfo:   FInfo;        a record including file type
ioFlNum:        LONGINT;      file number
ioFlStBlk:      INTEGER;      first 1024 block of data fork
ioFlLgLen:      LONGINT;      logical EOF of data fork
ioFlPyLen:      LONGINT;      physical EOF of data fork
ioFlRStBlk:     INTEGER;      first 1024 block of resource fork
ioFlRLgLen:     LONGINT;      logical EOF of resource fork
```

```
ioFlRPyLen:     LONGINT;    physical EOF of resource fork
ioFlCrDat:      LONGINT;    data & time of file creation
ioFlMDDat:      LONGINT;    data & time of last modification
```

This type of parameter block is used primarily when creating a new file; it supplies information to the Finder about a new file. An application will rarely have to check any of its fields directly. Those parameters which must be passed as part of the file creation sequence are discussed later in this chapter.

Specific Fields for Volume Information Routines

One File Manager routine, **GetVolInfo**, collects information about a specific disk volume. That routine requests its own parameter block, with 14 fields in addition to the eight common fields:

```
filler2:        LONGINT;    unused
ioVolIndex:     INTEGER;    volume index
ioVCrDate:      LONGINT;    data & time of initialization
ioVLsBkUp:      LONGINT;    data & time of last backup
ioVAtrb:        INTEGER;    bit 15 set if volume locked
ioVNmFls:       INTEGER;    number of files on volume
ioVDirSt:       INTEGER;    first block of file directory
ioVBlLen:       INTEGER;    number of blocks in directory
ioVAlBlkSiz:    LONGINT;    bytes/allocation block
ioVClpSiz:      LONGINT;    number of bytes to allocate
ioAlBlSt:       INTEGER;    first block in volume block map
ioVNextFNum:    LONGINT;    next free file number
ioVFrBlk:       INTEGER;    number of free allocation blocks
```

As with the file information parameters, most of the volume information parameters are used by the system and not directly by an application.

Storage Space for Parameter Blocks

Storage space for File Manager parameter blocks should be allocated in the application globals area. For example, the following allocates an I/O parameter block:

```
ioParamBlock  DS.B  ioQElSize
```

ioQElSize is defined in the system equates file. Its value is the total number of bytes (50) in an I/O parameter block. Note that offsets for the fields within all three types of parameter blocks are also contained in the system equates file.

A file information parameter block might be defined as:

```
fiParamBlock  DS.B  ioFQElSize
```

and a volume information parameter block as:

```
vParamBlock  DS.B  ioVQElSize
```

How many parameter blocks of each type do you need? That depends on two things: the number of access paths that will be open at any one time and how much parameter shuffling you want to do. Since the Video Tape Index program never has more than one access path open at any given time, only one parameter block of each type is required.

An application that simultaneously maintains more than one access path can handle the parameter block situation in one of two ways. The entire application can use a single set of parameter blocks if data returned by File Manager routines are removed from the parameter blocks and stored elsewhere before the blocks are used by a different access path. On the other hand, each access path can be allocated its own set of parameter blocks. In that case, data is left in the parameter block and doesn't need to be reloaded for subsequent calls to File Manager routines.

It may also be necessary to retrieve information from parameter blocks, even if only one access path is open at a time, if the application makes calls to the Printing Manager. Since the Printing Manager tends to disrupt data in the applications globals area, an application should be careful to at least store the access path reference number elsewhere.

Translating the Pascal syntax for File Manager routines into assembly language is not as straightforward as with the routines of other managers. All of the low-level File Manager routines which must be used from assembly language have the form:

```
FUNCTION ProcedureName (paramBlock: ParamBlkPtr;
    async: BOOLEAN): OSErr;
```

In practical terms, this means that for synchronous operations the address of the appropriate parameter block must be loaded into A0 just before the routine is called, and that **OSErr** (technically, an "operating system error" code, but in reality, one of the codes in Table 11.1) will be returned in D0. Therefore, the major portion of the setup for a File Manager routine involves loading the necessary information into a parameter block.

Creating a Data File

Creating a new file involves three steps:

1. Create the file (**Create**)
2. Assemble information about the file that the Finder already has (**GetFileInfo**)
3. Fill in the remaining information that the Finder needs (**SetFileInfo**)

The actual creation of a new file requires three pieces of information: the name to be given to the file, its location (usually given as a drive number), and the version number (should always be 0). These parameters must be moved into the I/O parameter block:

```
LEA       'Tape.Master',A0
MOVE.L    A0,ioParamBlock+ioFileName(A5)    ;address of
                                            file name
MOVE      #1,ioParamBlock+ioDrvNum(A5)      ;drive #
MOVE.B    #0,ioParamBlock+ioFileType(A5)    ;version #
```

The name selected for a file should be assembled with a length byte. If you wish to avoid worrying about the **STRING__FORMAT** assembler directive, allocate strings with **LEA** rather than defining them as constants. Remember that strings allocated with **LEA** and **PEA** are assembled with length bytes; those allocated with **DC** are assembled without length bytes.

The drive number parameter should be passed as 1 for the internal drive or 2 for the external drive. If you are working with a hard drive, consult the documentation that accompanied the drive to determine the drive's number.

File version number should always be 0.

Once the parameters are loaded into the parameter block, the starting address of the block is loaded into A0. Then the routine can be called:

```
LEA   ioParamBlock(A5),A0
__Create
```

Whenever a file is successfully created, the Finder must be supplied with information about that file. Therefore, **Create** should be followed by calls to **GetFileInfo** and **SetFileInfo**.

Both routines use the file information parameter block. To call **GetFileInfo** you must supply:

1. The file's name (**ioFileName**)
2. The drive number where the file is located (**ioDrvNum**)

3. The file's version number (**ioFileType**)
4. The file's directory index (**ioDirIndex**)

ioDirIndex contains an integer that tells the File Manager what information should be used to locate the file. If its value is greater than 0, **GetFileInfo** will use that number to identify the file, assuming that it refers to the file's position in the disk directory. If its value is 0 or negative, **GetFileInfo** will use the file's name, drive number, and version number to locate the file. In either case, assuming that the requested file exists, the call to **GetFileInfo** will fill in the remainder of the fields in the file information parameter block with the correct data about that file.

SetFileInfo assures that the Finder has correct information about a given file. It requires the following information:

1. The file's name (**ioFileName**)
2. The drive number where the file is located (**ioDrvNum**)
3. The file's version number (**ioFileType**)
4. The file's type (**ioFndrInfo**)
5. The file's time and date of creation (**ioFlCrDat**)
6. The file's time and date of last modification (**ioFlMdDat**)

The last two items listed above are supplied by the call to **GetFileInfo**. The first three are loaded into the parameter block when setting up for the call to **GetFileInfo**. The setup for **SetFileInfo** therefore involves loading the file type and reloading the address of the parameter block into A0.

A file's type is a four-character string. Files with type 'TEXT' can be read by Macintosh text processing programs such as MacWrite and Microsoft Word. Data files created by an application should therefore be type 'TEXT' unless there is some specific reason for preventing the user from viewing and possibly modifying the files.

The Video Tape Index uses the following code to set up and call **GetFileInfo** and **SetFileInfo** after creating a new Tape.Master file (Tape.Master holds the information from TapeArray):

```
LEA      'Tape.Master',A0
MOVE.L   A0,fiParamBlock+ioFileName(A5)      ;file name
MOVE     #1,fiParamBlock+ioDrvnum(A5)        ;drive number
MOVE.B   #0,fiParamBlock+ioFileType(A5)      ;version number
MOVE     #0,fiParamBlock+ioFDirIndex(A5)     ;use name & version
                                             number to find file
LEA      fiParamBlock(A5),A0
_GetFileInfo

MOVE.L   $'TEXT',fiParamBlock+ioFlUsrWds     ;start of ioFndrInfo
                                             record
```

```
LEA     fiParamBlock(A5),A0
_SetFileInfo
```

Opening a File

Before a file can be read from or written to, it must be opened. Creating a file merely creates a disk directory entry that will produce a document icon when the disk's contents are viewed from the Finder; creating does not open a file. The File Manager routine **Open** will open a file by creating an access path to that file. It returns a reference number to the access path.

The information required by **Open** is:

1. the name of the file
2. the drive number
3. the file's version number
4. the permission code for this access path (Remember that only one access path to any file can allow writing.)
5. in **ioMisc**, a pointer to an *access path buffer*

An access path buffer is a block of RAM that is used as temporary storage by the access path. Either allocate the access path buffer explicitly, in which case it should be defined as 522 bytes long, or instruct the system to use the volume's buffer by passing a value of 0. It is important that all access paths to one file share the same buffer, regardless of whether it is an application-defined buffer or the volume's buffer.

The Video Tape Index uses the following code to open the Annotations file:

```
LEA       'Annotations',A0
MOVE.L    A0,ioParamBlock+ioFileName(A5)    ;file name
MOVE      #1,ioParamBlock+iodrvnum(A5)      ;drive #
MOVE.B    #0,ioParamBlock+ioFileType(A5)    ;version #
MOVE.B    #3,ioParamBlock+ioPermssn(A5)     ;read & write
                                             permission
CLR.L     ioParamBlock+ioOwnBuf(A5)         ;use volume buffer
LEA       ioParamBlock(A5),A0
_Open

CMP       #0,D0                             ;any errors?
BNE       FileError                         ;handle error

LEA       fiRefNum,A0                       ;save access path
MOVE      ioParamBlock+ioRefNum(A5),(A0)    ;reference number
```

The final step in the sequence above explicitly retrieves the access path reference number from the parameter block and stores it elsewhere. This is necessary because calls to the Printing Manager disrupt the values in the parameter block and their integrity cannot be ensured. The access path reference number is therefore always reloaded into the parameter block before any further operations are performed on that file.

Writing to Disk Files

A single File Manager routine, **Write**, performs both sequential and direct access write operations. The difference between the two types of processing is in how an application specifies where writing should begin.

Writing a Sequential File

The Video Tape Index stores the data from the RAM-based TapeArray in a sequential file (Tape.Master). This file is read into RAM when the program is launched and rewritten to disk when the user selects Quit from the Options menu. Since the format of the file is exactly the same as the format of TapeArray, the block of storage occupied by TapeArray can be used as the I/O buffer for both read and write operations.

TapeArray has fixed field, and therefore fixed record, lengths. That characteristic makes it easy to do direct access operations on the array while it is in RAM. Nonetheless, do not assume that all sequential files need to have fixed record lengths; on the contrary, they do not. Generally, a carriage return is used to mark the end of a record in a sequential file. The carriage return is not automatically inserted by the system; it must be written explicitly as the last character of each record.

Data are written to disk in 512-byte blocks. If a write operation ends up with a final segment of less than 512 bytes, that data is stored temporarily in the access path buffer until either another write request brings the total number of bytes to 512, or until the application calls a routine that flushes the buffer. **FlushFile** will explicitly write all contents of an access path buffer to disk (requires only the access path reference number in the I/O parameter block). **Close** also flushes the access path buffer. (See the section later in this chapter on closing files.)

Write requires the following parameters in the I/O parameter block:

1. access path reference number (**ioRefNum**)
2. starting address of the I/O buffer (**ioBuffer**)
3. number of bytes that should be transferred (**ioReqCount**)
4. the position mode (**PosMode**)

5. the offset (**ioPosOffset**)

Write returns another result in addition to the error code in D0. **ioActCount** will contain the actual number of bytes that were written.

To write the entire Tape.Master file, the Video Tape Index uses the following code:

```
MOVE    fiRefNum,ioParamBlock+ioRefNum(A5)      ;access path
LEA     TapeArray(A5),A0
MOVE.L  A0,ioParamBlock+ioBuffer(A5)            ;I/O buffer
MOVE    TotalRecords,D0
MULU    #64,D0                                  ;total bytes to
                                                move
MOVE.L  D0,ioParamBlock+ioByteCount(A5)
MOVE    #0,ioParamBlock+ioPosMode(A5)           ;(see below)
LEA     ioParamBlock(A5),A0
_Write
```

The **ioPosMode** necessary for a sequential write has a code of 0. That indicates that the write operation should begin at the current position of the mark. As mentioned earlier in this chapter, when **ioPosMode** is zero, the offset parameter is ignored.

To append to a sequential file, use an **ioPosMode** of 2 and an **ioPosOffset** of 0. The write will then begin exactly at the logical end-of-file.

If you look at the listing of the Video Tape Index program, you will notice that there is a write operation that occurs before TapeArray is written. Like many sequential files, Tape.Master stores "housekeeping" information in its first record; the term "housekeeping" usually refers to data needed to process the rest of the file, or constants that must be retained from one program run to another. The first four bytes of Tape.Master contain two integers — the total number of records in the file and the last annotation number used. Those bytes are therefore processed separately:

```
MOVE    TotalRecords,D0                 ;retrieve total records
SWAP    D0                              ;(see below)
AND.L   #$FFFF0000,D0                   ;clear low order byte
MOVE    LastAnnotNumb,D0                ;retrieve last annot.#
MOVE.L  D0,DataBuffer(A5)
MOVE    fiRefNum,ioParamBlock+ioRefNum(A5)
                                        ;access path reference #
LEA     DataBuffer(A5),A0
MOVE.L  A0,ioParamBlock+ioBuffer(a5)
                                        ;I/O buffer
MOVE.L  #4,ioParamBlock+ioByteCount(A5)
                                        ;write only four bytes
```

```
MOVE        #0,ioParamBlock+ioPosMode(A5)
                                        ;write at mark
LEA         ioParamBlock(A5),A0
_Write
```

The five first steps in this block of code prepare the total number of records and the last annotation number for writing. When the total number of records is moved into D0, it is stored in the low-order word of the register, since the **MOVE** was specified as a word-length operation. The next instruction, **SWAP** inverts the position of the high- and low-order words of registers. In the example above, it puts the total number of records into the high-order word. **AND**ing D0 with the mask of $FFFF0000 preserves whatever is stored in the high-order word (the total number of records) and clears out the low-order word. The second **MOVE**, since it is also a word-sized instruction, puts the last annotation number in the low-order word of D0 without disturbing the total number of records in the high-order word. Finally, the contents of D0 are transferred to the first four bytes of the storage location set aside as an I/O buffer. (This buffer is 256 bytes long — just enough space for an annotation.)

Writing to a Direct Access File

The only difference between writing to a direct access file and to a sequential file lies in **ioPosMode**. Generally, a direct access operation occurs with a byte offset relative to the beginning of the file (**ioPosMode** = 1) or relative to the current position of the mark (**ioPosMode** = 3).

The Video Tape Index program stores annotations for the tapes in a direct access file. The last field in the TapeArray records is an integer that corresponds to the record number of each tape's annotation. Annotation record numbers are assigned sequentially as new tapes are entered. In other words, the 15th tape entered will have an annotation number of 15, regardless of where the tape's title falls in the alphabetical sequence of tapes. Therefore, an annotation number will generally not correspond to a tape's record number in TapeArray.

The code to write an annotation appears in Listing 11.1. The first step (a) fills the 256-byte I/O buffer with blanks. Though there is nothing that says any given annotation must use all 256 bytes allocated for it, it is essential that the space between the last character of the annotation and the end of the record is padded with blanks. If it is not, and only the exact number of characters in the annotation are written to the file, a subsequent read will transfer garbage characters at the end of the record as well as the annotation itself.

After filling the I/O buffer with blanks, the annotation is moved to the buffer. **TEGetText** provides a handle to the text (b) and **BlockMove** transfers the characters (c). The next step is to figure out exactly where this annotation should be placed in the file. This requires the annotation number, which is stored as the last field in the matching **TapeArray** record.

Listing 11.1 Writing an Annotation to its Direct Access File

```
        LEA     AnnotRecMask,AØ
        LEA     DataBuffer(A5),A1
        MOVE    #256,DØ
(a)     _BlockMove                          ;fill buffer with blanks

        CLR.L   -(SP)                       ;place for CharsHandle result
        MOVE.L  AnnotationTextHandle,-(SP)
(b)     _TEGetText                          ;get handle to text in Annotation record
        MOVE.L  (SP)+,A2                    ;recover CharsHandle
        MOVE.L  (A2),AØ                     ;de-referencing handle to get pointer
        LEA     DataBuffer(A5),A1           ;text goes into disk buffer
        MOVE.L  AnnotationTextHandle,A3
        MOVE.L  (A3),A4                     ;de-reference again
        MOVE    teLength(A4),DØ             ;number of characters to move
(c)     _BlockMove                          ;puts annotation in disk output buffer

        LEA     RecordCounter,AØ
(d)     MOVE    (AØ),D5
(e)     MULU    #64,D5
(f)     ADD     #oAnnotNum,D5               ;offset into tape array
        LEA     TapeArray(A5),AØ
        ADD.L   D5,AØ
(g)     MOVE    (AØ),DØ
(h)     MULU    #256,DØ                     ;offset into file

        LEA     DataBuffer(A5),AØ
        MOVE.L  AØ,ioParamBlock+ioBuffer(A5)
        MOVE.L  #256,ioParamBlock+ioByteCount(A5) ;write 256 bytes, blanks and all
(i)     MOVE    #1,ioParamBlock+ioPosMode(A5)     ;offset is relative to beginning of file
(j)     MOVE.L  DØ,ioParamBlock+ioPosOffset(A5)   ;offset in bytes
        MOVE    fiRefNum,ioParamBlock+ioRefNum(A5) ;file reference number
        LEA     ioParamBlock(A5),AØ
        _Write
```

To locate the annotation number, the program gets the **TapeArray** record number (d) and uses it to compute first an offset into the array (e) and then an offset into the record (f). That address is used to retrieve the annotation number (g). The annotation number is multiplied by 256 (h), the number of characters in each annotation, to produce a byte offset from the beginning of the file.

The setup for the call to **Write** is exactly the same as that used for a sequential write with two exceptions. **ioPosMode** is set to 1 to indicate that the offset is relative to the beginning of the file (i) and **ioPosOffset** (j) is loaded with the computed offset.

Reading From Disk Files

Reading from a file is exactly the same as writing to a file except that the data transfer is in the opposite direction. In a read operation, the I/O buffer is the location

into which data is read. As with writing, the buffer can be a storage location specifically set aside for I/O, or a storage location used for another purpose as well.

The **Read** routine requires precisely the same parameters as a **Write**:

1. the access path reference number (**ioRefNum**)
2. a pointer to the I/O buffer (**ioBuffer**)
3. the number of bytes that should be transferred (**ioByteCount**)
4. the position mode (**ioPosMode**)
5. the offset (**ioPosOffset**)

Read returns two results in addition to the error code in D0. **ioActCount** will contain the actual number of bytes that were transferred. **ioPosOffset** will contain the position of the mark after the read is completed.

All read operations transfer data in blocks of 512 bytes. If a read request involves less than 512 bytes, a full 512 bytes will be brought into RAM (into the access path buffer), but the application will receive only those bytes that were specified in the I/O parameter block.

Reading From Sequential Files

A sequential read is simply a read that begins at the current position of the mark and reads forward. As an example, consider the procedure used by the Video Tape Index to load TapeArray at the beginning of every program run. Assume that the file has just been opened and that the access path reference number is therefore already in the parameter block (since the Tape.Master file is closed after its contents are read into RAM, there is no need to worry about the parameter block being disturbed by the Printing Manager).

First, the housekeeping information is retrieved:

```
LEA       DataBuffer(A5),A0                ;place to receive data
MOVE.L    A0,ioParamBlock+ioBuffer(A5)
MOVE      #4,ioParamBlock+ioByteCount(A5)  ;read just first 4 bytes
MOVE      #0,ioParamBlock+ioPosMode(A5)    ;read from mark
LEA       ioParamBlock(A5),A0
_Read

MOVE.L    DataBuffer(A5),D0                ;get 4 bytes just read
LEA       LastAnnotNumb,A0
MOVE      D0,(A0)                          ;store last annot. #
SWAP      D0
LEA       Total Records,A0
MOVE      D0,(A0)                          ;store total records
```

After the above read operation, the mark will be positioned at the fifth byte in the file, the starting location of the first record of TapeArray. The program can then load all of TapeArray with one call to **Read:**

```
LEA       TapeArray(A5),A0                ;I/O buffer
MOVE.L    A0,ioParamBlock+ioBuffer(A5)
MOVE      TotalRecords, D0
MULU      #64,D0                          ;number of bytes to
                                          read
MOVE.L    D0,ioParamBlock+ioByteCount(A5)
MOVE      #0,ioParamBlock+ioPosMode(A5)
                                          ;read from mark
LEA       ioParamBlock(A5),A0
_Read
```

Reading From Direct Access Files

Reading from a direct access file needs an **ioPosMode** of 1, 2, or 3 and an appropriate value for **ioPosOffset**. In all other respects, the process is identical to doing a sequential read. Because the annotations are so long (up to 256 characters), the Video Tape Index program leaves them on disk and reads a single annotation into RAM when needed. The procedure to read a single annotation record is:

```
LEA       DataBuffer(A5),A0               ;place to receive data
MOVE.L    A0,ioParamBlock+ioBuffer(A5)
MOVE.L    #256,ioParamBlock+ioByteCount(A5)
                                          ;read 256 characters
MOVE      #1,ioParamBlock+ioPosMode(A5);  ;relative to beginning
                                          of file
MOVE      RecordCounter,D5                ;current record #
MULU      #64,D5
ADD       #oAnnotNum,D5                   ;offset into TapeArray
LEA       TapeArray(A5),A0
ADD       D5,A0                           ;address of annot #
MOVE      (A0),D0                         ;retrieve annot. #
MULU      #256,D0                         ;offset into file
MOVE.L    D0,ioParamBlock+ioPosOffset(A5)
LEA       ioParamBlock(A5),A0
_Read
```

Closing a File

An application should explicitly close all files with **Close** before returning to the Finder. Though files will be closed automatically whenever the system is rebooted, the **Close** routine flushes the access path buffer, completing any write operations that were temporarily held because they involved less than 512 bytes. **Close** also deletes the access path. Files that are not closed cannot be deleted by the Finder.

Close requires only one parameter – the access path reference number:

```
MOVE    fiRefNum,ioParamBlock+ioRefNum(A5)
LEA     ioParamBlock(A5),A0
_Close
```

Timing Out for File I/O

Next to printing, disk I/O is the slowest part of an application. Often the user will have to wait more than a few seconds for some file operation to be completed. For example, as the number of records in Tape.Master grows, the time needed to read and write the file will continue to increase. Applications that adhere to the Macintosh user interface should change the shape of the cursor to the wrist watch (indicating a long wait) for any time-consuming operation.

The shape of the cursor is controlled by the QuickDraw routine **SetCursor**:

```
PROCEDURE SetCursor (crsr: Cursor);
```

This routine's single parameter is actually a pointer to the location of a resource. The resource is a cursor definition. Four cursors are defined in the system resource file: an I-Beam (resource ID = 1), a cross (resource ID = 2), a plus sign that looks like an outlined cross (resource ID = 3), and the wristwatch (resource ID = 4). A handle to the resource definition is returned by a routine from the ToolBox utilities – **GetCursor**:

```
FUNCTION GetCursor (cursorID: INTEGER); CursHandle;
```

cursorID refers to the resource ID of one particular cursor.

The following code will set the cursor to the wrist watch:

```
CLR.L     -(SP)          ;space for cursor handle result
MOVE      #4,-(SP)       ;resource ID for wristwatch
_GetCursor
```

```
MOVE.L    (SP)+A0        ;retrieve cursor handle
MOVE.L    (A0),A0        ;de-reference to get pointer
MOVE.L    A0,-(SP)       ;put pointer on stack
_SetCursor               ;change arrow to wristwatch
```

The cursor can be returned to the arrow cursor with a call to **InitCursor**.

Managing Disk Changes and Choosing File Names — the Standard File Package

Many Macintosh applications will have a standard File menu with options that allow a user to open, close and save files. Opening and saving files should allow the user to enter a file name and to change disks and drives if necessary. The application should also take care of initializing disks if an uninitialized disk is inserted. The Standard File Package (package #3) provides routines that collect information from predefined dialog boxes and take care of initializing disks.

The two routines that most programmers will use are **SFGetFile** (routine #2 in the package) and **SFPutFile** (routine #1). **SFGetFile** is used to open files and **SFPutFile** to save files. Both routines return information to the application in a standard file reply record:

```
SFReply = RECORD
    good:       BOOLEAN;    set FALSE if user cancels
    copy:       BOOLEAN;    unused
    fType:      OSType;     file type or unused
    vRefNum:    INTEGER;    drive number
    version:    INTEGER;    file version number
    fName:      STRING[63]; file name
```

The first five fields occupy 10 bytes. Therefore, an application should allocate a total of 74 bytes of space for the file reply record. Offsets for the fields in the reply record are assigned symbolic addresses in the Package equates file, which should be INCLUDEd in the application's source code.

Selecting a File to Open

The dialog box displayed by **SFGetFile** appears in Figure 11.1. It allows the user to change disks and the default drive, lists all files on the default drive that can be opened, and accepts a command to either open a file or cancel the request.

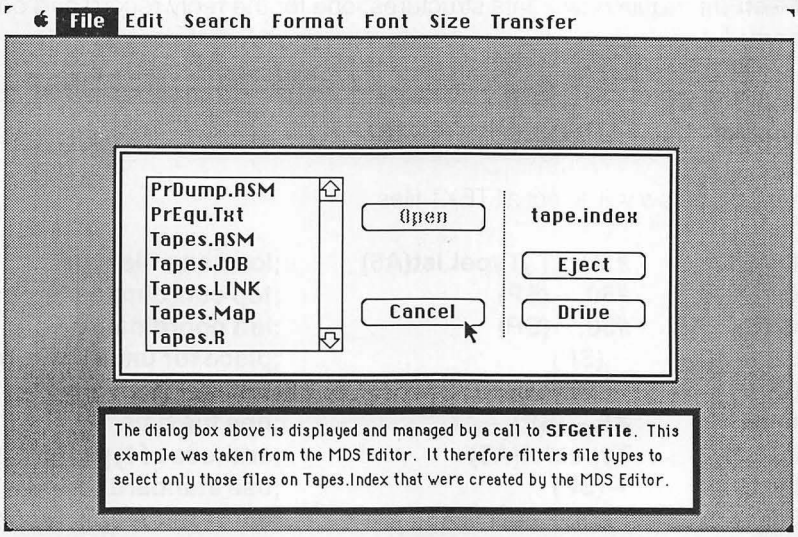


Figure 11.1 "Get File" Dialog Box from the Standard File Package

This is a stack-based routine:

```
PROCEDURE SFGetFile (where: Point; prompt: Str 255; fileFilter:
    ProcPtr; numTypes: INTEGER; typelist: SFTypelist; dlgHook:
    ProcPtr; VAR reply: SFReply);
```

The parameter **where** contains, in global coordinates, the location of the upper left-hand corner of the dialog box. The **prompt** is ignored.

The next three parameters specify what types of files should be presented to the user as candidates for opening. **numTypes** contains an integer indicating the number of types of files that should be selected. The maximum value is four; a value of −1 will select all files on the default volume. The actual types to be selected are loaded into **typeList**. **typeList** is large enough to hold 16 characters (it is a packed array, 16 bytes long). Since it is larger than a longword, a pointer to **typeList** is pushed onto the stack. **fileFilter** is a pointer to a function that can perform additional file filtering. For example, files could be filtered by last date of modification. In most cases though, no additional filtering is necessary and **fileFilter** is set to 0.

dlgHook is a pointer that allows an application to display a dialog box other than the standard seen in Figure 11.1. Normally, it will be set to 0. The final parameter, **reply**, is a pointer to the reply record.

SFGetFile requires two data structures, one for the reply record and one for the file type list:

```
ReplyRecord     DS.B     74
TypeList        DS.B     16
```

The code below will select all TEXT files:

```
MOVE.L      #'TEXT',TypeList(A5)      ;load one file type
MOVE        #50,-(SP)                 ;top coordinate
MOVE        #50,-(SP)                 ;left coordinate
CLR.L       -(SP)                     ;place for unused prompt
CLR.L       -(SP)                     ;no filter procedure
MOVE        #1,-(SP)                  ;one file type
PEA         TypeList(A5)              ;address of type list
CLR.L       -(SP)                     ;use standard dialog
PEA         ReplyRecord(A5)           ;address of reply record
MOVE        #SFGetFile,-(SP)          ;routine #
_Pack3                                ;invoke the package
```

SFGetFile monitors events and automatically takes care of ejecting disks and changing drives when the user clicks the appropriate button. If an uninitialized disk is inserted, the Standard File Package calls the Disk Initialization Package and handles the entire initialization process. The dialog box is closed when the user chooses Cancel or when a file is selected. A file can be selected by one click on the file name and a second click in the Open button, or by a double-click on the file name.

Once the dialog box has been removed, it is up to the application to retrieve information from the reply record and continue with the file operation. The first action is generally to check the **good** field to determine whether the file request has been canceled.

Naming a File

SFPutFile provides a standard dialog box (Figure 11.2) that permits a user to name a file as well as to eject a disk and change the default drive:

```
PROCEDURE SFPutFile (where: Point; prompt: Str 255; origName:
    Str255; dlgHook: ProcPtr; VAR reply: SFReply);
```

Most of the parameters are the same as those for **SFGetFile**. In this case, though, **prompt** has meaning; it is displayed above the window where the file name is entered and usually has a value like 'Save current file as:'. **origName** determines what will be displayed within the file name window when the dialog box first appears. If the current file has a name that should be assigned to **origName**;

otherwise, **origName** should be set to the null string. To indicate the null string as a literal, type two single quotes or two double quotes right next to each other.

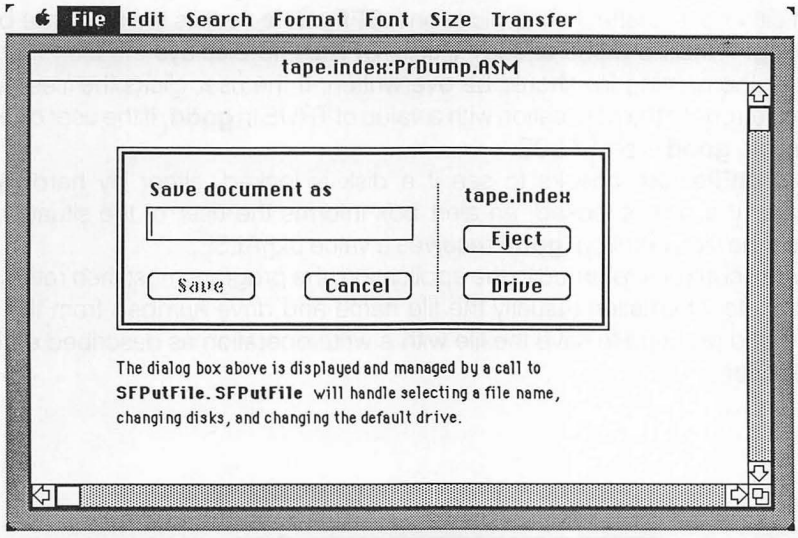


Figure 11.2 "Put File" Dialog from the Standard File Package

If we assume that a user has selected Save As from a File menu to save a new text file, the assembly language code would appear as:

```
MOVE    #50,-(SP)          ;top coordinate
MOVE    #50,-(SP)          ;left coordinate
PEA     'Save current file as'  ;prompt
PEA     ''                 ;file name (null string)
CLR.L   -(SP)              ;use standard dialog
PEA     ReplyRecord        ;address of reply record
MOVE    #SFPutFile,-(SP)   ;routine #
_Pack3                     ;invoke the package
```

Pointers to the text of the prompt and the file name can be pushed as literals (as above) or by symbolic addresses. Since their data type is Str255, they must have a length byte. Pushing them as literals will automatically ensure that the length byte is present.

SFPutFile will continue to monitor events until the user either:

1. clicks the Cancel button

2. types a file name and clicks the Save button or
3. types a file name and hits the Enter or Return key.

If the Cancel button has been clicked, control returns immediately to the application.

In either of the latter two applications, **SFPutFile** verifies the file name before returning. If the file name already exists, **SFPutFile** displays the alert that asks whether the existing file should be overwritten. If the user clicks the Yes button, control returns to the application with a value of TRUE in **good**. If the user clicks the No button, **good** is set FALSE.

SFPutFile also checks to see if a disk is locked, either by hardware or software. If a disk is locked, an alert box informs the user of the situation and cancels the file operation. **good** receives a value of FALSE.

When control is returned to the application, the program must then retrieve the appropriate information (usually the file name and drive number) from the reply record and proceed to save the file with a write operation as described earlier in this chapter.

Questions and Problems

1. Assume that an I/O parameter block has been allocated with the statement:

   ioParamBlock DS ioQElSize

   where **ioQElSize** is defined in the system equates file as equal to the number of bytes in an I/O parameter block. Using the offsets into the parameter block defined in the system equates file, write assembly language code to load the following data:

   A. a path reference number that has been stored in the applications globals area under the symbolic address of **PathRefNum**
   B. a version number of 0
   C. an I/O buffer in the applications globals area identified by the symbolic address **MyBuffer**
   D. write only permission
   E. the appropriate values for **ioPosMode** and **ioPosOffset** so that new records will be *appended* to the end of the file.

2. A. Write assembly language code to create a file named **TextFile.txt** on the internal drive. Remember to collect all the information needed by the Finder as well as simply creating the file. Allocate any data structures your code will use.

   B. At the end of your block of code, is **TestFile.txt** ready for read and write operations? Why or why not?

   Problems 3 - 8 refer to the **BookStuff** array first introduced in problem 5. The structure of the array is defined as:

```
Title       EQU  0
Author      EQU  30
Publisher   EQU  50
Date        EQU  75
```

   The total length of a record is 80 bytes. The file **BookStuff.data** holds the same data as the array in RAM.

3. Write assembly language code to open **BookStuff.data** for input and output on the external drive. Be sure to allocate required data structures. Use the RAM array as an I/O buffer.

4. Write assembly language code to write the entire **BookStuff** array *sequentially* to **BookStuff.data**. Assume that the total number of records in the array is stored in D0. Assume also that the file has just been opened by the code you wrote for problem 3.

5. Write a block of code to perform a direct access write for one record from **BookStuff** to **BookStuff.data**. The record number is stored in D0. Assume the file has been opened by the code you wrote for problem 3.

6. Write a block of code to read the entire **BookStuff.data** file into the **BookStuff** array in main memory. The total number of records in the file is stored in D0. Assume the file has just been opened by the code you wrote for problem 3.

7. Write a block of code to close **BookStuff.data**.

8. Assume now that **BookStuff.data** has been opened with write-only permission and that the data for a single record has been stored in the applications globals area with a symbolic address of **OneRecord**. Write a block of code to *append* the new record to **BookStuff.data**.

9. Assume that a standard file reply record has been defined in the applications globals area with a symbolic address of **ReplyRecord**. Write a block of code that will display the standard "get file" dialog box and then retrieve the name and drive number of the file the user selects. Anchor the top left corner of the dialog box at 100,80. Display the names of all files of type TEXT and MACA (MacWrite version 4.5) in the dialog box. Allocate any other data structures your code will use.

10. Assume that a standard file reply record has been defined in the applications globals area with a symbolic address of **ReplyRecord**. Write a block of code that will display the standard "save as" dialog box and then retrieve the file name and drive number from the reply record. The top left corner of the dialog box is at 75, 100. Select an appropriate prompt for the dialog box. Allocate any necessary data structures.

CHAPTER TWELVE

ARITHMETIC I/O: FLOATING POINT ARITHMETIC

Chapter Objectives

1. To understand the problems associated with numeric I/O
2. To understand the Macintosh's floating point formats
3. To learn to do binary/decimal conversions for integers and floating point numbers
4. To learn to use the Macintosh's arithemetic packages to perform advanced mathematical operations
5. To learn to use separately assembled subroutines
6. To learn to create macros to simplify program code

Introduction

While microprocessor instruction sets contain instructions that perform integer arithmetic, they make no provision for arithemetic with numbers that contain fractional portions. Integer arithmetic is also limited to quantities that will fit into a single register (32 bits). As well as manipulating fractions and very large and very small numbers, it would also be useful to have routines that evaluate logarithmic

and trigonometric functions. Most microcomputers, therefore, have software that provides for a variety of advanced mathematic operations. Because the numbers processed by these routines have decimal points that move, they are referred to as *floating point* numbers and operations on them as *floating point arithmetic*. The Macintosh has a powerful floating point arithmetic package called FP68K. Trigonometric, exponential and logarithmic functions are provided by the elementary functions package, ELEMS68K.

The format of floating point numbers closely resembles scientific notation, where a *mantissa* is multiplied by 10 raised to a power (the *exponent*). For example, $3.98 * 10^{-15}$ is a very small number (.00000000000000398). The mantissa is 3.98; the exponent is −15. The exact format in which floating point numbers are stored by computers differs from machine to machine. The Macintosh format is described below.

Arithmetic, whether it be floating point or integer, presents a significant I/O problem. All input from the keyboard is in ASCII; numbers enter the system as a string of ASCII character codes. That means that the ASCII codes must be converted from a string of decimal characters into a binary quantity before any math can be done. Integer conversion is handled by the Binary-Decimal Conversion Package. Floating point conversion is a two-step process; the ASCII character string must first be put into an intermediate format (the *canonical decimal format*) which is then used by the decimal-to-binary conversion routines. The Pascal implementation of FP68K provides routines that will convert directly from an ASCII string to binary and back again. Unfortunately, those routines are not available from assembly language. An application must therefore provide the code that puts the ASCII string into the intermediate format. After discussing the integer conversion routines, this chapter will look in detail at a subroutine that will properly reformat strings of decimal characters.

The Binary- Decimal Conversion Package

The Binary-Decimal Conversion Package contains only two routines: one to translate a string of ASCII decimal characters into a binary integer and another to take a binary integer and convert it to a string.

NumToString is the routine that converts a longinteger into a string of characters:

```
PROCEDURE NumToString (theNum: LONGINT; VAR theString:
    Str255);
```

Since the data type of the string produced by this routine is **Str255**, it will have a length byte.

Before calling this routine, a pointer to a storage location for the string is placed in A0. The number that is to be converted is loaded into D0. **NumToString** will place the string at the location specified by the address in A0. The string can then be displayed with **DrawString**, for example, or incorporated into a text edit record.

The code below will convert an integer to a string:

```
        MOVE.L    #134599,D0
        LEA       StringStorage(A5),A0
        MOVE      #0,-(SP)          ;select the NumToString routine
        _Pack7                      ;invoke the package
StringStorage     DS.B  20
```

StringToNum is the exact opposite of **NumToString**; it converts a string with the data type Str255 into a longinteger:

```
PROCEDURE StringToNum (theString: Str255; VAR theNum:
    LONGINT);
```

A pointer to the string to be converted is loaded into A0. The number will be returned in D0. The system determines the number of characters in the string by examining its length byte:

```
LEA    #'123456',A0
MOVE   #1,-(SP)              ;select the StringToNum routine
_Pack7                       ;invoke the package
```

StringToNum does not check to be sure that all characters in the string are digits. The routine is based on the fact that the ASCII codes for the digits are $30 through $39. If it looks just at the four low-order bits of the ASCII code, it has the quantity for the digit. This procedure, assuming that the four low-order bits contain the quantity, can be applied to any other character as well as a digit without creating a system error. Therefore, any character checking must be performed by the application.

Floating Point Decimal-to-Binary Conversions

The FP68K decimal-to-binary conversion routines work from a canonical decimal format that is defined as:

```
TYPE
        SigDig = String[20]
        Decimal = record
                sgn: 0..1;
                exp: INTEGER;
                sig: SigDig

        end;
```

The numbers described by the decimal record are stored as a string of up to 20 significant digits that are multiplied by 10 raised to some power (the exponent). For example, in the number $34567 * 10^{-6}$, 34567 are the significant digits and -6 is the exponent. The decimal point is always directly to the right of the most significant digit: that is, the mantissa is always presented as if it were an integer. The decimal point is not stored in the decimal record but its presence is inferred. The exponent is stored as an integer; the significant digits are a string of ASCII characters preceeded by a length byte (their data type is **Str20**). The sign (**sgn**) is stored in bit 8 of the sign word. A value of 0 indicates a positive number; a value of 256 (a 1 in bit 8) indicates a negative number.

There is one major problem with Macintosh's canonical decimal format — user's don't enter data that way. An application must therefore have some way to convert strings of digits with embedded decimal points into that format. Listing 12.1 is an example of a subroutine that will "parse" (break down into constituent parts) character strings and reformat them into the canonical decimal format.

Listing 12.1 Parsing Numeric Strings

```
;---------------------- Simple Parser ----------------------------
;
; Register Usage
;       AØ      starting address of numeric string (load before calling routine)
;       A2      starting address of decimal record (result will go here)
;       DØ      starting character position in string
;       D5      exponent
;       D6      number of significant digits
;       D7      total length of string (load before calling routine)
;-----------------------------------------------------------------
```

(continued)

```
        XDEF   Parser
Parser
        MOVE   D7,D6            ;initialize significant digits
        MOVE   #Ø,DØ            ;initialize starting character position
        MOVE.B (AØ),D2          ;get first character
        CMP.B  #'-',D2          ;negative number?
        BNE    Positive
        MOVE   #256,(A2)        ;store negative sign
        ADDQ   #1,DØ            ;skip sign
        SUBQ   #1,D6            ;don't include sign in significant digit count
        BRA    Parse

Positive
        MOVE   #Ø,(A2)          ;store positive sign
        CMP.B  #'+',D2          ;is there a positive sign?
        BNE    Parse
        ADDQ   #1,DØ            ;skip sign
        SUBQ   #1,D6            ;don't include sign in significant digit count

Parse   MOVE   DØ,D3            ;save position of beginning character position

NoDecimal
        MOVE.B (AØ,D3),D2       ;get a character
        CMP.B  #'.',D2          ;decimal point found?
        BEQ    DecimalPoint
        ADDQ   #1,D3            ;skip to next character
        CMP    D3,D7            ;past last character?
        BGT    NoDecimal        ;not decimal point or end of string

;This block handles number of the form XXXXXXXX - No decimal point present
;at all (i.e., they're integers)

        MOVE   #Ø,D5            ;set exponent (decimal point at right of #)

        MOVE.B D6,4(A2)         ;load length byte
        BRA    FillRecord

DecimalPoint
        CMP    D3,DØ            ;is decimal point in first position?
        BNE    GreaterThanOne

;This block takes care of numbers of the form .XXXXXXXXXXX
;The next step is to get rid of zeros between the decimal point and the
;first significant digit.

        ADDQ   #1,DØ            ;skip over decimal point

MoreZeros
        MOVE.B (AØ,DØ),D2       ;get character
        CMP.B  #'Ø',D2          ;is it a zero?
        BNE    SetExponent
        ADDQ   #1,DØ
        CMP    DØ,D7            ;at end of string?
        BGT    MoreZeros

SetExponent
        SUBQ   #1,D6            ;don't include decimal point in sig. digits
        MOVE   D6,D5
        MULU   #-1,D5           ;final exponent value                    (continued)
```

Listing 12.1 (continued)

```
;note - DØ has position of first significant digit

        SUB    DØ,D7          ;number of significant digits
        MOVE   D7,D6
        MOVE.B D6,4(A2)       ;load length byte
        BRA    FillRecord

;This block handles numbers that are greater than 1 and contain a decimal
;point. They translated to XXXXXXXXX. (note that decimal point is implied and not stored)

GreaterThanOne
        SUBQ   #1,D6          ;don't include decimal point in sig. digits
        MOVE   D3,D1          ;get position of decimal point
        MOVE   D6,D5          ;move sig. digits to sign register
        MOVE   (AØ),D2        ;get sign word again
        BEQ    NoAdjustment
        SUBQ   #1,D1          ;adjust for presence of sign
NoAdjustment
        SUB    D1,D5          ;subtract position of decimal point
        MULU   #-1,D5         ;make it negative
        MOVE   D3,D1          ;reload position of decimal point

Shift   ADDQ   #1,D1
        CMP    D7,D1          ;beyond last character?
        BGT    Done           ;beyond last character
        BLT    Continue       ;before last character
        MOVE.B (AØ,D1),D2
        CMP.B  #'.',D2        ;decimal point in last position?
        BEQ    Done           ;ignore trailing decimal point - otherwise move last digit

Continue
        MOVE.B (AØ,D1),(AØ,D3)      ;shift character one position to the left
        ADDQ   #1,D3
        BRA    Shift


Done    MOVE.B D6,4(A2)       ;load length byte

FillRecord
        MOVE   D5,2(A2)       ;load exponent
        MOVE   #Ø,D1          ;initialize loop counter
        MOVE   #5,D2          ;starting offset of string in decimal record
        ADDQ   #1,D6          ;include length byte in count

Top     MOVE.B (AØ,DØ),(A2,D2)      ;move one character
        ADDQ   #1,D1
        CMP    D1,D6
        BEQ    Return         ;all characters moved
        ADDQ   #1,DØ
        ADDQ   #1,D2
        BRA    Top

Return  RTS
```

The Parser

The parser subroutine, like any routine that examines strings and makes decisions based on the characters that are present, works on a set of rules that describe possible character sequences and the actions to be taken when those sequences are found. There are three general formats in which numbers might be entered from the keyboard: XXXX (an integer without a decimal point); .000XXX (a fraction less than one, with or without zeros between the decimal point and the significant digits); and XXXX.XX (a combination of integer and fraction). This simple parser does not handle numbers entered in scientific notation (e.g., 1.345E+06), though it could certainly be expanded to do so.

To better understand the logic of the parser, take a look at the pseudocode in Figure 12.1. This presents an English-like version of the subroutine's logic. The general strategy is to first examine the string for a plus or minus sign in the first character position, at which point the sign of the number can be determined and stored directly into the data structure set aside to hold the canonical decimal format. The second step is to determine which of the three forms described in the previous paragraph (integer, fraction, or combination) fits the character string.

Figure 12.1 Parser Pseudocode

```
Initialize number of significant digits as equal to total characters in string.

Get the first character in the source string.

If the first character is a minus sign then

        Store value for negative number directly into canonical data structure;

        Decrement the number of significant digits by 1 (sign doesn't count)

Else

        If first character is a plus sign then

                Decrement the number of significant digits by 1;

        Store value for positive number directly into canonical data structure.

Get the "next" chracter.                {will be first character again if no sign was present}

While the character being examined is not a decimal point do

        Get another character.
```

Figure 12.1 (continued)

```
If no decimal point is found then                    {number is an integer}
        Set Ø as the exponent value;
        Store number of significant digits in canonical data structure
Else
        If the decimal point is in the first position then    {number is all fraction}
                Get next character;
                While the character being examined is not a Ø do
                        Get next character;
                Decrement number of significant digits by 1 to ignore decimal point;
                Compute exponent by subtracting position of first non-zero digit from number of
                        significant digits and mulitplying by -1;
                Store number of significant digits in canonical data structure
        Else                                         {number has integer and fraction parts}
                Decrement number of significant digits by 1 to ignore decimal point;
                Compute exponent by subtracting position of decimal point from number of
                        significant digits and multiplying by -1;
                Set a pointer to the first character to the right of the decimal point;
                While the pointer less than the last character do
                        Move the character one place to the left; {eliminates decimal point from
                                                                  source string}
                        Increment the pointer;
                If the last character is not a decimal point then
                        Move the last character;
                Store in number of significant digits in the canonical data structure.
Store the exponent in the canoncial data structure.
Initialize a counter to Ø.
```

(continued)

While the counter is less than or equal to the number of signficant digits **do**

Move one characterfrom the source string to the canonical data structure;

Increment the counter.

Stop.

Handling integers is straightforward; the decimal point is already in the correct place. Though it is not stored with the number, all integers have implied decimal points directly to the right of the number. The exponent for an integer is always 0.

If the decimal point is in the first position (after the sign, if one is present), then the number is a fraction. Fractions must be converted to integers with no leading zeros and the exponent adjusted accordingly. A factional exponent will be equal to the number of digits in the original number (including leading zeros) multiplied by −1; a negative exponent indicates that the decimal point should be moved to the left. The number of significant digits for the canonical decimal format is determined by finding the left-most non-zero digit. All characters from that point to the end of the string are considered significant digits.

Numbers that contain both integer and factional portions have an exponent equal to the number of fractional digits multiplied by −1. The string must also be adjusted to remove the decimal point; each digit in the fractional portion of the string is moved one position to the left. The number of significant digits is equal to the number of characters in the string less one for the decimal point and one for a sign, if present.

Programming Technique — Using Separately Assembled Subroutines

The parser just described is designed so that it can be used by many different applications. It appears to an application much like one of Macintosh's operating system routines in that parameters are passed to it in registers — A0 contains the address of the source string, A2 the address of the destination data structure, and D7 the total number of characters in the source string. An application loads the registers and then does a **JSR** to call the routine.

It would be inefficient to include the code for the parser in each application that needs to do decimal-to-binary conversions. Instead, the parser is assembled separately and kept in its own **.Rel** file that can be used whenever needed. As you write many applications, you may develop an entire library of utilities like the parser that can be used whenever needed without duplicating their code.

In order to use separately assembled subroutines, three things must happen:

1. The source code of the subroutine must indicate that it will be called by another program (an external definition);
2. The source code of any application calling the subroutine must indicate that the subroutine is not part of the application's code (an external reference);
3. The subroutine must be linked to the application during the linking process.

The assembler directive **XDEF** (external definition) is used whenever a symbolic address in a piece of code will be referenced by another program. For example, the first line in the parser subroutine is:

```
XDEF  Parser
```

which indicates that some other piece of code will be using that symbolic address.

The assembler directive **XREF** (external reference) alerts the Assembler that a specific symbolic address cannot be found in the code being assembled but can be found in some other program. Any application that uses the parser must therefore include the directive:

```
XREF  Parser
```

before it executes a **JSR** to the code. The **XREF** will prevent the Assembler from returning an "undefined label" error.

External references are satisfied by the Linker, which provides the actual addresses of all external routines. Therefore, the names of any **.Rel** files that contain symbolic addresses defined in **XREF** directives must be included in the Linker control file. If a program called **Math** uses the parser, its Linker control file will include:

```
Math.Rel
Parser.Rel
```

Formats Available Through FP68K's Conversion Routines

FP68K has routines to generate six different numeric formats from the canonical decimal format:

1. Extended — an 80- bit floating point number
2. Double — a 64- bit floating point number
3. Single — a 32- bit floating point number
4. Integer — a 16- bit integer
5. Longinteger — a 32- bit integer
6. Computational (also known as Accounting) — a 64- bit integer

Arithmetic operations return their results in the extended format. That format looks somewhat like a binary version of the canonical decimal format. Bit 79 is reserved as a sign bit for the mantissa; it holds 0 for a positive number and 1 for a negative number. The exponent is 15 bits long, stored in bits 64 through 78. Bits 0 through 63 are reserved for the mantissa.

Floating point exponents are stored as binary integers. They are the power to which 2 is raised and then multiplied by the mantissa. One way to store them would be to allocate one exponent bit as a sign bit and use two's complement notation. The resulting 14-bit exponent would have the range ±116,383. Exponents, though, are stored without a sign bit using a technique known as *excess notation*.

Excess notation means that some fixed quantity is added to every value of the exponent. The exact value of the excess varies from computer to computer, but it is always enough to make the smallest exponent value 0. The Macintosh uses an excess factor of $3FFF, or 16,383. That means that the smallest possible exponent that can be stored in 15 bits is −16,383 and the largest +16,384. The Macintosh can therefore store floating point numbers in the range $2^{-16,383}$ through $2^{+16,384}$. This is an enormous range, well beyond that demanded by all but the most intensive scientific and statistical applications.

The mantissa is also a binary number. The first bit (bit 63) always has the value one. There is an implied decimal point directly between bits 62 and 63; bits 0 through 62 contain the fractional portion of the mantissa.

As an example, consider the decimal number 32. It is passed to FP68K's decimal to binary conversion routines with a sign of 0, an exponent of 0, and two significant digits (3 and 2). After being converted, it will appear in memory as

$4004 8000 0000 0000 0000. The leftmost word contains the sign and the exponent: %0100 0000 0000 0100. Note that the high-order bit, the sign bit, is 0 to indicate a positive mantissa. The other 15 bits are the exponent. To determine the true value of a Macintosh floating point exponent for a positive number, subtract $3FFF (or subtract $4000 and add 1): $4004 – $3FFF leaves $0005. The mantissa will therefore be multiplied by 2^5. If we expand the first word of the mantissa to binary, we get %1000 0000. Since the decimal place is directly to the right of the high-order bit, the mantissa is actually %1.0000000. The complete value of the number is %1.000 0000 * 2^5 or 32.

Any floating point number with a positive exponent and and positive mantissa will have an exponent word with a value between $4000 and $7FFF. It is useful to become accustomed to viewing floating point representations in hexadecimal, since that is how the contents of memory locations are displayed by the debugger.

As a second example, let's include a fraction with the test number and make it 32.5. Like 32, .5 is an even power of 2, 2^{-1}. The canonical decimal format will contain a 0 for the sign bit, a –1 for the exponent, and a 3 for the number of significant digits (3, 2, and 5). FP68K will convert 32.5 to $4004 8200 0000 0000 0000. The exponent is the same as that for the even value 32; it is the mantissa that is different. If we expand the first word of the mantissa to binary, we get %1000 0010 0000 0000 or %1.000 0010 0000 0000 * 2^5. Moving the decimal point in the mantissa five places to the right, produces %100000.1, which is precisely 32.5.

Negative mantissas produce a change in the value of the exponent word. For example, –32.5 is stored as $C004 8000 0000 0000 0000. In binary, the exponent word is %1100 0000 0000 0100. The high-order bit is set, representing a negative mantissa. To determine the true value of the exponent, first subtract $8000 to strip off the sign bit and then subtract $3FFF to get rid of the excess. For example, $C004 – $8000 = $4004; $4004 – $3FFF = $0005. Numbers with negative mantissas and positive exponents will have exponent word values between $C000 and $FFFF.

Numbers with positive mantissas and negative exponents produce exponent word values in the range $0000 - $3FFF. For example, the quantity .5 generates an exponent of –1. It is stored by adding –1 to $3FFF, which produces an exponent of $3FFE. Numbers with negative mantissas and negative exponents have exponent word values in the range $8000 - $BFFF; – .5 has an exponent word of $BFFE.

Macintosh's other two floating point formats (with 32 and 64-bit mantissas) are stored exactly like the extended format. They simply have less accuracy in the mantissa, since they store fewer bits.

The 16- and 32-bit integer formats are the same as those manipulated by the integer arithmetic instructions that are part of the 68000 instruction set. The 64-bit integer format can be used to obtain extra accuracy and range when doing computations. It is, however, too long for conversion with the Binary-Decimal Conversion Package.

Executing a Binary-to-Decimal Conversion

The FP68K routines are part of Package 4. Like all packages, its routines are called by pushing the routine identifier onto the stack and then calling the package with **__Pack4**. The packages we have discussed previously, though, have had a relatively small number of routines, while FP68K has somewhere around 120. For most FP68K routines, the routine identifier is the sum of the operation code (identifying the type of operation the routine will perform) and an operand format code that identifies the format of the source operand.

The operation code for converting from decimal to binary is $0009. To produce an extended floating point result, $0000 is added to the operation code. If the conversion should produce a longinteger result, $2800 is added to the operation code. Each of the six available formats has a unique operand format code.

Most FP68K routines, including decimal to binary conversions, require the following actions:

1. Push a pointer to the source operand onto the stack.
2. Push a pointer to the destination operand onto the stack.
3. Push the routine identifier onto the stack.
4. Invoke the package.

To convert from the canonical decimal format to an extended floating point number, you might use this code:

```
        PEA     DecimalRecord(A5)
        PEA     BinaryNumber(A5)
        MOVE    #$0009,-(SP)
        __Pack4
DecimalRecord       DS      24
BinaryNumber        DS      5
```

Doing the actual conversion is really quite straightforward. The biggest problem facing a programmer is generating the appropriate routine identifier. The Macintosh 68000 Development System has simplified the process by providing a file (SANEMacs.Txt) containing equates and *macros*.

Programming Technique — Using Macros

A macro is a short block of code that is assigned a name. The name of the macro is then used within an application to represent the entire macro. During assembly, the macro name is *replaced* by the block of code associated with the macro's name. Note that this is very different from using a subroutine. If a subroutine is called repeatedly, the program merely branches to where the subroutine is located and executes it; the code of the subroutine appears only once in the program. A macro name is a place holder that will be replaced by the body of the macro when the program is assembled; a macro that is used repeatedly in the same program will generate repeated code. Macros are therefore generally short, less than 10 lines of code.

Macros must be defined before they can be used. Macintosh macros can have one to two formats. Either:

```
        .MACRO NameOfMacro          [ArgumentList]
{body of macro goes here - any executable code is allowed}
        .ENDM
```

or

```
        MACRO    NameOfMacro        [ArgumentList =]
{body of macro goes here - any executable code is allowed}
        |
```

The first format is referred to as a "Lisa-style" macro, the second as a "Macintosh-style" macro. Both work equally well with the MDS.

Macros can contain arguments, data that are passed to the macro from the application. Macro arguments work very much like the arguments passed to Pascal functions and procedures. The arguments used in the macro definition are dummy arguments. When the program containing the macro is assembled, the arguments are substituted by position. Consider, for example, a macro that will compute the position of a single field within **TapeArray**:

```
MACRO       AddressCompute      R1,R2,R3 =
            MULU        #64,{R1}
            ADD         {R1},{R2}
            ADD         {R3},{R2}
            |
```

In this particular macro, R1 is a place holder for some register that contains the record number. R2 stands for an address register containing the starting address

of **TapeArray**. R3 is a constant that stands for the byte offset into a **TapeArray** record. Each dummy argument is surrounded by braces.

When this macro is used in an application, the programmer will write:

```
MOVE            TotalRecords,D0
LEA             TapeArray, A0
MOVE            #oRating,D1
AddressCompute  D0,A0,D1
```

When the program is assembled, this code will be generated:

```
MOVE            TotalRecords,D0
LEA             TapeArray,A0
MOVE            #oRating,D1
MULU            #64,D0
ADD             D0,A0
ADD             D1,A0
```

The arguments specified after the name of the macro in the program code will be substituted by position for the dummy arguments in the macro's argument list.

The file SANEMacs.Txt can be found on MDS2. It contains equates for the FP68K and ELEMS68K operand format codes and operation codes. More importantly, it also contains one macro for each FP68K and ELEMS68K routine. The macros compute the appropriate routine identifier, push it onto the stack, and then invoke the package. SANEMacs.Txt should be INCLUDEd in any application that uses FP68K or ELEMS68K.

The macro for converting from the canonical decimal format to the extended floating point format is:

```
.MACRO          FDEC2X
MOVE.W          #FFEXT+FOD2B,-(SP)
JSRFP
.ENDM
```

where **FFEXT** has previously been equated to $0000 and **FOD2B** to $0009. **JSRFP** is another macro defined within SANEMacs.Txt. It takes care of invoking the package. If you look at the definition of **JSRFP**, you will see that the package is invoked with **__FP68K**, but if disassembled by the debugger, it appears as **__Pack4**. Both have the same trap value and are equivalent. **__ELEMS68K** is also equivalent to **__Pack5**.

There is an important naming convention to be aware of in the operation code macros. The last character of most of the macro names identifies the type of source operand the operation will handle. For example, **FADDX** will look for an extended source operand to add to an extended destination operand. **FADDD** will add a double source operand to an extended destination operand. The suffix **S** indicates

a single source operand, **C** a computational, **L** a longinteger, and **I** an integer. For each type of operation (e.g., addition, subtraction, comparison, etc.) there are six routines, one for each possible type of source operand.

The binary to decimal conversion can be simplified by using the pre-defined macro:

```
PEA         DecimalRecord(A5)
PEA         BinaryNumber(A5)
FDEC2X
```

The discussion in the rest of this chapter assumes that SANEMacs.txt has been INCLUDED in the application source code and that the pre-defined macros are available.

An Overview of the FP68K and ELEMS68K Routines

FP68K routines fall into two major groups — arithmetic routines and those that provide non-arithmetic utility functions.

The Arithmetic Routines

The arithmetic routines include:

1. Addition (one for each type of source operand — **FADDX, FADDD, FADDS, FADDI, FADDL, FADDC**)
2. Subtraction (one for for each type of source operand — **FSUB** + the letter that identifies the operand type)
3. Multiplication (one for each type of source operand — **FMUL** + operand type identifier)
4. Division (one for each type of source operand — **FDIV** +operand type identifier)
5. Square root (**FSQRTX** — works only with an extended operand)
6. Round to integer (**FRINTX** — works only with an extended operand)
7. Truncate to integer (**FTINTX** — works only with an extended operand)

8. Remainder – returns the remainder of a division operation (one for each type of source operand – **FREM** + operand type identifier)
9. Base 2 logarithm – returns the exponent (**FLOBX** – works only with an extended operand)
10. Base 2 exponentiation – the source operand is the power to which 2 is raised and then multiplied by the destination operand (**FSCALBX** – works only with an extended source operand)

Calls to arithmetic routines (with the exception of numbers 4 - 7 and 8 - 10 above) have the following general form:

```
PEA   source operand
PEA   destination operand
OperationMacroName
```

The result of the operation is placed in the destination operand. That means the original contents of the destination operand is erased by the result. For example, a **FADD** operation has the same effect as the Pascal statement:

```
A := A + B
```

Therefore, if the destination operand must be retained for further use, it should be copied to another storage location before being passed to the FP68K routine.

Code to add a longinteger to an extended floating point number appears as:

```
        PEA         LongIntegerNumber(A5)
        PEA         ExtendedNumber(A5)
        FADDL
LongIntegerNumber   DS.L  1
ExtendedNumber      DS    5
```

Note that all operands are passed as pointers to main memory locations where the operands are actually stored.

The other routines, including square root and rounding, require only one operand:

```
        PEA         source operand
        OperationMacroName
```

The result replaces the source operand. In the case of square root, it has the effect of executing the Pascal statement:

```
A := SQRT(A)
```

To actually compute a square root:

```
        PEA                 ExtendedNumber(A5)
        FSQRTX
ExtendedNumber  DS      5
```

The Utility Routines

FP68K non-arithmetic routines include:

1. Negation (**FNEGX** — works only with an extended operand)
2. Absolute value (**FABSX** — works only with an extended operand)
3. Conversion from all six formats to extended (**FX2X, FD2X, FS2X, FI2X, FL2X, FC2X**)
4. Conversion from extended to the other five formats (**FX2D, FX2S, FX2I, FX2L, FC2X**)
5. Decimal to binary conversion (**FDEC2** + operand type identifier, as discussed above)
6. Binary to decimal conversion (**F?2DEC**, where **?** is replaced by the operand-type identifier).
7. Comparison between two floating point numbers (**FCMP** + operand-type identifier or **FCPX** + operand-type identifier). These comparisons can be used where it makes logical sense to use the **CMP** instruction.
8. Branching based on the result of floating point comparisons (**FBEQ, FBLT, FBLE**, etc.). These macros contain instructions that test the condition codes. They assume that the appropriate floating point comparison has been performed. They should be used in place of a **Bcc** instruction.

Negation and absolute value each require only one operand. For example, to obtain the absolute value of some floating point number:

```
        PEA                 SomeNumber(A5)
        FABSX
SomeNumber      DS      5
```

As with the single operand arithmetic routines, the result of a single operand utility routine will overwrite the source operand.

The internal conversion routines, the decimal-to-binary conversion routines, and the comparison routines require two operands. As discussed earlier, the pointer to the source operand goes deepest in the stack, followed by the pointer to

the destination operand. Note that while the first two sets of routines replace the destination operand with the result of the operation, the comparison operations do not affect either operand; they merely set the flags in the status register.

Binary-to-decimal conversions are the only routines that use three operands. Performing these conversions is discussed later in the chapter.

The floating point branch instructions are used exactly like any other **Bcc** instruction. For example:

```
FBEQ  NextLabel
```

assumes that two floating point numbers have just been compared. The program will branch to **NextLabel** if the two numbers were equal. Note that **FBEQ** is not a new instruction; it is a macro with an argument. Nonetheless, the floating point branch macros can be used as if they were actual instructions.

The ELEMS68K Routines

ELEMS68K contains a number of advanced logarithmic, trigonometric, and exponential functions. Most work only with extended operands. The following routines require one extended operand and replace it with the result:

1. Natural (base *e*) logarithm (**FLNX**)
2. Base 2 logarithm (**FLOG2X**)
3. Natural logarithm of 1 + extended operand (**FLN1X**)
4. Base 2 logarithm of 1 + extended operand (**FLOG21X**)
5. Raising *e* to a power specified by the extended operand (**FEXPX**)
6. Raising 2 to a power specified by the extended operand (**FEXP2X**)
7. Raising *e* to a power specified by the extended operand − 1 (**FEXP1X**)
8. Raising 2 to a power specified by the extended operand − 1 (**FEXP21X**)
9. Sine (**FSIX**)
10. Cosine (**FCOSX**)
11. Tangent (**FTANX**)
12. Arctangent (**FATANX**)
13. Random number generator (**FRANDX**)

For example, to find the sine of a number:

```
        PEA             ExtendedNumber(A5)
        FSINX
ExtendedNumber  DS      5
```

The two exponential routines require two operands:

1. Raise an extended operand (the destination operand) to an integer power (the source operand) (**FXPWRI**)
2. Raise an extended operand (the destination operand) to an extended power (the source operand) (**FXPWRY**)

Note that even when using an integer operand, a pointer to that operand is pushed onto the stack rather than value of the operand itself. For example, to perform an integer exponentiation:

```
        PEA             IntegerExponent(A5)
        PEA             ExtendedNumber(A5)
        FXPWRI
IntegerExponent  DS     1
ExtendedNumber   DS     5
```

ELEMS68K also contains routines to compute compound interest and annuities. Each requires three extended operands — two source (the interest rate and the number of compounding periods) and one destination (the starting principle). A pointer to the interest rate is deepest in the stack, followed by a pointer to the number of compounding periods and a pointer to the destination operand:

1. Compound interest (**FCOMPOUND**)
2. Annuity (**FANNUITY**)

For example, this code will compute compound interest:

```
        PEA             InterestRate(A5)
        PEA             NumbOfPds(A5)
        PEA             StartPrinc(A5)
        FCOMPOUND
InterestRate    DS      5
NumbOfPds       DS      5
StartPrinc      DS      5
```

Finishing the Task — Doing Binary to Decimal Conversions and Formatting Output

Converting from a binary number back to the canonical decimal format is not precisely the opposite of converting from decimal to binary. There are two possible output formats — floating point and fixed point, both of which are delivered in the canonical decimal format record.

To see the difference, consider the number 32.5. As noted earlier, the extended floating point format of 32.5 is $4004 8200 0000 0000 0000. If converted to a floating point number with three significant digits, the canonical decimal format will appear as $FFFF 0333 3235 .... or 325 * 10^{-1}. A floating point version of the number (assuming that the conversion requests three digits to the right of the decimal point) appears as $FFFD 0533 3235 3030... which is 32500 * 10^{-3} or 32.500. Floating point numbers are designed to be displayed in the mantissa and exponent format (e.g., 3.25E1) while fixed point numbers have their decimal points embedded in the number itself, as in 32.500.

The output format of a binary-to-decimal routine is controlled by a format record:

```
TYPE DecForm = RECORD
       style : (0, 256); {0 = float; 256 = fixed}
       digits : INTEGER
       END;
```

The style word stores the flag for the style in bit 8. Therefore, a value of 0 indicates that the number should be converted to a floating point number, while a value of 256 (a 1 in bit 8) indicates that the conversion should be to fixed point.

The meaning of the **digits** field depends on whether the conversion is to float or fixed. For a floating point number, **digits** indicates the total number of significant digits that should be stored in the canonical decimal format. For a fixed point number, the same field contains the number of fractional digits (those to the right of the decimal point) that are to be stored.

Doing a Binary to Decimal Conversion

The macro for binary to decimal conversions is **F?2DEC**, where **?** is replaced by the letter which indicates the format of the source binary number. For example,

FX2DEC will convert an extended operand while FI2DEC will convert an integer operand. Note that while the FP68K routines will handle integer and longinteger operands, they can more easily be converted by using the Binary-Decimal Conversion Package.

The binary-to-decimal conversion routines require three operands. A pointer to the format record is deepest in the stack, followed by a pointer to the source operand and finally a pointer to the destination data structure (the canonical decimal format). Assuming that a binary number in extended floating point format is stored in **BinaryNumber(A5)**, the following code will convert that binary number to its floating point representation in the canonical decimal format with six significant digits (the number of significant digits in the example is arbitrary):

```
LEA       FormatRec(A5),A0
MOVE      #0,(A0)              ;style = float
MOVE      #6,2(A0)             ;six significant digits
MOVE.L    A0,-(SP)             ;put pointer on stack
PEA       BinaryNumber(A5)     ;pointer to source operand
PEA       DecimalRec(A5)       ;destination data structure
FX2DEC                         ;routine macro

FormatRec     DS    2
BinaryNumber  DS    5
DecimalRec    DS    23
```

Converting the same extended binary number to a fixed point format with an arbitrary three digits to the right of the decimal point is only slightly different:

```
LEA       FormatRec(A5),A0
MOVE      #256,(A0)            ;style = fixed
MOVE      #3,2(A0)             ;three digits to right of
                               decimal point
MOVE.L    A0,-(SP)             ;pointer to format record
PEA       BinaryNumber(A5)     ;pointer to source operand
PEA       DecimalRec(A5)       ;destination data structure
FX2DEC                         ;routine macro

;uses same data structures as example immediately above
```

The question remains as to when binary numbers should be converted to fixed point and when they should be converted to floating point. The answer lies in how the numbers will be displayed.

Displaying Numbers from a Canonical Decimal Format

Numbers that are to be displayed in fixed point format (i.e., with embedded decimal points) should be converted to fixed and numbers that are to be displayed

in floating point format (i.e., with mantissa and exponent) should be converted to float. The decision generally rests on the size of the number; that is, there comes a point where numbers contain too many digits for effective display. For example, 3.78E44 is the digits 378 followed by 42 zeros. Most applications will choose to display such a large number in its floating point form. On the other hand, 37.8 is conveniently displayed as a floating point number and makes more sense to the user than 3.78E1. The actual point at which any given application will switch from fixed to floating point display will vary from application to application.

Whichever format an application chooses to use, there still remains the problem of taking the number from the canonical decimal format and reformatting it into a string of ASCII characters that can be either printed with **DrawString** or incorporated into a text edit record. The task is more or less the opposite of the function provided by the parser subroutine, which converts strings to the canonical decimal format.

Listing 12.2 contains two subroutines that will convert floating and fixed point numbers to ASCII strings for output. Like the parser, the formatter routines are designed as utility routines to be assembled separately from program code and then called as external references. Each subroutine requires two parameters as input — a pointer to the string containing the number in canonical decimal format (in A1) and a pointer to the output string (in A2). To call either routine (assuming it has been properly linked to the main program code), load the pointers in the address registers and do a **JSR** to the appropriate symbolic address (FormatFloat or FormatFixed).

Listing 12.2 Formatting Numeric Strings for Output

```
;------------------------ Numeric Output Formatter -------------------
;
; Parameters on entry:
;       A1      ;pointer to record containing canonical decimal format
;       A2      ;pointer to output string
;
;---------------------------------------------------------------------

        XDEF    FormatFloat
        XDEF    FormatFixed
        .TRAP   _Pack7 $A9EE

FormatFloat
        MOVE.L  #Ø,DØ               ;initialize register
        MOVE    #1,D3               ;character pointer in output string
                                    ;starts at one to leave room for length byte
        MOVE    #Ø,D5               ;initialize character counter
        MOVE.B  4(A1),D1            ;number of significant digits
        MOVE    2(A1),D2            ;exponent in canonical decimal format
        MOVE    D1,DØ               ;place for output exponent
        ADD     D2,DØ
        SUBQ    #1,DØ               ;final output exponent (exp.+ sig. digits -1)
```

(continued)

Listing 12.2 (continued)

```
        MOVE  (A1),D6           ;get sign
        CMP   #Ø,D6
        BEQ   NoSignNeeded      ;positive number
        MOVE.B #'-',(A2,D3)     ;load a negative sign
        ADDQ  #1,D3

NoSignNeeded
        MOVE  #5,D4             ;offset into canonical decimal format
        MOVE.B (A1,D4),(A2,D3)  ;move first character
        ADDQ  #1,D3             ;move pointer
        ADDQ  #1,D5             ;count the character
        CMP.B D1,D5             ;is there only one digit?
        BEQ   InsertExponent
        MOVE.B #'.',(A2,D3)     ;insert decimal point


MoreDigits
        ADDQ  #1,D3             ;increment pointer
        ADDQ  #1,D4             ;increment offset into canonical decimal format
        MOVE.B (A1,D4),(A2,D3)  ;move a character
        ADDQ  #1,D5             ;count the character
        CMP.B D1,D5             ;all characters moved?
        BNE   MoreDigits

InsertExponent
        ADDQ  #1,D3
        MOVE.B #'E',(A2,D3)
        ADDQ  #1,D3
        LEA   ExponentString(A5),AØ
        EXT.L DØ                ;propogate sign through high-order word of register
        MOVE  #Ø,-(SP)
        _Pack7                  ;convert integer to string
        MOVE.B (AØ),D1          ;length of exponent string
        MOVE  #1,DØ             ;starting offset into exponent string

MoreExponent
        MOVE.B (AØ,DØ),(A2,D3)  ;move one exponent character
        CMP.B D1,DØ
        BEQ   SetLength         ;all characters moved
        ADDQ  #1,DØ
        ADDQ  #1,D3
        BRA   MoreExponent

SetLength
        MOVE.B D3,(A2)          ;install length byte in first position

        RTS

FormatFixed
        MOVE.B 4(A1),D1         ;number of significant digits
        MOVE  2(A1),D2          ;exponent
        MOVE.B D1,D5            ;save significant digits to fool with
        MOVE  D2,D7             ;save exponent to fool with
        BGE   OK
        MULU  #-1,D7            ;make negative exponent positive
```

(continued)

```
OK      SUB    D7,D5
        BLE    Fraction              ;number is a fraction - must handle separately

        ADD.B  D1,D2                 ;number of digits to left of decimal point
        MOVE   #1,D3                 ;position pointer in output string
        MOVE   #Ø,D4                 ;digit counter
        MOVE   #5,D5                 ;initial offset into canonical decimal record
        MOVE   (A1),D6               ;get sign
        BEQ    CopyLoop              ;positive number
        MOVE.B #'-',(A2,D3)          ;load a negative sign

CopyLoop
        CMP.B  D2,D4
        BNE    MoveOne
        ADDQ   #1,D3
        MOVE.B #'.',(A2,D3)          ;insert decimal point


MoveOne
        ADDQ   #1,D3
        MOVE.B (A1,D5),(A2,D3)       ;move one character
        ADDQ   #1,D4
        ADDQ   #1,D5
        CMP    D4,D1
        BNE    CopyLoop

        MOVE.B D3,(A2)               ;load length byte
        RTS

Fraction
        MOVE   #1,D3                 ;initialize position pointer
        MOVE   (A1),D6               ;get sign
        BEQ    None
        MOVE.B #'-',(A2,D3)          ;load negative sign
        ADDQ   #1,D3

None    MOVE.B #'Ø',(A2,D3)          ;loading leading zero and decimal point
        ADDQ   #1,D3                 ;must be two steps because of possibility of
        MOVE.B #'.',(A2,D3)          ;uneven starting address

        MOVE   #Ø,DØ                 ;count zeros
        MOVE   D5,D4                 ;this move is just to affect status register
        BGT    AnotherZero
        MULU   #-1,D5                ;get absolute value

AnotherZero
        CMP    DØ,D5                 ;enough Ø's added?
        BEQ    GetDigits
        ADDQ   #1,D3
        MOVE.B #'Ø',(A2,D3)
        ADDQ   #1,DØ
        BRA    AnotherZero

GetDigits
        MOVE   #Ø,DØ                 ;to count significant digits
```

(continued)

Listing 12.2 (continued)

```
        MOVE  #5,D5                ;offset into canoncial decimal format
AnotherDigit
        ADDQ  #1,D3
        MOVE.B  (A1,D5),(A2,D3)
        ADDQ  #1,D5
        ADDQ  #1,DØ
        CMP   DØ,D1
        BGT   AnotherDigit

        MOVE.B  D3,(A2)            ;load length byte

        RTS

ExponentString      DS.B   6

        END
```

Formatting Floating Point Numbers

Pseudocode for FormatFloat, the floating point formatter, can be found in Figure 12.2. The routine must first compute the exponent for output. This is different from the exponent stored in the canonical decimal format, since the significant digits are stored as an integer but will be displayed in the form X.XXXX.... In fact, the exponent for output is equal to:

Exponent from canonical decimal format - # sig. digits + 1

This exponent is an integer and must ultimately be converted to a string. FormatFloat uses **NumToString** from the Binary-Decimal Conversion Package for that purpose. **NumToString** is very convenient, since it will insert a minus sign at the head of its output string if the integer being converted is negative.

Figure 12.2 Floating Point Formatter Pseudocode

```
Initialize pointer to output string        {set to Ø if no length byte; set to 1 if length byte is
                                            required}

Get number of significant digits from canonical decimal format.

Get exponent from canonical decimal format.

Compute exponent for output as Exponent from canoncial decimal format - Number of Significant
        Digits + 1.

Get sign from canonical decimal format.
```

(continued)

```
If number is negative then
        Put negative sign in first position of output string;
        Increment pointer to output string.
Move first significant digit from canonical decimal format to output string.
Increment pointer to output string.
Move decimal point to output string.
Increment pointer to output string.
Repeat
        Move one significant digit from the canonical decimal format to the output string;
        Increment pointer to output string
Until no significant digits remain.
Put "E" in output record.
Increment pointer to output string.
Convert integer value of exponent for output into a string.
While exponent characters remain do
        Move one exponent character to the output string;
        Increment pointer to output string.
Load length byte at beginning of output string (equal to pointer to output string)
                                {the length byte is optional - leave it out if output
                                 string will be incorporated into a text edit record}
```

FormatFloat checks the first word of the canonical decimal format to determine the sign of the number. If the number is negative, a minus sign is stored in the first position of the output string. Then the first significant digit is moved from the canonical decimal format record to the output record, followed by a decimal point. The remaining significant digits are placed immediately after the decimal point. The next character is an 'E'. Finally, the exponent, as converted by **NumToString**, is moved to the output string.

FormatFloat also places a length byte at the beginning of the output string. If the string is to be displayed by **DrawString**, then the length byte is required, but if the output string is to be incorported into a text edit record, then there should be no

length byte. To modify FormatFloat to format without a length byte, do the following:

1. Initialize the output string position pointer to 0 rather than 1 (register D3)
2. Remove the instruction that loads the lengths byte (**MOVE.B D3,(A2)**)

The same holds true for FormatFixed, the fixed point formatter, since it too was designed to include a length byte.

If you look closely at the assembly language code for FormatFloat in Figure Listing 12.2, you will see one 68000 instruction that we haven't discussed: **EXT**. **EXT** stands for "extend"; it takes one operand – a data register. If the instruction is word-sized, it will copy, or extend, the value of bit 7 into bits 8 through 15. A longword-sized operation will copy the value of bit 15 into bits 16 through 31.

Why is **EXT** important? When the exponent is retrieved from the canonical decimal format it is word-sized. The operations that compute the final exponent are also word-sized. That means that the exponent is stored in D0 as $0000XXXX, where the X's represent the magnitude of the exponent. A problem arises if the word-sized exponent is passed to **NumToString**. **NumToString** expects a longword operand. It makes a decision as to the sign of the number on the value in bit 31. The value of bit 31, therefore, also determines whether the number in D0 will be interpreted as true magnitude or two's complement form.

Consider an exponent of −3. In its word-sized form it will be stored as $0000FFFC. **NumToString**, though, will pick up the zero in bit 31 and assume that the register contains a positive number. The $FFFC will be interpreted as the true magnitude of a positive number, or 65533. The solution is to extend the sign bit of the word-sized operand (bit 15) into the high-order word of the register. Assuming that the contents of D0 are $0000FFFC, the instruction:

```
EXT.L   D0
```

will produce a result of $FFFFFFFC. Since bit 31 is set, **NumToString** will correctly interpret the contents of D0 as a negative number in two's complement form.

Formatting Fixed Point Numbers

Pseudocode for FormatFixed appears in Figure 12.3. Formatting fixed point numbers is slightly more complex than formatting floating point numbers, since numbers that are all fraction must be handled separately from numbers that have both integer and fractional parts. Numbers that are all fraction can be detected by subtracting the absolute value of the exponent in the canonical decimal format from the number of significant digits; any number that has to have its decimal point moved more places to the left than there are significant digits is less than one.

For numbers that have both integer and fractional parts, the first task is to determine how many of the significant digits lie to the right of the decimal point by

summing the exponent and the number of significant digits. Though this procedure may at first seem a bit odd, consider that since the significant digits are stored in the canonical decimal format as if they were an integer, the exponent will always be negative or zero.

Figure 12.3 Fixed Point Formatter Pseudocode

```
Get number of significant digits from canonical decimal format.

Get exponent from canonical decimal format.

Make negative exponent positive.              {need absolute value of exponent}

Subtract absolute value of exponent from number of significant digits.

If subtraction gives positive result then     {number is integer or integer and fraction}

        Initialize pointer to output string;  {Ø for no length byte; 1 for length byte}

        Compute number of digits to left of decimal point by adding exponent to number of
                significant digits;

        Get sign of number from canonical decimal format;

        If number is negative then

                Put a negative sign in output string;

                Increment output string pointer;

        While significant digits remain do

                If place for decimal point found then

                        Put decimal point in output string;

                        increment output string pointer;

                Move on significant digit from the canonical decimal format to the output string;

                Increment output string pointer;

        Load length byte at beginning of output string        {optional}

Else                                                          {number is all fraction}

        Initialize pointer to output string;

        Get sign of number from canonical decimal format;                    (continued)
```

Figure 12.3 (continued)

```
If number is negative then
        Put negative sign in output string;
        Increment output string pointer;
        Put leading zero in output string;
        Increment output string pointer;
        Put decimal point in output string;
        Increment output string pointer;
        Compute number of zeros needed between decimal point and first significant digit as
                absolute value of difference between number of significant digits and exponent
        While zeros remain do
                Put zero in output string;
                Increment output string pointer;
        Repeat
                Move a significant digit from canonical decimal format to output string;
                Increment output string pointer
        Until all significant digits have been moved;
        Load length byte as equal to output string pointer.          {optional}
```

FormatFixed then checks the sign of the number by looking at the first word of the canonical decimal format record and moves a minus sign to the ouput string if appropriate. It then begins to move the significant digits, checking after each digit is moved to determine if the place to insert the decimal point has been found. The decimal point is inserted and the remaining significant digits are transferred.

In order to format a number that is less than one, FormatFixed must determine how many zeros must be inserted between the decimal point and the first significant digit. The number of zeros is equal to the difference between the absolute value of the exponent from the canonical decimal format and the number of significant digits.

As with formatting fixed point numbers greater than one, the procedure for numbers less than one first handles the sign of the number by checking the first word of the canonical decimal format record. A minus sign is moved to the output

string if appropriate. Then a leading zero and a decimal point are inserted in the output string; the leading zero is, of course, not required, but simply creates a nicer-appearing number.

The zeros which come between the decimal point and the significant digits are the next characters that are inserted in the output string. Finally, the significant digits themselves are moved.

Like the parser, the formatters are intended as examples. Feel free to enhance and modify them to suit the needs of your particular application.

Questions and Problems

1. What will be stored in register D0 after the execution of the following block of code:

```
LEA    #'3000000000',A0
MOVE   #1,-(SP)
_Pack7                          ;convert to longinteger
```

   Hint: consider the maximum quantity that can be stored in a longinteger location and what happens when it overflows.

2. For each floating point number below, indicate the value of the sign, exponent, and significant digits as they would be stored in Macintosh's canonical decimal format.

   a. 84867
   b. 363.985
   c. −.00126
   d. $-48.88 * 10^{12}$
   e. $-3.1313 * 10^{-9}$
   f. $.011927 * 10^{43}$

3. Convert the following decimal floating point numbers to Macintosh's 80-bit extended floating point format. Express your answer in hexadecimal.

   a. 32,767
   b. −32,767
   c. $8.99 * 10^{38}$
   d. $-10.33 * 10^{-18}$
   e. $.003 * 10^{-51}$
   f. $-.0101 * 10^{67}$

4. Convert each 80-bit floating point number below to decimal. For base 10 exponents between 4 and −4 produce a fixed-point number; otherwise, produce a decimal floating point number.

   a. $400A 32A0 0000 0000 0000
   b. $6BBB 1246 0000 0000 0000

c. $D01C 32A0 0000 0000 0000
d. $F010 AAA0 0000 0000 0000
e. $2004 96B4 1000 0000 0000
f. $FF34 8111 3131 3100 0000
g. $0001 1246 1444 0000 0000
h. $3FA1 4766 6120 0000 0000

5. Write a Macintosh-style macro that computes the area of a circle. Pass the radius of the circle to the macro in a data register. Return the answer in a different data register.

6. Write a Macintosh-style macro that compares two characters and returns whichever character is alphabetically greater. Pass the characters to the macro in D0 and D1. Return the result in D2.

7. Using the macros defined in SANEMacs.Txt, write code to perform the floating point conversions below. Assume the canonical decimal format is stored in the applications globals area under **DecimalFormat**; storage for the result has been allocated as **ConvertedNumber**.

   a. canonical decimal format to double precision (64-bit) floating point
   b. canonical decimal format to longinteger
   c. canonical decimal format to computational

8. Using the macros defined in SANEMacs.Txt, write code to perform the floating point operations below. A destination operand in extended floating point format is stored in the applications globals area as **DesExtended**. Source operands are stored as **DoubleSource** (64-bit floating point), **SingleSource** (32-bit floating point), **IntSource** (integer), **LongintSource** (longinteger) and **CompSource** (computational).

   a. add a double-precision source operand to the destination operand
   b. multiply an integer source operand by the destination operand
   c. round the destination operand to an integer
   d. invert the sign of the destination operand
   e. find the cosine of the destination operand
   f. generate a random number

9. Write a block of code that compares two operands in extended floating point format and then puts a pointer to the larger operand in A0 and a pointer to the smaller operand in A1. Use the macros defined in SANEMacs.Txt and allocate any necessary data structures.

10. Write a block of code that will create a format record for a binary-to-decimal conversion that will produce a floating point number with eight significant digits.

11. Write pseudocode that summarizes the procedure for doing a binary to decimal conversion, assuming that you are starting with a string of ASCII characters.

12. Using the subroutines Parser and FormatFloat, write a subroutine that:

    A. accepts a pointer to a source operand string in A0 and a pointer to a destination operand string in A1;
    B. converts both operands to the extended floating point format;
    C. subtracts the source operand from the destination operand; and
    D. returns the result as a floating point number properly formatted for output

APPENDIX A

THE VIDEO TAPE INDEX PROGRAM

The Video Tape Index Program is a specialized database program that maintains listings and annotations of tapes. It can also be used to handle, for example, audio tapes, records, and video discs.

To run the program, double-click on its icon from the Finder. It will automatically create and open any necessary files. You may then select from the Options menu to update the database (entering, changing, deleting), do on-screen data display, or print the database.

The program does have some limitations. Those limitations and suggested modifications to overcome them are:

1. The program will support up to 100 titles. To increase this, increase the size of the **TapeArray** storage area. A 512K Mac will support as many as 500 titles, though if that much memory is used for the RAM array, there may not be enough left to image a spooled print file. In that case, you must always draft print.

2. Search hits are based only on equality of the search data with data in **TapeArray**. To implement searches on equalities, allow the user to enter a symbol for the inequality (e.g., <, >=, etc.) at the beginning of the search text. Then add code to the binary and sequential search routines that identifies the search criteria and, based on that criteria, makes the appropriate comparisons.

3. All **TapeArray** data are stored in a file named TAPE.MASTER. All annotations are stored in ANNOTATIONS. To allow the user to have multiple sets of master and annotation files, use the standard "get file" dialog box twice, once to select a tape file and once to select an annotation file.

4. The program will print only the entire file, either with or without annotations. To print only selected records, allow the user to enter selection criteria and verify each record against that criteria before printing.

5. The program will print only in tape-name order. It can be easily sorted to change that sequencing. Since the file must be maintained in tape-name order for the binary search to work, it is probably best to sort the array to a copy in RAM. The same straight-insertion sort that inserts new records can be used for that purpose.

6. Deleting a record from the tape master file does not delete its annotation. Deleting annotations requires a routine that completely re-writes the annotation file. It should read sequentially through **TapeArray**, retrieving each record's annotation and writing it out to the new annotation file.

Listing A.1 Source Code of the Video Tape Index Program

```
        Include MacTraps.D      ;Includes addresses of ToolBox routines
        Include ToolEqu.D       ;Includes the ToolBox equates
        Include SysEqu.D        ;Includes the System equates
        Include QuickEqu.D      ;the QuickDraw equates
        Include PrEqu.Txt       ;printer equates

;---------------------------- EQUATES ----------------------------
;------- (must go at the top or program won't assemble!) ----------
        oTapeName       EQU     Ø               ;offsets in tape record
        oProducer       EQU     3Ø
        oReleaseDate    EQU     5Ø
        oRating         EQU     54
        oTapeNumber     EQU     58
        oAnnotNum       EQU     62

;---------------------- Initialize managers ----------------------
        PEA -4(A5)
        _InitGraf               ;Initializes QuickDraw
        _InitFonts              ;Initializes the Font Manager
        _InitWindows            ;Initializes the Window Manager
        _InitMenus              ;Initializes the Menu Manager
        CLR.L   -(SP)           ;no restart procedure
        _InitDialogs            ;initializes dialog manager
        _TEInit                 ;Initializes Text Edit

; This section gets all eight menus from the resource file and makes them
;  available to the program through their handles

        CLR.L   -(SP)           ;Clear space for menu handle
        MOVE    #1,-(SP)        ;This will be menu 1
        _GetRMenu               ;Apple menu comes in from resource file

        LEA     AppleHandle,AØ  ;Get address for handle
        MOVE.L  (SP)+,A1        ;Pull handle off stack
        MOVE.L  A1,(AØ)         ;Store handle
```

(continued)

Listing A.1 (continued)

```
        LEA     AppleHandle,A1
        MOVE.L  (A1),-(SP)      ;Put handle back on stack
        MOVE.L  #'DRVR',-(SP)   ;Identify desk accessories
        _AddResMenu             ;Get desk accessories from system

        CLR.L   -(SP)           ;Clear space for handle
        MOVE    #2,-(SP)        ;menu #2
        _GetRMenu               ;Edit menu

        LEA     EditHandle,A0   ;Get address for handle
        MOVE.L  (SP)+,A1        ;Pull handle off stack
        MOVE.L  A1,(A0)         ;Store handle

        CLR.L   -(SP)           ;Clear space for handle
        MOVE    #3,-(SP)        ;menu #3
        _GetRMenu               ;Options menu

        LEA     OptionsHandle,A0        ;Get address for handle
        MOVE.L  (SP)+,A1        ;Pull handle off stack
        MOVE.L  A1,(A0)         ;Store handle

        CLR.L   -(SP)
        MOVE    #4,-(SP)
        _GetRMenu               ;Enter menu

        LEA     EnterHandle,A0
        MOVE.L  (SP)+,A1
        MOVE.L  A1,(A0)

        CLR.L   -(SP)
        MOVE    #5,-(SP)
        _GetRMenu               ;Change menu

        LEA     ChangeHandle,A0
        MOVE.L  (SP)+,A1
        MOVE.L  A1,(A0)

        CLR.L   -(SP)
        MOVE    #6,-(SP)
        _GetRMenu               ;Delete menu

        LEA     DeleteHandle,A0
        MOVE.L  (SP)+,A1
        MOVE.L  A1,(A0)

        CLR.L   -(SP)
        MOVE    #7,-(SP)
        _GetRMenu               ;Select menu

        LEA     SelectHandle,A0
        MOVE.L  (SP)+,A1
        MOVE.L  A1,(A0)
```

(continued)

```
        CLR.L   -(SP)
        MOVE    #8,-(SP)
        _GetRMenu               ;Print menu

        LEA     PrintHandle,A0
        MOVE.L  (SP)+,A1
        MOVE.L  A1,(A0)

; This section gets the seven windows from the resource file and allocates
; their storage.  They are invisible at this point.

        CLR.L   -(SP)           ;space for window handle
        MOVE    #7,-(SP)        ;Annotation window
        PEA     AnnotationWindowStorage(A5)     ;address for window record
        MOVE.L  #-1,-(SP)       ;put window in front
        _GetNewWindow

        LEA     AnnotationWindowPtr,A0 ;destination address for pointer
        MOVE.L  (SP)+,A1        ;get pointer from stack
        MOVE.L  A1,(A0)         ;save pointer

        CLR.L   -(SP)           ;space for window handle
        MOVE    #6,-(SP)        ;Tape Number window
        PEA     NumberWindowStorage(A5)         ;address for window record
        MOVE.L  #-1,-(SP)       ;put window in front
        _GetNewWindow

        LEA     NumberWindowPtr,A0      ;destination address for pointer
        MOVE.L  (SP)+,A1        ;retrieve pointer from stack
        MOVE.L  A1,(A0)         ;save pointer

        CLR.L   -(SP)
        MOVE    #5,-(SP)        ;Rating window
        PEA     RatingWindowStorage(A5)
        MOVE.L  #-1,-(SP)
        _GetNewWindow

        LEA     RatingWindowPtr,A0
        MOVE.L  (SP)+,A1
        MOVE.L  A1,(A0)

        CLR.L   -(SP)
        MOVE    #4,-(SP)        ;Date window
        PEA     DateWindowStorage(A5)
        MOVE.L  #-1,-(SP)
        _GetNewWindow

        LEA     DateWindowPtr,A0
        MOVE.L  (SP)+,A1
        MOVE.L  A1,(A0)

        CLR.L   -(SP)                                   (continued)
```

Listing A.1 (continued)

```
        MOVE    #3,-(SP)        ;Producer window
        PEA     ProducerWindowStorage(A5)
        MOVE.L  #-1,-(SP)
        _GetNewWindow

        LEA     ProducerWindowPtr,AØ
        MOVE.L  (SP)+,A1
        MOVE.L  A1,(AØ)

        CLR.L   -(SP)
        MOVE    #2,-(SP)        ;Tape Name window
        PEA     NameWindowStorage(A5)
        MOVE.L  #-1,-(SP)
        _GetNewWindow

        LEA     NameWindowPtr,AØ
        MOVE.L  (SP)+,A1
        MOVE.L  A1,(AØ)

        CLR.L   -(SP)           ;make space for window handle
        MOVE    #1,-(SP)        ;this is window #1
        PEA     MainWindowStorage(A5)  ;address for window record storage
        MOVE.L  #-1,-(SP)       ;put this window in front
        _GetNewWindow           ;get window definition from resource file

        LEA     MainWindowPtr,AØ        ;load destination address for pointer
        MOVE.L  (SP)+,A1        ;get pointer from stack
        MOVE.L  A1,(AØ)         ;put pointer into WindowPtr

;---------------  Allocate TextEdit Records ----------------------------
        MOVE.L  NameWindowPtr,-(SP)
        _SetPort
        CLR.L   -(SP)           ;clear space for text handle
        PEA     NameDestRect
        PEA     NameViewRect
        _TENew                  ;allocate text record
        LEA     NameTextHandle,AØ       ;get address for text handle
        MOVE.L  (SP)+,(AØ)      ;take handle from stack and store

        MOVE.L  ProducerWindowPtr,-(SP)
        _SetPort
        CLR.L   -(SP)
        PEA     ProducerDestRect
        PEA     ProducerViewRect
        _TENew
        LEA     ProducerTextHandle,AØ
        MOVE.L  (SP)+,(AØ)

        MOVE.L  DateWindowPtr,-(SP)
        _SetPort
        CLR.L   -(SP)
        PEA     DateDestRect
```

(continued)

```
        PEA     DateViewRect
        _TENew
        LEA     DateTextHandle,AØ
        MOVE.L  (SP)+,(AØ)

        MOVE.L  RatingWindowPtr,-(SP)
        _SetPort
        CLR.L   -(SP)
        PEA     RatingDestRect
        PEA     RatingViewRect
        _TENew
        LEA     RatingTextHandle,AØ
        MOVE.L  (SP)+,(AØ)

        MOVE.L  NumberWindowPtr,-(SP)
        _SetPort
        CLR.L   -(SP)
        PEA     NumberDestRect
        PEA     NumberViewRect
        _TENew
        LEA     NumberTextHandle,AØ
        MOVE.L  (SP)+,(AØ)

        MOVE.L  AnnotationWindowPtr,-(SP)
        _SetPort
        CLR.L   -(SP)
        PEA     AnnotationDestRect
        PEA     AnnotationViewRect
        _TENew
        LEA     AnnotationTextHandle,AØ
        MOVE.L  (SP)+,(AØ)

;---------------- Change cursor to watch for file operations --------------
        CLR.L   -(SP)           ;space for cursor handle result
        MOVE    #4,-(SP)        ;indicates the watch cursor for long wait
        _GetCursor              ;get handle to cursor definition

        MOVE.L  (SP)+,AØ
        MOVE.L  (AØ),AØ                 ;de-reference the handle to get pointer
        MOVE.L  AØ,-(SP)        ;put pointer on stack
        _SetCursor              ;set cursor to watch

;----------------- Load TapeArray or create new file ----------------------
        LEA     'Tape.Master',AØ                ;file name
        MOVE.L  AØ,ioParamBlock+ioFileName(A5)
        MOVE    #1,ioParamBlock+ioDrvNum(A5)    ;on drive 1
        MOVE.B  #Ø,ioParamBlock+ioFileType(A5)  ;version number Ø
        LEA     ioParamBlock(A5),AØ
        _Create                                 ;attempt to create file

        CMP     #-48,DØ                                 ;duplicate file name
        BEQ     OpenTapeFile
```

(continued)

Listing A.1 (continued)

```
        CMP     #Ø,DØ
        BEQ     TapeFileInfo
        JMP     FileError

TapeFileInfo
        LEA     'Tape.Master',AØ
        MOVE.L  AØ,fiParamBlock+ioFileName(A5)          ;name
        MOVE    #1,fiParamBlock+ioDrvNum(A5)            ;drive
        MOVE.B  #Ø,fiParamBlock+ioFileType(A5)          ;version #
        MOVE    #Ø,fiParamBlock+ioFDirIndex(A5)         ;use name and drive to find file
        LEA     fiParamBlock(A5),AØ
        _GetFileInfo

        MOVE.L  #'TEXT',fiParamBlock+ioFlUsrWds(A5)     ;file type
        LEA     fiParamBlock(A5),AØ
        _SetFileInfo

        LEA     TotalRecords,AØ
        MOVE    #Ø,(AØ)
        BRA     CloseTapeFile

OpenTapeFile
        LEA     'Tape.Master',AØ
        MOVE.L  AØ,ioParamBlock+ioFileName(A5)
        MOVE    #1,ioParamBlock+ioDrvNum(A5)
        MOVE.B  #Ø,ioParamBlock+ioFileType(A5)
        MOVE.B  #1,ioParamBlock+ioPermssn(A5)  ;read only permission
        CLR.L   ioParamBlock+ioOwnBuf(A5)
        LEA     ioParamBlock(A5),AØ
        _Open

        CMP     #Ø,DØ
        BNE     FileError

        LEA     DataBuffer(A5),AØ
        MOVE.L  AØ,ioParamBlock+ioBuffer(A5)
        MOVE.L  #4,ioParamBlock+ioByteCount(A5) ;just get tape & annot. totals
        MOVE    #Ø,ioParamBlock+ioPosMode(A5)  ;read from mark
        LEA     ioParamBlock(A5),AØ
        _Read

        MOVE.L  DataBuffer(A5),DØ       ;get numbers just read
        LEA     LastAnnotNumb,AØ
        MOVE    DØ,(AØ)                 ;recover last annotation number
        SWAP    DØ                      ;put total records in lower half
        LEA     TotalRecords,AØ
        MOVE    DØ,(AØ)                 ;recover total records

        LEA     TapeArray(A5),AØ        ;destination for tape records
        MOVE.L  AØ,ioParamBlock+ioBuffer(A5)
        MOVE    TotalRecords,DØ
        MULU    #64,DØ                  ;number of bytes to read
```

(continued)

```
        MOVE.L  DØ,ioParamBlock+ioByteCount(A5)
        MOVE    #Ø,ioParamBlock+ioPosMode(A5)  ;read from mark
        LEA     ioParamBlock(A5),AØ
        _Read

CloseTapeFile
        LEA     ioParamBlock(A5),AØ
        _Close
;----------------- Open Annotations file or create new file ------------------

        LEA     'Annotations',AØ
        MOVE.L  AØ,ioParamBlock+ioFileName(A5) ;file name
        MOVE    #1,ioParamBlock+ioDrvNum(A5)   ;on drive 1
        MOVE.B  #Ø,ioParamBlock+ioFileType(A5) ;version number of Ø
        LEA     ioParamBlock(A5),AØ            ;point to parameter block
        _Create

        CMP     #-48,DØ                                ;duplicate file name
        BEQ     OpenAnnotFile
        CMP     #Ø,DØ                          ;file successfully created
        BEQ     AnnotFileInfo
        JMP     FileError

AnnotFileInfo
        LEA     'Annotations',AØ
        MOVE.L  AØ,fiParamBlock+ioFileName(A5)
        MOVE    #1,fiParamBlock+ioDrvNum(A5)
        MOVE.B  #Ø,fiParamBlock+ioFileType(A5)
        MOVE    #Ø,fiParamBlock+ioFDirIndex(A5)
        LEA     fiParamBlock(A5),AØ
        _GetFileInfo

        MOVE.L  #'TEXT',fiParamBlock+ioFlUsrWds(A5)
        LEA     fiParamBlock(A5),AØ
        _SetFileInfo

        LEA     LastAnnotNumb,AØ
        MOVE    #-1,(AØ)

OpenAnnotFile
        LEA     'Annotations',AØ
        MOVE.L  AØ,ioParamBlock+ioFileName(A5) ;load file name
        MOVE    #1,ioParamBlock+ioDrvNum(A5)   ;load drive number
        MOVE.B  #Ø,ioParamBlock+ioFileType(A5) ;a version number of Ø
        MOVE.B  #3,ioParamBlock+ioPermssn(A5)  ;allow reading and writing
        CLR.L   ioParamBlock+ioOwnBuf(A5)      ;use volume access path buffer
        LEA     ioParamBlock(A5),AØ                    ;point to parameter block
        _Open

        CMP     #Ø,DØ                          ;result code in DØ
        BNE     FileError
```

(continued)

Listing A.1 (continued)

```
        LEA     fiRefNum,AØ
        MOVE    ioParamBlock+ioRefNum(A5),(AØ) ;save reference number
        BRA     BeginProgram                   ;file open and all's well

FileError
        CLR     -(SP)
        MOVE    #6,-(SP)
        CLR.L   -(SP)
        _Alert
        MOVE    (SP)+,DØ

        RTS                                    ;returns to Finder

;--------------- Make main window visible and bring to front -----------
BeginProgram

        MOVE.L  MainWindowPtr,-(SP)
        _SelectWindow

        MOVE.L  MainWindowPtr,-(SP)
        _SetPort
        _InitCursor             ;set the cursor to the arrow

        MOVE.L  everyEvent,DØ   ;Mask to select all events
        _FlushEvents            ;Clear the event queue

        JSR     MainMenuBar     ;Set up and draw main menu bar

;--------------- Main Event Loop ------------------------

Event   _SystemTask             ;update desk accessories

        CLR     -(SP)           ;Space for boolean result
        MOVE    #-1,-(SP)       ;Mask for keyboard - select all events
        PEA     EventRecord     ;Place to receive event info
        _GetNextEvent           ;Get next event from queue

        MOVE    (SP)+,DØ        ;Recover event result
        CMP     #Ø,DØ
        BEQ     Event           ;If no event, branch to look again

        MOVE    What,DØ         ;Recover event ID
        CMP     #mButDwnEvt,DØ          ;Was mouse button pressed?
        BEQ     MouseEvent

        CMP     #keyDwnEvt,DØ   ;Was key pressed?
        BEQ     KeyEvent

        BRA     Event           ;Look for another event
```

(continued)

```
KeyEvent
        MOVE.B  Modify,DØ       ;Recover modifier bytes
        CMP.B   #$Ø1,DØ         ;Was command key pressed
        BEQ     KeyboardCommand

        BRA     Event

KeyboardCommand
        CLR.L   -(SP)           ;space for menu item selection
        MOVE    Message+2,-(SP) ;put character pressed on stack
        _MenuKey                ;figure out what key was pressed
        BRA     Selections

MouseEvent
        CLR     -(SP)           ;Place for "what" result
        MOVE.L  Point,-(SP)     ;Point = mouse coordinates
        PEA     WhichWindowPtr  ;Push place for window handle of window
        _FindWindow             ;Where was button pushed?

        MOVE    (SP)+,DØ        ;Recover FindWindow result

        CMP     #inMenuBar,DØ   ;Was mouse clicked in menu bar?
        BEQ     MenuBar         ;Mouse clicked in menu bar
        CMP     #inSysWindow,DØ         ;Was mouse clicked in system window?
        BEQ     SysEvent        ;Mouse clicked in system window

        BRA     Event           ;go back to check for another event

SysEvent
        PEA     EventRecord     ;Event record goes on stack
        MOVE.L  WhichWindowPtr,-(SP)    ;Window pointer goes on stack, too
        _SystemClick            ;System handles it

        BRA     Event

MenuBar CLR.L   -(SP)           ;Place for menu ID and Menu item
        MOVE.L  Point,-(SP)     ;Push mouse coordinates
        _MenuSelect             ;Find out exactly where mouse was clicked

Selections
        MOVE.L  (SP)+,D2        ;Recover result

        LEA     WhichMenu,AØ    ;get address for high-order byte of result
        MOVE.L  D2,(AØ)         ;Store result

        CLR     -(SP)           ;get set to unhighlight all menus
        _HiLiteMenu             ;Unhighlight the menus

        MOVE    WhichMenu,DØ    ;Put menu number in DØ

        CMP     #1,DØ   ;In apple menu?
```

(continued)

Listing A.1 (continued)

```
        BNE     Menu2
        JSR     AppleMenu

Menu2   CMP     #2,D0   ;In edit menu?
        BNE     Menu3
        JSR     EditMenu

Menu3   CMP     #3,D0   ;In options menu?
        BNE     NoMenu
        JSR     Options

NoMenu  BRA     Event           ;Return to look for another event

AppleMenu
        LEA     AppleHandle,A0  ;Get address of menu handle
        MOVE.L  (A0),-(SP)      ;Put menu handle of stack
        MOVE    WhatItem,D0
        MOVE    D0,-(SP)        ;Put ID# of item clicked on stack
        PEA     DeskAccName     ;Push address where desk acc. name should go
        _GetItem                ;Figure out which one was selected

        CLR     -(SP)           ;Leave space for reference number
        PEA     DeskAccName     ;Put address of name on stack
        _OpenDeskAcc            ;Open the desk accessory
        MOVE    (SP)+,D0        ;Pull reference number off stack

        CLR     -(SP)
        _HiLiteMenu             ;Unhighlight the menu title

        MOVE    #9,D0
        RTS

EditMenu
        MOVE    WhatItem,D0     ;Figure out which command is selected
        SUBQ    #1,D0           ;adjust number to pass to SysEdit
        CLR     -(SP)           ;space for result if there's a problem
        MOVE    D0,-(SP)        ;let system know what item was chosen
        _SysEdit                ;let the system handle the edit
        MOVE    (SP)+,D1        ;clear problem result from stack
        MOVE    #9,D0
        RTS

Options MOVE    WhatItem,D0     ;Move item selected to D0

        CMP     #1,D0
        BNE     Item2
        JSR     Enter           ;Enter new tapes

Item2   CMP     #2,D0
        BNE     Item3
        JSR     Change          ;Modify existing tapes
```

(continued)

```
Item3   CMP     #3,D0
        BNE     Item4
        JSR     Delete          ;Delete tapes

Item4   CMP     #4,D0
        BNE     Item5
        JSR     Select          ;Retrieve info

Item5   CMP     #5,D0
        BNE     Item6
        JSR     Print           ;Print lists

Item6   CMP     #6,D0
        BEQ     Quit            ;Exit the program

        MOVE.L  MainWindowPtr,-(SP)
        _SelectWindow

        MOVE.L  MainWindowPtr,-(SP)
        _SetPort

        PEA     MainWindowRect
        _EraseRect              ;clears out text window prompts

        JSR     ReDrawMainMenu ;put options menu back in menu bar

        MOVE.L  EditHandle,-(SP)
        MOVE    #1,-(SP)        ;"UnDo"
        _EnableItem             ;highlight "UnDo", since systems windows use it

        MOVE.L  MainWindowPtr,-(SP)
        PEA     'Video Tape Index'
        _SetWTitle

        RTS                     ;Return to main program

Quit    CLR.L   -(SP)           ;space for cursor handle
        MOVE    #4,-(SP)        ;ID for watch cursor
        _GetCursor
        MOVE.L  (SP)+,A0        ;recover handle
        MOVE.L  (A0),A0                 ;de-reference handle to get pointer
        MOVE.L  A0,-(SP)        ;pointer to cursor definition
        _SetCursor              ;set watch cursor for file operations

        MOVE    fiRefNum,ioParamBlock+ioRefNum(A5)
        LEA     ioParamBlock(A5),A0
        _Close                  ;close the annotations file

        LEA     'Tape.Master',A0
        MOVE.L  A0,ioParamBlock+ioFileName(A5)
        MOVE    #1,ioParamBlock+ioDrvNum(A5)
```

(continued)

Listing A.1 (continued)

```
        MOVE.B  #Ø,ioParamBlock+ioFileType(A5)
        MOVE.B  #2,ioParamBlock+ioPermssn(A5)  ;write only permission
        CLR.L   ioParamBlock+ioOwnBuf(A5)
        LEA     ioParamBlock(A5),AØ
        _Open

        CMP     #Ø,DØ
        BNE     FileError
        MOVE    TotalRecords,DØ
        SWAP    DØ                      ;put total records in high order bits
        AND.L   #$FFFFØØØØ,DØ           ;clear out low order bits
        MOVE    LastAnnotNumb,DØ
        MOVE.L  DØ,DataBuffer(A5)
        LEA     DataBuffer(A5),AØ
        MOVE.L  AØ,ioParamBlock+ioBuffer(A5)
        MOVE.L  #4,ioParamBlock+ioByteCount(A5) ;write just the header info
        MOVE    #Ø,ioParamBlock+ioPosMode(A5)  ;write at current position of mark
        LEA     ioParamBlock(A5),AØ
        _Write

        LEA     TapeArray(A5),AØ                ;tape array location doubles as buffer
        MOVE.L  AØ,ioParamBlock+ioBuffer(A5)
        MOVE    TotalRecords,DØ
        MULU    #64,DØ                          ;total number of bytes to move
        MOVE.L  DØ,ioParamBlock+ioByteCount(A5)
        MOVE    #Ø,ioParamBlock+ioPosMode(A5)  ;sequential write
        LEA     ioParamBlock(A5),AØ
        _Write

        LEA     ioParamBlock(A5),AØ
        _Close                                  ;close the tape master file
        _InitCursor             ;re-set to arrow cursor

        MOVE.L  (SP)+,DØ        ;pop subroutine return address off stack
        RTS                     ;This return goes back to the Finder

;-------------------- Enter New Titles ----------------------

Enter
        MOVE.L  MainWindowPtr,-(SP)
        PEA     'Enter New Titles and Annotations'
        _SetWTitle

        JSR     DisplayPrompts  ;make text window prompts visible

        JSR     DisplayWindows  ;make the text entry windows visible

        MOVE    #3,-(SP)
        _DeleteMenu             ;Remove Options menu from menu list

        LEA     EnterHandle,AØ  ;get address for Enter menu's handle
        MOVE.L  (AØ),-(SP)      ;put handle on stack
```

(continued)

```
        CLR     -(SP)           ;this menu will go at the end of the list
        _InsertMenu

        _DrawMenuBar            ;Re-draw the menu bar

        MOVE.L  EditHandle,-(SP)
        MOVE    #1,-(SP)        ;"UnDo" is not supported
        _DisableItem            ;make "UnDo" appear dimmed

EnterEvent
        MOVE.L  ActiveTextHandle,-(SP)
        _TEIdle                 ;make a blinking cursor appear

        _SystemTask             ;update desk accessories

        CLR     -(SP)           ;space for boolean result
        MOVE    #-1,-(SP)       ;mask to select all events
        PEA     EventRecord     ;place to accept event
        _GetNextEvent           ;get next event from queue

        MOVE    (SP)+,D0        ;recover event result
        CMP     #0,D0
        BEQ     EnterEvent      ;no event encountered - keep checking

        MOVE    What,D0         ;recover event ID
        CMP     #mButDwnEvt,D0          ;mouse button pressed?
        BEQ     EnterMouseEvent

        CMP     #keyDwnEvt,D0   ;was key pressed?
        BEQ     EnterKeyEvent

        CMP     #activateEvt,D0 ;activate event posted?
        BEQ     EnterActivateEvent

        CMP     #updatEvt,D0    ;text window needs updating?
        BEQ     EnterUpdateEvent

        BRA     EnterEvent      ;look for another event

EnterActivateEvent
        JSR     ActivateTextWindow

        BRA     EnterEvent

EnterUpdateEvent
        JSR     UpdateTextWindows

        BRA     EnterEvent

EnterKeyEvent
        MOVE.B  Modify,D0       ;recover modifier byte
```

(continued)

Listing A.1 (continued)

```
        CMP.B   #$Ø1,DØ                 ;was command key pressed?
        BEQ     EnterKeyboardCommand

        MOVE    Message+2,-(SP) ;character that was pressed
        MOVE.L  ActiveTextHandle,-(SP)  ;holds handle to current text record
        _TEKey                  ;insert the character

        BRA     EnterEvent

EnterKeyboardCommand
        CLR.L   -(SP)           ;place for menu item selection
        MOVE    Message+2,-(SP) ;put character pressed on stack
        _MenuKey
        BRA     EnterSelections

EnterMouseEvent
        CLR     -(SP)           ;space for "What" result
        MOVE.L  Point,-(SP)     ;put mouse coordinates on stack
        PEA     WhichWindowPtr  ;push pointer to window record
        _FindWindow             ;where was buttom pressed?

        MOVE    (SP)+,DØ        ;recover FindWindow result

        CMP     #inMenuBar,DØ   ;was mouse clicked in menu bar?
        BEQ     EnterMenuBar    ;mouse clicked in menu bar

        CMP     #inSysWindow,DØ         ;was mouse clicked in a desk accessory?
        BEQ     EnterSysEvent

        CMP     #inContent,DØ   ;mouse clicked in content area of user window?
        BEQ     EnterInWindow

        BRA     EnterEvent

EnterSysEvent
        PEA     EventRecord     ;pointer to event record goes on stack
        MOVE.L  WhichWindowPtr,-(SP)    ;window pointer on stack, too
        _SystemClick            ;let the system handle it

        BRA     EnterEvent

EnterMenuBar
        CLR.L   -(SP)           ;place for menu ID and menu item
        MOVE.L  Point,-(SP)     ;push mouse coordinates
        _MenuSelect             ;which menu?

EnterSelections
        MOVE.L  (SP)+,D2        ;recover result

        LEA     WhichMenu,AØ    ;get address for high-order byte of result
        MOVE.L  D2,(AØ)         ;store result
```

(continued)

```
        CLR     -(SP)           ;mask to indicate all menus
        _HiLiteMenu             ;unhighlight the menus

        MOVE    WhichMenu,DØ    ;put menu number in DØ

        CMP     #1,DØ           ;in Apple menu?
        BNE     EnterMenu2
        JSR     AppleMenu

EnterMenu2
        CMP     #2,DØ           ;in edit menu?
        BNE     EnterMenu4

        JSR     EditMenu        ;was edit command in system window?
        CMP     #Ø,D1
        BNE     EnterEvent      ;edit was in system window and system handled it

        JSR     DoEditing
        BRA     EnterEvent

EnterMenu4
        CMP     #4,DØ
        BNE     EnterEvent

EnterMenuOptions
        MOVE    WhatItem,DØ     ;Move item selected to DØ

        CMP     #1,DØ           ;Add a new item?
        BNE     OtherOne
        JSR     AddNewTitle

OtherOne
        CMP     #2,DØ           ;Quit?
        BNE     EnterEvent      ;not what we want - look for another event

        MOVE    #4,-(SP)
        _DeleteMenu             ;remove enter menu

        MOVE    #9,DØ
        RTS                     ;return to options block

EnterInWindow

        CLR.L   -(SP)           ;make room for pointer as result
        _FrontWindow            ;find out which window is in front (i.e., active)
        MOVE.L  (SP)+,AØ        ;recover FrontWindow result
        CMP.L   WhichWindowPtr,AØ       ;is front window same as clicked window?
        BNE     MustActivate    ;window is inactive

        PEA     Point           ;place where mouse buttom was clicked
        _GlobalToLocal          ;convert coordinates to local system
```

(continued)

Listing A.1 (continued)

```
        MOVE.L  Point,-(SP)       ;coordinates now local
        BTST    #shiftKey,Modify          ;shift key bit set?
        SNE     DØ                ;set true if shift key was held down
        MOVE.B  DØ,-(SP)          ;moving byte puts boolean in high order byte
        MOVE.L  ActiveTextHandle,-(SP)   ;this will be currently active window
        _TEClick

        BRA     EnterEvent

MustActivate
        JSR     SelectTextWindow
        BRA     EnterEvent

AddNewTitle
;---------------- assemble an input record ------------------------

        JSR     ClearNewRecord
        JSR     MoveName
        JSR     MoveProducer
        JSR     MoveDate
        JSR     MoveRating
        JSR     MoveNumber

        MOVE    LastAnnotNumb,DØ
        ADDQ    #1,DØ
        MOVE    DØ,NewRecord+oAnnotNum(A5)
        LEA     LastAnnotNumb,AØ
        MOVE    DØ,(AØ)
;---------------- Straight-Insertion Sort -------------------

        MOVE    TotalRecords,D1
        LEA     TapeArray(A5),A2
        CMP     #Ø,D1
        BEQ     InsertNew         ;if first record, insert immediately
        SUBQ    #1,D1             ;otherwise, adjust for record #'s beginning with Ø
Checking

        JSR     ComputeAddress1           ;Address returned in A3
        MOVE.L  D1,-(SP)                  ;save D1 on stack
        CLR.W   -(SP)                     ;space for result
        MOVE.L  A3,-(SP)                  ;pointer to record in array
        PEA     NewRecord(A5)             ;pointer to new record
        MOVE.W  #3Ø,-(SP)                 ;characters to look at in first string
        MOVE.W  #3Ø,-(SP)                 ;characters to look at in second string
        MOVE.W  #1Ø,-(SP)                 ;ID for IUMagString
        _Pack6                            ;invoke the package
        MOVE.W  (SP)+,DØ                  ;recover result
        MOVE.L  (SP)+,D1                  ;recover former contents of D1

        CMP     #Ø,DØ
        BLE     JustBeforeInsert ;found place to insert record
        BGT     MoveOld                   ;move existing record down
```

(continued)

```
MoveOld
        MOVE    D1,D5
        ADDQ    #1,D5                   ;record # to move to
        JSR     ComputeAddress1                 ;offset returned in A3
        JSR     ComputeAddress2                 ;offset returned in A4

        MOVE.L  A3,AØ           ;source pointer for block move
        MOVE.L  A4,A1           ;destination pointer for block move
        MOVE.L  #64,DØ                  ;64 bytes will be moved
        _BlockMove                      ;move an entire record

        SUBQ    #1,D1                   ;move back a record
        CMP     #-1,D1                  ;does new record go in first position?
        BEQ     JustBeforeInsert
        BRA     Checking

JustBeforeInsert
        ADDQ    #1,D1                   ;insert just below where comparing

InsertNew
        MOVE    D1,D5
        JSR     ComputeAddress2

        LEA     NewRecord(A5),AØ        ;pointer to source (the new record)
        MOVE.L  A4,A1                   ;pointer to destination
        MOVE.L  #64,DØ                  ;number of bytes to move
        _BlockMove                      ;move a record

        LEA     TotalRecords,AØ
        ADDQ    #1,(AØ)                 ;increment number of records

;----------------- Write the annotation directly to the Annotation file ------
        LEA     AnnotRecMask,AØ
        LEA     DataBuffer(A5),A1
        MOVE    #256,DØ
        _BlockMove                      ;fill first half of buffer with blanks

        CLR.L   -(SP)                   ;place for CharsHandle result
        MOVE.L  AnnotationTextHandle,-(SP)
        _TEGetText                      ;get handle to text in Annotation record
        MOVE.L  (SP)+,A2                ;recover CharsHandle
        MOVE.L  (A2),AØ                 ;de-referencing handle to get pointer
        LEA     DataBuffer(A5),A1       ;text goes into disk buffer
        MOVE.L  AnnotationTextHandle,A3
        MOVE.L  (A3),A4                 ;de-reference again
        MOVE    teLength(A4),DØ         ;number of characters to move
        _BlockMove                      ;puts annotation in disk output buffer


        MOVE    #256,DØ                         ;characters per annotation record
        MULU    LastAnnotNumb,DØ        ;offset into annotations file
```

(continued)

Listing A.1 (continued)

```
        LEA     DataBuffer(A5),AØ
        MOVE.L  AØ,ioParamBlock+ioBuffer(A5)
        MOVE.L  #256,ioParamBlock+ioByteCount(A5)       ;write 256 bytes, blanks and all
        MOVE    #1,ioParamBlock+ioPosMode(A5)  ;offset is relative to beginning of file
        MOVE.L  DØ,ioParamBlock+ioPosOffset(A5) ;offset in bytes
        MOVE    fiRefNum,ioParamBlock+ioRefNum(A5)      ;file reference number
        LEA     ioParamBlock(A5),AØ
        _Write

        JSR     DisplayWindows          ;clear windows and text edit records

        RTS                             ;return

ComputeAddress1
        MOVE.L  D1,D6                   ;offset = record # * 64 bytes
        MULU    #64,D6
        MOVE.L  A2,A3
        ADDA.L  D6,A3
        RTS

ComputeAddress2
        MOVE.L  D5,D7
        MULU    #64,D7
        MOVE.L  A2,A4
        ADDA.L  D7,A4
        RTS

;---------------------- Change Existing Data --------------------------

Change  MOVE.L  MainWindowPtr,-(SP)
        PEA     'Change Existing Titles and Annotations'
        _SetWTitle

        JSR     DisplayPrompts
        JSR     DisplayWindows

        MOVE    #3,-(SP)
        _DeleteMenu             ;remove Options menu from menu list

        LEA     ChangeHandle,AØ ;get address for Change menu's handle
        MOVE.L  (AØ),-(SP)      ;put handle on stack

        CLR     -(SP)           ;this menu goes at the end
        _InsertMenu

        _DrawMenuBar

        MOVE.L  EditHandle,-(SP)
        MOVE    #1,-(SP)
        _DisableItem
```

(continued)

```
ChangeEvent
        MOVE.L  ActiveTextHandle,-(SP)
        _TEIdle

        _SystemTask             ;update desk accessories

        CLR     -(SP)           ;space for boolean result
        MOVE    #-1,-(SP)       ;mask to select all events
        PEA     EventRecord     ;place to accept event
        _GetNextEvent           ;get an event from the queue

        MOVE    (SP)+,D0        ;recover event record
        CMP     #0,D0
        BEQ     ChangeEvent     ;no event - keep looking

        MOVE    What,D0         ;recover event ID
        CMP     #mButDwnEvt,D0          ;mouse button pressed?
        BEQ     ChangeMouseEvent

        CMP     #keyDwnEvt,D0   ;key pressed?
        BEQ     ChangeKeyEvent

        CMP     #activateEvt,D0 ;activate event posted?
        BEQ     ChangeActivateEvent

        CMP     #updatEvt,D0    ;text window needs updating?
        BEQ     ChangeUpdateEvent

        BRA     ChangeEvent

ChangeActivateEvent
        JSR     ActivateTextWindow
        BRA     ChangeEvent

ChangeUpdateEvent
        JSR     UpdateTextWindows
        BRA     ChangeEvent

ChangeKeyEvent
        MOVE.B  Modify,D0       ;recover modifier byte
        CMP.B   #1,D0           ;was command key pressed?
        BEQ     ChangeKeyboardCommand

        MOVE    Message+2,-(SP)
        MOVE.L  ActiveTextHandle,-(SP)
        _TEKey

        BRA     ChangeEvent

ChangeKeyboardCommand
        CLR.L   -(SP)           ;place for menu item selection
```

(continued)

Listing A.1 (continued)

```
        MOVE    Message+2,-(SP) ;put character pressed on stack
        _MenuKey
        BRA     ChangeSelections

ChangeMouseEvent
        CLR     -(SP)           ;space for "What" result
        MOVE.L  Point,-(SP)     ;put mouse coordinates on stack
        PEA     WhichWindowPtr  ;push pointer to window record
        _FindWindow             ;where was mouse button pushed?

        MOVE    (SP)+,D0        ;recover FindWindow result

        CMP     #inMenuBar,D0   ;was mouse clicked in menu bar?
        BEQ     ChangeMenuBar

        CMP     #inSysWindow,D0         ;was mouse clicked in a desk accessory?
        BEQ     ChangeSysEvent

        CMP     #inContent,D0
        BEQ     ChangeInWindow

        BRA     ChangeEvent

ChangeSysEvent
        PEA     EventRecord     ;pointer to event record goes on stack
        MOVE.L  WhichWindowPtr,-(SP)    ;window pointer goes on stack, too
        _SystemClick            ;let the system handle it

        BRA     ChangeEvent

ChangeMenuBar
        CLR.L   -(SP)           ;place for menu ID and menu item
        MOVE.L  Point,-(SP)     ;push mouse coordinates
        _MenuSelect             ;which menu? which item?

ChangeSelections
        MOVE.L  (SP)+,D2        ;recover result

        LEA     WhichMenu,A0    ;get address for high order byte of result
        MOVE.L  D2,(A0)         ;store result

        CLR     -(SP)           ;mask to indicate all menus
        _HiLiteMenu             ;unhighlight all menus

        MOVE    WhichMenu,D0    ;put menu number in D0

        CMP     #1,D0           ;in Apple menu?
        BNE     ChangeMenu2
        JSR     AppleMenu
```

(continued)

```
ChangeMenu2
        CMP     #2,DØ           ;in Edit menu?
        BNE     ChangeMenu5

        JSR     EditMenu        ;was edit request in system window?
        CMP     #Ø,D1
        BNE     ChangeEvent     ;edit was in system window and system handled it

        JSR     DoEditing
        BRA     ChangeEvent

ChangeMenu5
        CMP     #5,DØ           ;in Change menu?
        BNE     ChangeEvent

ChangeMenuOptions
        MOVE    WhatItem,DØ     ;move item selected to DØ

        CMP     #1,DØ           ;find a record?
        BNE     ChangeItem2
        MOVE    #1,ReturnFlag(A5)       ;set return flag to show origin of call
        JSR     SelectOneTitle  ;note: record number returned in RecordCounter(A5)
        BRA     ChangeEvent

ChangeItem2
        CMP     #2,DØ           ;save a change?
        BNE     ChangeItem3
        JSR     ChangeSave
        BRA     ChangeEvent

ChangeItem3

        CMP     #3,DØ           ;abandon a change?
        BNE     ChangeItem4
        JSR     DisplayWindows  ;clear text windows
        BRA     ChangeEvent

ChangeItem4
        CMP     #4,DØ           ;quit?
        BNE     ChangeEvent     ;get another event

        MOVE    #5,-(SP)
        _DeleteMenu             ;remove Change menu

        MOVE    #9,DØ
        RTS                     ;return to options block

ChangeInWindow
        CLR.L   -(SP)
        _FrontWindow
        MOVE.L  (SP)+,AØ
        CMP.L   WhichWindowPtr,AØ
```

(continued)

Listing A.1 (continued)

```
        BNE     ChangeMustActivate      ;window is inactive

        PEA     Point
        _GlobalToLocal

        MOVE.L  Point,-(SP)
        BTST    #shiftkey,Modify
        SNE     DØ
        MOVE.B  DØ,-(SP)
        MOVE.L  ActiveTextHandle,-(SP)
        _TEClick                ;re-position the cursor

        BRA     ChangeEvent

ChangeMustActivate
        JSR     SelectTextWindow
        BRA     ChangeEvent

ChangeSave

        JSR     ClearNewRecord
        JSR     MoveName
        JSR     MoveProducer
        JSR     MoveDate
        JSR     MoveRating
        JSR     MoveNumber

        LEA     TapeArray(A5),A2        ;start of Tape Array
        LEA     RecordCounter,AØ
        MOVE    (AØ),D5 ;record number
        JSR     ComputeAddress2                 ;get address of record - returned in A4

        LEA     NewRecord(A5),AØ        ;source of data
        MOVE.L  A4,A1                   ;destination of data
        MOVE.L  #62,DØ                  ;move only 62 bytes so annotation # isn't disturbed
        _BlockMove

;------------------- re-write the annotation -------------------------------
        LEA     AnnotRecMask,AØ
        LEA     DataBuffer(A5),A1
        MOVE    #256,DØ
        _BlockMove                      ;fill first half of buffer with blanks

        CLR.L   -(SP)                   ;place for CharsHandle result
        MOVE.L  AnnotationTextHandle,-(SP)
        _TEGetText                      ;get handle to text in Annotation record
        MOVE.L  (SP)+,A2                ;recover CharsHandle
        MOVE.L  (A2),AØ                 ;de-referencing handle to get pointer
        LEA     DataBuffer(A5),A1       ;text goes into disk buffer
        MOVE.L  AnnotationTextHandle,A3
        MOVE.L  (A3),A4                 ;de-reference again
```

(continued)

```
        MOVE    teLength(A4),DØ         ;number of characters to move
        _BlockMove                      ;puts annotation in disk output buffer

        LEA     RecordCounter,AØ
        MOVE    (AØ),D5
        MULU    #64,D5
        ADD     #oAnnotNum,D5           ;offset into tape array
        LEA     TapeArray(A5),AØ
        ADD.L   D5,AØ
        MOVE    (AØ),DØ
        MULU    #256,DØ                         ;offset into file

        LEA     DataBuffer(A5),AØ
        MOVE.L  AØ,ioParamBlock+ioBuffer(A5)
        MOVE.L  #256,ioParamBlock+ioByteCount(A5)       ;write 256 bytes, blanks and all
        MOVE    #1,ioParamBlock+ioPosMode(A5)  ;offset is relative to beginning of file
        MOVE.L  DØ,ioParamBlock+ioPosOffset(A5) ;offset in bytes
        MOVE    fiRefNum,ioParamBlock+ioRefNum(A5)      ;file reference number
        LEA     ioParamBlock(A5),AØ
        _Write

        JSR     DisplayWindows

        RTS

;------------------ Delete Titles ---------------------------------

Delete  MOVE.L  MainWindowPtr,-(SP)
        PEA     'Delete Existing Titles'
        _SetWTitle

        JSR     DisplayPrompts
        JSR     DisplayWindows

        MOVE    #3,-(SP)
        _DeleteMenu             ;remove options menu from menu list

        LEA     DeleteHandle,A1 ;get address for Delete menu's handle
        MOVE.L  (A1),-(SP)      ;put handle on stack
        CLR     -(SP)           ;this menu will go at the end of the list
        _InsertMenu             ;put Delete menu into menu list

        _DrawMenuBar            ;re-draw the menu bar

        MOVE.L  EditHandle,-(SP)
        MOVE    #1,-(SP)
        _DisableItem

DeleteEvent
        MOVE.L  ActiveTextHandle,-(SP)
        _TEIdle
```

(continued)

Listing A.1 (continued)

```
        _SystemTask             ;update desk accessories

        CLR     -(SP)
        MOVE    #-1,-(SP)
        PEA     EventRecord

        _GetNextEvent           ;get next event from queue

        MOVE    (SP)+,D0
        CMP     #0,D0
        BEQ     DeleteEvent     ;no event encountered - keep looking

        MOVE    What,D0
        CMP     #mButDwnEvt,D0
        BEQ     DeleteMouseEvent        ;mouse button pressed

        CMP     #keyDwnEvt,D0
        BEQ     DeleteKeyEvent          ;key pressed

        CMP     #activateEvt,D0
        BEQ     DeleteActivateEvent

        CMP     #updatEvt,D0
        BEQ     DeleteUpdateEvent

        BRA     DeleteEvent     ;look for another event

DeleteActivateEvent
        JSR     ActivateTextWindow
        BRA     DeleteEvent

DeleteUpdateEvent
        JSR     UpdateTextWindows
        BRA     DeleteEvent

DeleteKeyEvent
        MOVE.B  Modify,D0
        CMP.B   #1,D0
        BEQ     DeleteKeyboardCommand   ;command key was held down

        MOVE    Message+2,-(SP)
        MOVE.L  ActiveTextHandle,-(SP)
        _TEKey

        BRA     DeleteEvent

DeleteKeyboardCommand
        CLR.L   -(SP)
        MOVE    Message+2,-(SP)
        _MenuKey                ;figure out what key was pressed
        BRA     DeleteSelections
```

(continued)

```
DeleteMouseEvent
        CLR     -(SP)
        MOVE.L  Point,-(SP)
        PEA     WhichWindowPtr
        _FindWindow             ;where was mouse button pushed?

        MOVE    (SP)+,D0
        CMP     #inMenuBar,D0
        BEQ     DeleteMenuBar   ;mouse button pushed in the menu bar

        CMP     #inSysWindow,D0
        BEQ     DeleteSysEvent  ;mouse button pushed in desk accessory

        CMP     #inContent,D0
        BEQ     DeleteInWindow

        BRA     DeleteEvent

DeleteSysEvent
        PEA     EventRecord
        MOVE.L  WhichWindowPtr,-(SP)
        _SystemClick            ;let the system handle it

        BRA     DeleteEvent

DeleteMenuBar
        CLR.L   -(SP)
        MOVE.L  Point,-(SP)
        _MenuSelect             ;which menu?

DeleteSelections
        MOVE.L  (SP)+,D2

        LEA     WhichMenu,A0
        MOVE.L  D2,(A0)

        CLR     -(SP)
        _HiLiteMenu             ;unhighlight the menus

        MOVE    WhichMenu,D0

        CMP     #1,D0           ;in Apple menu?
        BNE     DeleteMenu2
        JSR     AppleMenu

DeleteMenu2
        CMP     #2,D0           ;in Edit menu?
        BNE     DeleteMenu6

        JSR     EditMenu
        CMP     #0,D1
```

(continued)

Listing A.1 (continued)

```
        BNE     DeleteEvent     ;system edit - has already been handled
        JSR     DoEditing
        BRA     DeleteEvent

DeleteMenu6
        CMP     #6,D0           ;in Delete menu?
        BNE     DeleteEvent     ;get another event

DeleteMenuOptions
        MOVE    WhatItem,D0
        CMP     #1,D0           ;Find a title?
        BNE     DeleteOption2
        MOVE    #1,ReturnFlag(A5)
        JSR     SelectOneTitle
        BRA     DeleteEvent

DeleteOption2
        CMP     #2,D0           ;Delete a title?
        BNE     DeleteOption3
        JSR     DoTheDelete
        BRA     DeleteEvent

DeleteOption3
        CMP     #3,D0           ;Cancel a delete?
        BNE     DeleteOption4
        JSR     DisplayWindows
        BRA     DeleteEvent

DeleteOption4
        CMP     #4,D0           ;Quit?
        BNE     DeleteEvent

        MOVE    #6,-(SP)
        _DeleteMenu             ;remove Delete menu from menu list

        MOVE    #9,D0
        RTS

DeleteInWindow
        CLR.L   -(SP)
        _FrontWindow
        MOVE.L  (SP)+,A0
        CMP.L   WhichWindowPtr,A0
        BNE     DeleteMustActivate      ;window is inactive

        PEA     Point
        _GlobalToLocal

        MOVE.L  Point,-(SP)
        BTST    #shiftkey,Modify
        SNE     D0
```

(continued)

```
        MOVE.B  DØ,-(SP)
        MOVE.L  ActiveTextHandle,-(SP)
        _TEClick                ;reposition the cursor

        BRA     DeleteEvent

DeleteMustActivate
        JSR     SelectTextWindow
        BRA     DeleteEvent

DoTheDelete
        LEA     TapeArray(A5),A2        ;start of TapeArray
        LEA     RecordCounter,AØ
        MOVE    (AØ),D5                 ;number of record to be deleted
        ADDQ    #1,D5                   ;record number of source
        JSR     ComputeAddress2                 ;get address of source
        MOVE.L  A4,AØ

        LEA     RecordCounter,AØ
        MOVE    (AØ),D5
        JSR     ComputeAddress2                 ;address of destination of move
        MOVE.L  A4,A1

        MOVE    TotalRecords,DØ
        LEA     RecordCounter,AØ
        SUB     (AØ),DØ
        MULU    #64,DØ                  ;number of bytes to move
        _BlockMove

        LEA     TotalRecords,AØ
        SUBQ    #1,(AØ)
        JSR     DisplayWindows

        RTS


;---------------------- Select Titles ---------------------------------

Select  MOVE.L  MainWindowPtr,-(SP)
        PEA     'Select Titles and Annotations'
        _SetWTitle

        JSR     DisplayPrompts
        JSR     DisplayWindows

        MOVE    #3,-(SP)
        _DeleteMenu             ;remove Options menu from list

        LEA     SelectHandle,A1
        MOVE.L  (A1),-(SP)
        CLR     -(SP)
        _InsertMenu             ;put Select menu after all others
```

(continued)

Listing A.1 (continued)

```
        _DrawMenuBar            ;re-draw menu bar

        MOVE.L  EditHandle,-(SP)
        MOVE    #1,-(SP)
        _DisableItem

SelectEvent
        MOVE.L  ActiveTextHandle,-(SP)
        _TEIdle

        _SystemTask             ;update desk accessories

        CLR     -(SP)
        MOVE    #-1,-(SP)
        PEA     EventRecord
        _GetNextEvent           ;get next event from queue

        MOVE    (SP)+,D0
        CMP     #0,D0
        BEQ     SelectEvent     ;no event encountered

        MOVE    What,D0
        CMP     #mButDwnEvt,D0
        BEQ     SelectMouseEvent        ;mouse button pressed

        CMP     #keyDwnEvt,D0
        BEQ     SelectKeyEvent          ;key pressed

        CMP     #activateEvt,D0
        BEQ     SelectActivateEvent     ;text window needs activating

        CMP     #updatEvt,D0
        BEQ     SelectUpdateEvent       ;window needs updating

        BRA     SelectEvent

SelectActivateEvent
        JSR     ActivateTextWindow
        BRA     SelectEvent

SelectUpdateEvent
        JSR     UpdateTextWindows
        BRA     SelectEvent

SelectKeyEvent
        MOVE.B  Modify,D0
        CMP.B   #1,D0
        BEQ     SelectKeyboardCommand   ;command key pressed

        MOVE    Message+2,-(SP)
        MOVE.L  ActiveTextHandle,-(SP)
```

(continued)

```
        _TEKey

        BRA     SelectEvent

SelectKeyboardCommand
        CLR.L   -(SP)
        MOVE    Message+2,-(SP)
        _MenuKey                ;find out what key was pressed
        BRA     SelectSelections

SelectMouseEvent
        CLR     -(SP)
        MOVE.L  Point,-(SP)
        PEA     WhichWindowPtr
        _FindWindow             ;where was mouse button pressed?
        MOVE    (SP)+,D0

        CMP     #inMenuBar,D0
        BEQ     SelectMenuBar   ;mouse button pressed in menu bar

        CMP     #inSysWindow,D0
        BEQ     SelectSysEvent  ;mouse button pressed in desk accessory

        CMP     #inContent,D0   ;mouse button pressed in content area of text window?
        BEQ     SelectInWindow

        BRA     SelectEvent

SelectSysEvent
        PEA     EventRecord
        MOVE.L  WhichWindowPtr,-(SP)
        _SystemClick            ;let the system handle it

        BRA     SelectEvent

SelectMenuBar
        CLR.L   -(SP)
        MOVE.L  Point,-(SP)
        _MenuSelect             ;which menu?

SelectSelections
        MOVE.L  (SP)+,D2

        LEA     WhichMenu,A0
        MOVE.L  D2,(A0)

        CLR     -(SP)
        _HiLiteMenu             ;unhighlight all menus

        MOVE    WhichMenu,D0

        CMP     #1,D0
```

(continued)

Listing A.1 (continued)

```
        BNE     SelectMenu2
        JSR     AppleMenu       ;in Apple menu

SelectMenu2
        CMP     #2,D0
        BNE     SelectMenu7
        JSR     EditMenu        ;in Edit menu

SelectMenu7
        CMP     #7,D0           ;in Select menu?
        BNE     SelectEvent

SelectMenuOptions
        MOVE    WhatItem,D0

        CMP     #1,D0           ;Display all?
        BNE     SelectOptions2
        MOVE    #1,D4           ;flag says "display annotations"
        JSR     SelectAll

SelectOptions2
        CMP     #2,D0           ;Display all titles?
        BNE     SelectOptions3
        MOVE    #0,D4           ;flag says "don't print annotations"
        JSR     SelectAll

SelectOptions3
        CMP     #3,D0           ;Display one title?
        BNE     SelectOptions4
        MOVE    #0,ReturnFlag(A5)       ;return flag (call is from Select)
        JSR     SelectOneTitle

SelectOptions4
        CMP     #4,D0           ;Select by producer
        BNE     SelectOptions5
        MOVE.L  ProducerTextHandle,A1
        MOVE.L  (A1),A2
        MOVE    teLength(A2),D0
        CMP     #0,D0
        BEQ     SelectGoof
        MOVE    #oProducer,D4   ;offset into record
        MOVE    #20,D6          ;number of characters in field
        JSR     ClearNewRecord
        JSR     MoveProducer
        JSR     SequentialSearch

SelectOptions5
        CMP     #5,D0           ;Select by date
        BNE     SelectOptions6
        MOVE.L  DateTextHandle,A1
        MOVE.L  (A1),A2
```

(continued)

```
        MOVE    teLength(A2),DØ
        CMP     #Ø,DØ
        BEQ     SelectGoof
        MOVE    #oReleaseDate,D4
        MOVE    #4,D6
        JSR     ClearNewRecord
        JSR     MoveDate
        JSR     SequentialSearch

SelectOptions6
        CMP     #6,DØ           ;Select by rating
        BNE     SelectOptions7
        MOVE.L  RatingTextHandle,A1
        MOVE.L  (A1),A2
        MOVE    teLength(A2),DØ
        CMP     #Ø,DØ
        BEQ     SelectGoof
        MOVE    #oRating,D4
        MOVE    #4,D6
        JSR     ClearNewRecord
        JSR     MoveRating
        JSR     SequentialSearch

SelectOptions7
        CMP     #7,DØ           ;Select by tape number
        BNE     SelectOptions8
        MOVE.L  NumberTextHandle,A1
        MOVE.L  (A1),A2
        MOVE    teLength(A2),DØ
        CMP     #Ø,DØ
        BEQ     SelectGoof
        MOVE    #oTapeNumber,D4
        MOVE    #4,D6
        JSR     ClearNewRecord
        JSR     MoveNumber
        JSR     SequentialSearch

SelectOptions8
        CMP     #8,DØ           ;Quit
        BNE     SelectEvent

        MOVE    #7,-(SP)
        _DeleteMenu

        MOVE    #9,DØ
        RTS

SelectInWindow
        CLR.L   -(SP)
        _FrontWindow
        MOVE.L  (SP)+,AØ
```

(continued)

Listing A.1 (continued)

```
        CMP.L   WhichWindowPtr,AØ
        BNE     SelectMustActivate

        PEA     Point
        _GlobalToLocal

        MOVE.L  Point,-(SP)
        BTST    #shiftKey,Modify
        SNE     DØ
        MOVE.B  DØ,-(SP)
        MOVE.L  ActiveTextHandle,-(SP)
        _TEClick

        BRA     SelectEvent

SelectMustActivate
        JSR     SelectTextWindow
        BRA     SelectEvent

SelectAll
        LEA     RecordCounter,AØ
        MOVE    #Ø,(AØ)                         ;initialize record number
        MOVE    TotalRecords,StopNumber(A5)

AllLoop
        JSR     DisplayOneRecord
        CMP     #1,D4
        BNE     Box
        JSR     DisplayAnnotation
Box     LEA     RecordCounter,AØ
        ADDQ    #1,(AØ)
        MOVE    StopNumber(A5),DØ
        CMP     (AØ),DØ
        BEQ     AlmostDone
        JSR     DisplayDialog2          ;displays "find more?" dialog box
        CMP     #2,D7                   ;did user cancel?
        BEQ     Cancelled
        BRA     AllLoop
AlmostDone
        JSR     DisplayDialog3          ;displays "find & wait" dialog box
Cancelled
        JSR     DisplayWindows          ;clear text records & windows
        MOVE    #9,DØ
        RTS

SelectOneTitle
        MOVE.L  NameTextHandle,A1
        MOVE.L  (A1),A2
        MOVE    teLength(A2),DØ
        CMP     #Ø,DØ
        BEQ     SelectGoof              ;if text length is Ø, no selection criteria
```

(continued)

```
        JSR     ClearNewRecord
        JSR     MoveName                ;put selected tape name into NewRecord

;----------------------------- Binary Search -----------------------------

        LEA     TapeArray(A5),A2        ;start of tape array
        MOVE    TotalRecords,D1
        SUBQ    #1,D1           ;bottom pointer
        MOVE    D1,D3
        SUBQ    #1,D3           ;save last record-1 # for future reference
        MOVE    #Ø,D2           ;top pointer

MidPoint
        MOVE    D2,D5           ;find middle record #
        ADD     D1,D5
        DIVU    #2,D5
        AND.L   #$ØØØØFFFF,D5 ;mask off remainder
        CMP     #1,D5
        BLE     TopRec          ;handle first two records
        CMP     D5,D3
        BLE     BottomRec               ;handle last two records

        JSR     ComputeAddress2
        MOVEM.L         D1-D5/A1-A2,-(SP)       ;save registers
        CLR.W   -(SP)           ;space for result
        MOVE.L  A4,-(SP)        ;pointer to record in tape array
        PEA     NewRecord(A5)   ;pointer to search string
        MOVE.W  #3Ø,-(SP)       ;number of characters to compare
        MOVE.W  #3Ø,-(SP)       ;number of characters to compare
        MOVE.W  #1Ø,-(SP)
        _Pack6                  ;invoke the package
        MOVE.W (SP)+,DØ         ;recover result
        MOVEM.L         (SP)+,D1-D5/A1-A2       ;restore registers

        CMP     #Ø,DØ           ;check result of string compare
        BGT     TopHalf         ;array greater than search string
        BLT     BottomHalf      ;array less than search string

        LEA     RecordCounter,AØ
        MOVE    D5,(AØ)
        JSR     DisplayOneRecord        ;must be equal - record has been found
        MOVE    ReturnFlag(A5),DØ
        CMP     #Ø,DØ           ;which module called this routine?
        BEQ     KeepGoing       ;call was from Select
        RTS                     ;call was from Change or Delete

KeepGoing
        JSR     DisplayDialog3  ;display find & wait dialog box
        JSR     DisplayWindows  ;clear text edit windows
        RTS                     ;return to Select menu
```

(continued)

Listing A.1 (continued)

```
BottomHalf
        MOVE    D5,D2           ;move top pointer down
        BRA     NoFindCheck
TopHalf
        MOVE    D5,D1           ;move bottom pointer up
NoFindCheck
        CMP     D2,D1
        BMI     NoFind          ;pointers have crossed
        BRA     MidPoint ;find new middle record and go again
NoFind
        JSR     DisplayDialog1  ;displays "none found" dialog box
        JSR     DisplayWindows  ;clear screen and text edit records
        RTS                     ;return to Select menu

TopRec  MOVE    #Ø,D5
        JSR     OneCheck
        MOVE    #1,D5
        JSR     OneCheck
        BRA     NoFind

BottomRec
        MOVE    D3,D5
        JSR     OneCheck
        ADDQ    #1,D3
        MOVE    D3,D5
        JSR     OneCheck
        BRA     NoFind

OneCheck
        JSR     ComputeAddress2

        MOVEM.L         D1-D5/A1-A2,-(SP)
        CLR.W   -(SP)           ;space for result
        MOVE.L  A4,-(SP)        ;pointer to array
        PEA     NewRecord(A5)   ;pointer to search string
        MOVE.W  #3Ø,-(SP)       ;number of characters to compare
        MOVE.W  #3Ø,-(SP)       ;number of characters to compare
        MOVE.W  #1Ø,-(SP)
        _Pack6                  ;invoke the package
        MOVE.W  (SP)+,DØ        ;recover result
        MOVEM.L         (SP)+,D1-D5/A1-A2

        CMP     #Ø,DØ
        BNE     WrongOne        ;correct record not found

        LEA     RecordCounter,AØ
        MOVE    D5,(AØ)
        JSR     DisplayOneRecord
        MOVE    ReturnFlag(A5),DØ
        CMP     #Ø,DØ           ;where does this call originate?
        BEQ     OneCheckContinues       ;call comes from Select
```

(continued)

```
        MOVE.L  (SP)+,DØ        ;pull extra subroutine return address from stack
        RTS                     ;call comes from Change or Delete

OneCheckContinues
        JSR     DisplayDialog3
        JSR     DisplayWindows
        MOVE    #9,DØ
        MOVE.L  (SP)+,D7        ;pop subroutine return address off stack
        RTS                     ;return directly to "Select" routine
WrongOne
        MOVE    #9,DØ
        RTS                     ;return to Top or Bottom

SelectGoof
        JSR     NoSelectionCriteria
        MOVE    #9,DØ
        RTS

;------- Sequential Search for equality on Producer, Rating, Date, or Number -----
SequentialSearch

        LEA     TapeArray(A5),A2
        LEA     NewRecord(A5),A1
        ADD.L   D4,A1                   ;adds offset into NewRecord
        MOVE    TotalRecords,D1
        SUBQ    #1,D1                   ;number of last records
        LEA     RecordCounter,AØ
        MOVE    #Ø,(AØ)                         ;initialize record counter

SequentialSearch1
        LEA     RecordCounter,AØ
        MOVE    (AØ),D5
        JSR     ComputeAddress2                 ;finds start of TapeArray record
        ADD.L   D4,A4                   ;adds offset into TapeArray record

        MOVEM.L         D1/A1/A2,-(SP) ;save critical registers
        CLR.W   -(SP)
        MOVE.L  A4,-(SP)
        MOVE.L  A1,-(SP)
        MOVE.W  D6,-(SP)                ;characters to compare
        MOVE.W  D6,-(SP)
        MOVE.W  #1Ø,-(SP)               ;IUMagString
        _Pack6
        MOVE.W  (SP)+,DØ
        MOVEM.L         (SP)+,D1/A1/A2          ;restore critical registers

        CMP     #Ø,DØ
        BEQ     SequentialDisplay

        LEA     RecordCounter,AØ
        CMP     (AØ),D1
```

(continued)

Listing A.1 (continued)

```
        BEQ     EndofArray
        ADDQ    #1,(AØ)

SequentialDisplay
        MOVEM.L         D1/A1/A2,-(SP)
        JSR     DisplayOneRecord
        MOVEM.L         (SP)+,D1/A1/A2

        LEA     RecordCounter,AØ
        CMP     (AØ),D1                         ;last record?
        BNE     SequentialDisplay2
        JSR     DisplayDialog3
        JSR     DisplayWindows
        MOVE    #9,DØ
        RTS

SequentialDisplay2
        MOVEM.L         D1/A1/A2,-(SP)
        JSR     DisplayDialog2
        MOVEM.L         (SP)+,D1/A1/A2
        LEA     RecordCounter,AØ
        ADDQ    #1,(AØ)
        BRA     SequentialSearch1

EndofArray
        JSR     DisplayWindows
        JSR     DisplayDialog1

        MOVE    #9,DØ
        RTS

;-------------------- Print Lists ----------------------------------

Print   MOVE.L  MainWindowPtr,-(SP)
        PEA     'Print Titles and Annotations'
        _SetWTitle

        MOVE    #3,-(SP)
        _DeleteMenu             ;remove Options menu from list

        LEA     PrintHandle,A1
        MOVE.L  (A1),-(SP)
        CLR     -(SP)
        _InsertMenu             ;put Print menu in list

        MOVE.L  EditHandle,-(SP)
        MOVE    #Ø,-(SP)
        _DisableItem            ;disable entire edit menu

        _DrawMenuBar            ;re-draw menu bar
```

(continued)

```
PrintEvent
        _SystemTask             ;update desk accessories

        CLR     -(SP)
        MOVE    #-1,-(SP)
        PEA     EventRecord
        _GetNextEvent           ;get next event from queue

        MOVE    (SP)+,D0
        CMP     #0,D0
        BEQ     PrintEvent      ;no event encountered - keep checking

        MOVE    What,D0
        CMP     #mButDwnEvt,D0          ;mouse button pressed?
        BEQ     PrintMouseEvent

        CMP     #keyDwnEvt,D0 ;key pressed?
        BEQ     PrintKeyEvent

        BRA     PrintEvent      ;look for another event

PrintKeyEvent
        MOVE.B  Modify,D0
        CMP.B   #1,D0           ;command key pressed?
        BEQ     PrintKeyboardCommand

        BRA     PrintEvent

PrintKeyboardCommand
        CLR.L   -(SP)
        MOVE    Message+2,-(SP)
        _MenuKey                ;what key was pressed?
        BRA     PrintSelections

PrintMouseEvent
        CLR     -(SP)
        MOVE.L  Point,-(SP)
        PEA     WhichWindowPtr
        _FindWindow             ;where was mouse button pressed?
        MOVE    (SP)+,D0

        CMP     #inMenuBar,D0 ;pressed in menu bar?
        BEQ     PrintMenuBar

        CMP     #inSysWindow,D0         ;pressed in desk accessory?
        BEQ     PrintSysEvent

        BRA     PrintEvent

PrintSysEvent
        PEA     EventRecord
```

(continued)

Listing A.1 (continued)

```
        MOVE.L  WhichWindowPtr,-(SP)
        _SystemClick            ;let the system handle it

        BRA     PrintEvent

PrintMenuBar
        CLR.L   -(SP)
        MOVE.L  Point,-(SP)
        _MenuSelect             ;which menu?

PrintSelections
        MOVE.L  (SP)+,D2

        LEA     WhichMenu,A0
        MOVE.L  D2,(A0)

        CLR     -(SP)
        _HiLiteMenu             ;unlightlight all menus

        MOVE    WhichMenu,D0

        CMP     #1,D0           ;in Apple menu?
        BNE     PrintMenu2
        JSR     AppleMenu

PrintMenu2
        CMP     #2,D0           ;in Edit menu?
        BNE     PrintMenu8
        JSR     EditMenu

PrintMenu8
        CMP     #8,D0           ;in Print menu?
        BNE     PrintEvent

PrintOptions
        MOVE    WhatItem,D0

        CMP     #1,D0           ;Print all?
        BNE     PrintOption2
        JSR     PrintAll

PrintOption2
        CMP     #2,D0           ;Print all titles?
        BNE     PrintOption3
        JSR     PrintAllTitles

PrintOption3
        CMP     #3,D0           ;quit?
        BNE     PrintEvent

        MOVE    #8,-(SP)
        _DeleteMenu             ;remove Print menu
```

(continued)

```
        MOVE.L  EditHandle,-(SP)
        MOVE    #Ø,-(SP)
        _EnableItem             ;enable entire edit menu

        MOVE    #9,DØ
        RTS

PrintAll
        JSR     PrOpen          ;open printing manager
        MOVE.L  #iPrintSize,DØ  ;size of print record
        _NewHandle              ;allocate heap space for print record
        LEA     PrintRecordHandle,A2
        MOVE.L  AØ,(A2)         ;store handle to print record

        MOVE.L  AØ,-(SP)        ;handle back on stack
        JSR     PrintDefault    ;fill default info into print record

        CLR     -(SP)           ;space for boolean result
        LEA     PrintRecordHandle,A2
        MOVE.L  (A2),-(SP)
        JSR     PrJobDialog     ;draft or spooled?
        MOVE    (SP)+,DØ        ;remove result
        BEQ     PrintFinish     ;user clicked cancel - close up shop

        JSR     PrintAlert      ;tell user to ready the printer
        CLR.L   -(SP)           ;space for pointer to printer port
        LEA     PrintRecordHandle,A2
        MOVE.L  (A2),-(SP)
        CLR.L   -(SP)           ;let system allocate new port
        CLR.L   -(SP)           ;use system I/O buffer
        JSR     prOpenDoc       ;allocate custom printer port
        MOVE.L  (SP)+,PrPortPtr(A5)     ;retrieve pointer

        MOVE.L  #Ø,D7           ;initialize a record counter
        MOVE.L  #Ø,D2           ;clear register
        LEA     TotalRecords,AØ
        MOVE    (AØ),D2

AnnotAnotherPage
        JSR     AnnotPrintOnePage
        CMP     D2,D7
        BLT     AnnotAnotherPage
        MOVE.L  PrPortPtr(A5),-(SP)
        JSR     PrCloseDoc      ;close the document
        BRA     PrintFinish     ;all done

AnnotPrintOnePage
        MOVEM.L     D2/D7,-(SP)     ;save record counter
        MOVE.L  PrPortPtr(A5),-(SP)     ;pointer to printer port
        CLR.L   -(SP)           ;no scaling
        JSR     PrOpenPage      ;open a new page
        MOVEM.L     (SP)+,D2/D7     ;restore record counters
```

(continued)

Listing A.1 (continued)

```
        MOVE    #monaco,-(SP)
        _TextFont

        MOVE    #12,-(SP)
        _TextSize

        MOVEM.L         D2/D7,-(SP)
        PEA     FontInfoStorage(A5)
        _GetFontInfo
        MOVEM.L         (SP)+,D2/D7
        MOVE    FontInfoStorage+ascent(A5),D4
        ADD     FontInfoStorage+descent(A5),D4
        ADD     FontInfoStorage+leading(A5),D4    ;height of line

        LEA     PrintRecordHandle,A2
        MOVE.L  (A2),AØ
        MOVE.L  (AØ),AØ                                   ;de-reference to get pointer
        MOVE    prInfo+rPage+bottom(AØ),D6        ;page bottom coordinate
        SUB     FontInfoStorage+descent(A5),D6

        MOVE    D4,D3

        JSR     ClearPrintLine
        ADD     D4,D3                             ;one blank line
        ADD     D4,D3                             ;another blank line

        MOVEM.L         D2/D7,-(SP)
        JSR     PrintHeadings
        MOVEM.L         (SP)+,D2/D7

AnnotRecordPrint
        MOVE    D7,DØ
        MULU    #64,DØ
        ADD     #oAnnotNum,DØ           ;offset into tape array
        LEA     TapeArray(A5),AØ
        ADD     DØ,AØ                   ;start of record in array
        MOVE    (AØ),DØ                 ;retrieve annotation number

        MOVE.L  #Ø,-(SP)
        MOVE.L  #256,-(SP)
        MOVE.L  AnnotationTextHandle,-(SP)
        _TESetSelect
        MOVE.L  AnnotationTextHandle,-(SP)
        _TeCut                          ;clear out the text edit record

        LEA     fiRefNum,AØ
        MOVE    (AØ),ioParamBlock+ioRefNum(A5) ;somehow Printing Manager trashes param block
        LEA     DataBuffer(A5),AØ
        MOVE.L  AØ,ioParamBlock+ioBuffer(A5)
        MOVE.L  #256,ioParamBlock+ioByteCount(A5)
        MOVE    #1,ioParamBlock+ioPosMode(A5)  ;read relative to start of file
```

(continued)

```
        MOVE    D7,D5                           ;number of current record
        MULU    #64,D5                          ;offset into tape array
        ADD     #oAnnotNum,D5
        LEA     TapeArray(A5),AØ
        ADD.L   D5,AØ                           ;AØ has location of annot. number
        MOVE    (AØ),DØ                         ;retrieve annot. number
        MULU    #256,DØ                                 ;offset into file
        MOVE.L  DØ,ioParamBlock+ioPosOffset(A5)

        LEA     ioParamBlock(A5),AØ
        _Read

        LEA     DataBuffer(A5),AØ
        MOVE.L  AØ,-(SP)
        MOVE.L  #256,-(SP)
        MOVE.L  AnnotationTextHandle,-(SP)
        _TEInsert                               ;annotation now in text edit record

        CLR.L   -(SP)
        MOVE.L  AnnotationTextHandle,-(SP)
        _TEGetText                              ;get handle to annotation text
        MOVE.L  (SP)+,A6                        ;retrieve handle
        MOVE.L  (A6),A6                         ;de-reference to get pointer

        MOVE    #4,D1
        LEA     AnnotationTextHandle,AØ
        MOVE.L  (AØ),AØ                                 ;get handle
        MOVE.L  (AØ),AØ                                 ;de-reference to get pointer
        MOVE    teNLines(AØ),DØ                 ;number of lines of text
        ADD     DØ,D1                           ;total number of lines in this entry

        MULU    D4,D1
        ADD     D3,D1                           ;where you will end up if this is printed
        CMP     D6,D1           ;will this one fit on the page?
        BLT     EnoughRoom
        BRA     PageFinish

EnoughRoom
        MOVEM.L         D2/D7,-(SP)
        JSR     PrintOneRecord
        JSR     ClearPrintLine
        ADD     D4,D3                   ;get a blank line
        MOVEM.L         (SP)+,D2/D7

        LEA     AnnotationTextHandle,A2
        MOVE.L  (A2),A2
        MOVE.L  (A2),A2
        MOVE    teNLines(A2),DØ         ;get number of lines again
        MOVE    #Ø,D1
```

(continued)

Listing A.1 (continued)

```
AnotherLine
        MOVEM.L     D2/D4,-(SP)          ;save D4 (line height) & D2 (total records)
        ADDQ    #1,D1                    ;look at next line
        CMP     D1,D0                    ;at last line?
        BEQ     LastLine
        SUBQ    #1,D1                    ;restore current line #
        MOVE    #2,D4
        MULU    D1,D4                    ;line starts are stored as integers
        MOVE    teLines(A2,D4),D2            ;line start of this line
        ADDQ    #2,D4
        MOVE    teLines(A2,D4),D5        ;start of next line
        SUB     D2,D5                    ;D5 has number of bytes
        MOVE    #20,-(SP)                ;annotation is indented 20 pixels
        MOVE    D3,-(SP)
        _MoveTo

        MOVEM.L     D0/D1/D7/A2/A6,-(SP)
        MOVE.L  A6,-(SP)                 ;pointer to text
        MOVE    D2,-(SP)                 ;starting position
        MOVE    D5,-(SP)                 ;number of bytes to print
        _DrawText
        MOVEM.L     (SP)+,D0/D1/D7/A2/A6
        MOVEM.L     (SP)+,D2/D4
        ADDQ    #1,D1                    ;increment line counter
        ADD     D4,D3                    ;space to next line
        BRA     AnotherLine
;
LastLine
        SUBQ    #1,D1                    ;restore current line #
        MOVEM.L     D1/D3/D7/A2/A6,-(SP)
        MULU    #2,D1
        MOVE    teLines(A2,D1),D5        ;start of last line
        MOVE    #257,D0                      ;total characters + 1
        SUB     D5,D0                    ;characters left to print

        MOVE    #20,-(SP)
        MOVE    D3,-(SP)
        _MoveTo

        MOVE.L  A6,-(SP)
        MOVE    D5,-(SP)
        MOVE    D0,-(SP)
        _DrawText
        MOVEM.L     (SP)+,D1/D3/D7/A2/A6
        MOVEM.L     (SP)+,D2/D4
;
        ADD     D4,D3
;
        JSR     ClearPrintLine
        ADD     D4,D3                        ;one blank line
        ADD     D4,D3                        ;another blank line
```

(continued)

```
        ADDQ    #1,D7
        CMP     D2,D7
        BEQ     PageFinish                      ;all records printed
        BRA     AnnotRecordPrint
;
;------------------ print without annotations -------------------------

PrintAllTitles
        JSR     PrOpen          ;open printing manager (on disk - not in ROM)
        MOVE.L  #iPrintSize,DØ  ;size of print record
        _NewHandle              ;allocate heap space for print record
        LEA     PrintRecordHandle,A2
        MOVE.L  AØ,(A2)         ;store handle to print record

        MOVE.L  AØ,-(SP)        ;put handle on stack
        JSR     PrintDefault    ;fill default info into print record

        CLR     -(SP)           ;space for boolean result
        LEA     PrintRecordHandle,A2
        MOVE.L  (A2),-(SP)
        JSR     PrJobDialog     ;draft or spooled?
        MOVE    (SP)+,DØ        ;remove result
        BEQ     PrintFinish     ;user clicked CANCEL - must close up shop

        JSR     PrintAlert      ;tell user to ready the printer
        CLR.L   -(SP)           ;space for pointer to printer port
        LEA     PrintRecordHandle,A2
        MOVE.L  (A2),-(SP)
        CLR.L   -(SP)           ;let system allocate new port
        CLR.L   -(SP)           ;use system I/O buffer
        JSR     prOpenDoc       ;allocate custom printer port
        MOVE.L  (SP)+,PrPortPtr(A5)     ;retrieve pointer

        MOVE.L  #Ø,D7           ;initialize a record counter
        MOVE.L  #Ø,D2           ;clear out register
        LEA     TotalRecords,AØ
        MOVE    (AØ),D2
AnotherPage
        JSR     PrintOnePage
        CMP     D2,D7
        BLT     AnotherPage
        MOVE.L  PrPortPtr(A5),-(SP)
        JSR     PrCloseDoc      ;close the document

PrintFinish
        MOVE.L  #Ø,DØ           ;clear out register
        LEA     PrintRecordHandle,A2
        MOVE.L  (A2),AØ
        MOVE.L  (AØ),AØ                 ;get pointer
        MOVE.B  prJob+bJDocLoop(AØ),DØ
        BEQ     Closeup         ;draft printing was done
```

(continued)

Listing A.1 (continued)

```
        LEA     PrintRecordHandle,A2
        MOVE.L  (A2),-(SP)
        CLR.L   -(SP)               ;let spooler set up its own printing port
        CLR.L   -(SP)               ;let spooler use its own buffer
        CLR.L   -(SP)               ;let spooler use its own device buffer
        PEA     PrinterStatusRec(A5)
        JSR     PrPicFile           ;image and print spool file
Closeup
        MOVE.L  PrintRecordHandle,AØ
        _DisposHandle               ;free space taken by print record

        JSR     PrClose             ;close print manager
        MOVE    #9,DØ
        RTS

PrintOnePage
        MOVEM.L         D2/D7,-(SP)     ;save record counter
        MOVE.L  PrPortPtr(A5),-(SP)     ;pointer to printer port
        CLR.L   -(SP)               ;no scaling
        JSR     PrOpenPage          ;begin a new page
        MOVEM.L         (SP)+,D2/D7     ;restore record counter
        MOVE    #monaco,-(SP)
        _TextFont                   ;printing will be in monaco font

        MOVE    #12,-(SP)
        _TextSize

        MOVEM.L         D2/D7,-(SP)
        PEA     FontInfoStorage(A5)     ;pointer to font info record
        _GetFontInfo                ;font characteristics needed to calculate end of page
        MOVEM.L         (SP)+,D2/D7
        MOVE    FontInfoStorage+ascent(A5),D4
        ADD     FontInfoStorage+descent(A5),D4
        ADD     FontInfoStorage+leading(A5),D4  ;calculates height of line

        LEA     PrintRecordHandle,A2
        MOVE.L  (A2),AØ
        MOVE.L  (AØ),AØ                             ;get pointer from handle
        MOVE    prInfo+rPage+bottom(AØ),D6      ;page bottom coordinate
        SUB     FontInfoStorage+descent(A5),D6  ;adjust for font descent

        MOVE    D4,D3                           ;initial vertical position

        JSR     ClearPrintLine
        ADD     D4,D3                           ;blank line
        ADD     D4,D3                           ;blank line

        MOVEM.L         D2/D7,-(SP)
        JSR     PrintHeadings
        MOVEM.L         (SP)+,D2/D7
```

(continued)

```
RecordPrint
        MOVEM.L         D2/D7,-(SP)
        JSR     PrintOneRecord
        MOVEM.L         (SP)+,D2/D7
        ADDQ    #1,D7
        CMP     D2,D7
        BEQ     PageFinish      ;all records printed - close up shop
        CMP     D6,D3           ;at bottom of page?
        BLT     RecordPrint     ;not at bottom - print another record

PageFinish
        MOVEM.L         D2/D7,-(SP)     ;save record counter
        MOVE.L  PrPortPtr(A5),-(SP)
        JSR     PrClosePage
        MOVEM.L         (SP)+,D2/D7     ;restore record counter
        RTS

ClearPrintLine                  ;fill print line with blanks
        LEA     PrintLineMask,A0
        LEA     PrintLine(A5),A1
        MOVE    #102,D0
        _BlockMove

        MOVE.B  #100,PrintLine(A5)              ;set length of print line

        RTS

PrintHeadings
        LEA     PageHead,A0
        LEA     PrintLine+40(A5),A1
        MOVE    #11,D0
        _BlockMove
        MOVE    #0,-(SP)
        MOVE    D3,-(SP)
        _MoveTo
        MOVEM.L         D1/D2/D7,-(SP)
        PEA     PrintLine(A5)
        _DrawString
        MOVEM.L         (SP)+,D1/D2/D7
        ADD     D4,D3

        JSR     ClearPrintLine
        ADD     D4,D3                   ;blank line
        ADD     D4,D3                   ;blank line

        MOVE    #4,-(SP)
        _TextFace                       ;underline the column headings
        LEA     TitleHead,A0
        LEA     PrintLine+12(A5),A1
        MOVE    #5,D0
        _BlockMove
```

(continued)

Listing A.1 (continued)

```
        LEA     ProducerHead,AØ
        LEA     PrintLine+44(A5),A1
        MOVE    #8,DØ
        LEA     DateHead,AØ
        LEA     PrintLine+66(A5),A1
        MOVE    #4,DØ
        _BlockMove

        LEA     RatingHead,AØ
        LEA     PrintLine+72(A5),A1
        MOVE    #4,DØ
        _BlockMove

        LEA     NumberHead,AØ
        LEA     PrintLine+78(A5),A1
        MOVE    #4,DØ
        _BlockMove

        MOVE    #Ø,-(SP)
        MOVE    D3,-(SP)
        _MoveTo
        MOVEM.L         D1/D2/D7,-(SP)
        PEA     PrintLine(A5)
        _DrawString
        MOVEM.L         (SP)+,D1/D2/D7

        ADD     D4,D3

        MOVE    #Ø,-(SP)        ;back to normal
        _TextFace

        JSR     ClearPrintLine
        ADD     D4,D3           ;blank line

        RTS

PrintOneRecord
        JSR     ClearPrintLine
        LEA     TapeArray(A5),A2

        MOVE.L  D7,-(SP)                ;save record counter
        MOVE    D7,D5
        JSR     ComputeAddress2                 ;address returned in A4
        MOVE.L  (SP)+,D7                ;restore record counter

        MOVE.L  A4,AØ                   ;start of record
        LEA     PrintLine+12(A5),A1
        MOVE    #3Ø,DØ
        _BlockMove                      ;moves TapeName

        MOVE.L  A4,AØ
        ADD.L   #oProducer,AØ
```

(continued)

```
        LEA     PrintLine+44(A5),A1
        MOVE    #20,D0
        _BlockMove                      ;moves Producer
        MOVE.L  A4,A0
        ADD.L   #oReleaseDate,A0
        LEA     PrintLine+66(A5),A1
        MOVE    #4,D0
        _BlockMove                      ;moves Date

        MOVE.L  A4,A0
        ADD.L   #oRating,A0
        LEA     PrintLine+72(A5),A1
        MOVE    #4,D0
        _BlockMove                      ;moves Rating

        MOVE.L  A4,A0
        ADD.L   #oTapeNumber,A0
        LEA     PrintLine+78(A5),A1
        MOVE    #4,D0
        _BlockMove                      ;moves Tape Number

        MOVE    #0,-(SP)
        MOVE    D3,-(SP)
        _MoveTo
        MOVEM.L         D1/D2/D7,-(SP)
        PEA     PrintLine(A5)
        _DrawString
        MOVEM.L         (SP)+,D1/D2/D7

        ADD     D4,D3

        RTS

PrintAlert
        CLR     -(SP)           ;space for integer result
        MOVE    #5,-(SP)        ;alert ID
        CLR.L   -(SP)           ;use standard filter procedure
        _Alert
        MOVE    (SP)+,D0        ;pop result

        RTS
;---------------------- Set up the main menu -------------------------

MainMenuBar
        LEA     AppleHandle,A1
        MOVE.L  (A1),-(SP)      ;Put handle on stack again
        CLR     -(SP)           ;shows that this menu is after all others
        _InsertMenu             ;Puts menu in list

        LEA     EditHandle,A1
        MOVE.L  (A1),-(SP)      ;Put handle on stack again
```

(continued)

Listing A.1 (continued)

```
        CLR     -(SP)           ;Put menu after the first one
        _InsertMenu             ;Put menu in list

ReDrawMainMenu
        LEA     OptionsHandle,A1
        MOVE.L  (A1),-(SP)      ;Put handle on stack again
        CLR     -(SP)           ;This menu is after the other two
        _InsertMenu             ;Put menu in list

        _DrawMenuBar            ;Draw the menu bar
        RTS
; ------------ Make the text windows visible -------------------------

DisplayWindows
        MOVE.L  AnnotationWindowPtr,-(SP)
        _SelectWindow
        MOVE.L  AnnotationWindowPtr,-(SP)
        _SetPort
        MOVE.L  #0,-(SP)
        MOVE.L  #256,-(SP)
        MOVE.L  AnnotationTextHandle,-(SP)
        _TESetSelect            ;select all the text in the window
        MOVE.L  AnnotationTextHandle,-(SP)
        _TECut                  ;cut out text from previous use

        MOVE.L  AnnotationWindowPtr,-(SP)
        SF      -(SP)
        _HiliteWindow           ;get rid of highlighting in this window

        MOVE.L  NumberWindowPtr,-(SP)
        _SelectWindow
        MOVE.L  NumberWindowPtr,-(SP)
        _SetPort
        MOVE.L  #0,-(SP)
        MOVE.L  20,-(SP)
        MOVE.L  NumberTextHandle,-(SP)
        _TESetSelect
        MOVE.L  NumberTextHandle,-(SP)
        _TECut

        MOVE.L  RatingWindowPtr,-(SP)
        _SelectWindow
        MOVE.L  RatingWindowPtr,-(SP)
        _SetPort
        MOVE.L  #0,-(SP)
        MOVE.L  #4,-(SP)
        MOVE.L  RatingTextHandle,-(SP)
        _TESetSelect
        MOVE.L  RatingTextHandle,-(SP)
        _TECut
```

(continued)

```
        MOVE.L  DateWindowPtr,-(SP)
        _SelectWindow
        MOVE.L  DateWindowPtr,-(SP)
        _SetPort
        MOVE.L  #0,-(SP)
        MOVE.L  #5,-(SP)
        MOVE.L  DateTextHandle,-(SP)
        _TESetSelect
        MOVE.L  DateTextHandle,-(SP)
        _TECut

        MOVE.L  ProducerWindowPtr,-(SP)
        _SelectWindow
        MOVE.L  ProducerWindowPtr,-(SP)
        _SetPort
        MOVE.L  #0,-(SP)
        MOVE.L  #22,-(SP)
        MOVE.L  ProducerTextHandle,-(SP)
        _TESetSelect
        MOVE.L  ProducerTextHandle,-(SP)
        _TECut

        MOVE.L  $00000010,D0        ;mask to remove activate events
        _FlushEvents

        MOVE.L  NameWindowPtr,-(SP)
        _SelectWindow               ;name window is activated at start
        MOVE.L  NameWindowPtr,-(SP)
        _SetPort
        MOVE.L  #0,-(SP)
        MOVE.L  #32,-(SP)
        MOVE.L  NameTextHandle,-(SP)
        _TESetSelect
        MOVE.L  NameTextHandle,-(SP)
        _TECut

        LEA     ActiveTextHandle,A0
        MOVE.L  NameTextHandle,(A0)     ;for TEIdle

        RTS

;---------------- Select the appropriate text window -------------------
SelectTextWindow

        LEA     ActiveTextHandle,A1
        MOVE.L  WhichWindowPtr,A0

        CMP.L   NameWindowPtr,A0        ;check to identify specific window
        BNE     Select1
        MOVE.L  NameTextHandle,(A1)             ;pass appropriate handle to TEIdle
        BRA     Select6
```

(continued)

Listing A.1 (continued)

```
Select1 CMP.L   ProducerWindowPtr,A0
        BNE     Select2
        MOVE.L  ProducerTextHandle,(A1)
        BRA     Select6

Select2 CMP.L   DateWindowPtr,A0
        BNE     Select3
        MOVE.L  DateTextHandle,(A1)
        BRA     Select6

Select3 CMP.L   RatingWindowPtr,A0
        BNE     Select4
        MOVE.L  RatingTextHandle,(A1)
        BRA     Select6

Select4 CMP.L   NumberWindowPtr,A0
        BNE     Select5
        MOVE.L  NumberTextHandle,(A1)
        BRA     Select6

Select5 CMP.L   AnnotationWindowPtr,A0
        BNE     Select7                 ;not a text window
        MOVE.L  AnnotationTextHandle,(A1)

Select6 MOVE.L  WhichWindowPtr,-(SP)
        _SelectWindow

Select7 RTS

; --------- Handle activate events in text windows ------------------
ActivateTextWindow
        MOVE.L  Message,A0      ;get pointer to window which posted event
        MOVE    Modify,D0
        BTST    #activeFlag,D0  ;activate bit set?
        BEQ     DeActivate      ;if not set, window was deactivated
Activate1
        CMP.L   NameWindowPtr,A0        ;name window event?
        BNE     Activate2
        MOVE.L  NameTextHandle,-(SP)
        _TEActivate
        BRA     Activate99

Activate2
        CMP.L   ProducerWindowPtr,A0
        BNE     Activate3
        MOVE.L  ProducerTextHandle,-(SP)
        _TEActivate
        BRA     Activate99

Activate3
        CMP.L   DateWindowPtr,A0
        BNE     Activate4
```

(continued)

```
        MOVE.L  DateTextHandle,-(SP)
        _TEActivate
        BRA     Activate99

Activate4
        CMP.L   RatingWindowPtr,A0
        BNE     Activate5
        MOVE.L  RatingTextHandle,-(SP)
        _TEActivate
        BRA     Activate99
Activate5
        CMP.L   NumberWindowPtr,A0
        BNE     Activate6
        MOVE.L  NumberTextHandle,-(SP)
        _TEActivate
        BRA     Activate99

Activate6
        CMP.L   AnnotationWindowPtr,A0
        BNE     Activate98              ;not one of our text windows
        MOVE.L  AnnotationTextHandle,-(SP)
        _TEActivate

Activate99
        MOVE.L  Message,-(SP)   ;make this the current grafport
        _SetPort

Activate98
        RTS

DeActivate
        CMP.L   NameWindowPtr,A0
        BNE     DeActivate1
        MOVE.L  NameTextHandle,-(SP)
        _TeDeActivate
        RTS

DeActivate1
        CMP.L   ProducerWindowPtr,A0
        BNE     DeActivate2
        MOVE.L  ProducerTextHandle,-(SP)
        _TeDeActivate
        RTS

DeActivate2
        CMP.L   DateWindowPtr,A0
        BNE     DeActivate3
        MOVE.L  DateTextHandle,-(SP)
        _TeDeActivate
        RTS
```

(continued)

Listing A.1 (continued)

```
DeActivate3
        CMP.L   RatingWindowPtr,A0
        BNE     DeActivate4
        MOVE.L  RatingTextHandle,-(SP)
        _TeDeActivate
        RTS

DeActivate4
        CMP.L   NumberWindowPtr,A0
        BNE     DeActivate5
        MOVE.L  NumberTextHandle,-(SP)
        _TeDeActivate
        RTS

DeActivate5
        CMP.L   AnnotationWindowPtr,A0
        BNE     DeActivate6             ;not a text window
        MOVE.L  AnnotationTextHandle,-(SP)
        _TeDeActivate
        RTS

DeActivate6
        RTS

; ------------------------ Update Text Windows -------------------------
; This updates all windows, regardless of which one was active
UpdateTextWindows

        MOVE.L  MainWindowPtr,-(SP)
        _BeginUpdate
        MOVE.L  MainWindowPtr,-(SP)
        _SetPort
        PEA     MainWindowRect
        _EraseRect
        JSR     DisplayPrompts          ;re-draw window's contents
        MOVE.L  MainWindowPtr,-(SP)
        _EndUpdate

        MOVE.L  NameWindowPtr,-(SP)
        _BeginUpdate
        MOVE.L  NameWindowPtr,-(SP)
        _SetPort
        PEA     NameViewRect
        _EraseRect
        PEA     NameViewRect
        MOVE.L  NameTextHandle,-(SP)
        _TEUpdate
        MOVE.L  NameWindowPtr,-(SP)
        _EndUpdate

        MOVE.L  ProducerWindowPtr,-(SP)
        _BeginUpdate
```

(continued)

```
MOVE.L  ProducerWindowPtr,-(SP)
_SetPort
PEA     ProducerViewRect
_EraseRect
PEA     ProducerViewRect
MOVE.L  ProducerTextHandle,-(SP)
_TEUpdate
MOVE.L  ProducerWindowPtr,-(SP)
_EndUpdate

MOVE.L  DateWindowPtr,-(SP)
_BeginUpdate
MOVE.L  DateWindowPtr,-(SP)
_SetPort
PEA     DateViewRect
_EraseRect
PEA     DateViewRect
MOVE.L  DateTextHandle,-(SP)
_TEUpdate
MOVE.L  DateWindowPtr,-(SP)
_EndUpdate

MOVE.L  RatingWindowPtr,-(SP)
_BeginUpdate
MOVE.L  RatingWindowPtr,-(SP)
_SetPort
PEA     RatingViewRect
_EraseRect
PEA     RatingViewRect
MOVE.L  RatingTextHandle,-(SP)
_TEUpdate
MOVE.L  RatingWindowPtr,-(SP)
_EndUpdate

MOVE.L  NumberWindowPtr,-(SP)
_BeginUpdate
MOVE.L  NumberWindowPtr,-(SP)
_SetPort
PEA     NumberViewRect
_EraseRect
PEA     NumberViewRect
MOVE.L  NumberTextHandle,-(SP)
_TEUpdate
MOVE.L  NumberWindowPtr,-(SP)
_EndUpdate

MOVE.L  AnnotationWindowPtr,-(SP)
_BeginUpdate
MOVE.L  AnnotationWindowPtr,-(SP)
_SetPort
PEA     AnnotationViewRect
_EraseRect
```

(continued)

Listing A.1 (continued)

```
        PEA     AnnotationViewRect
        MOVE.L  AnnotationTextHandle,-(SP)
        _TEUpdate
        MOVE.L  AnnotationWindowPtr,-(SP)
        _EndUpdate

        RTS

;----------------- Display prompts for text entry windows ---------------
DisplayPrompts
        MOVE    #sysFont,-(SP)
        _TextFont

        PEA     NameTitle               ;text to print
        MOVE.L  #11,-(SP)               ;number of characters to print
        PEA     NamePromptBox           ;rectangle where text should be printed
        MOVE    #-1,-(SP)               ;to right justify text
        _TextBox

        PEA     ProducerTitle
        MOVE.L  #22,-(SP)
        PEA     ProducerPromptBox
        MOVE    #-1,-(SP)
        _TextBox

        PEA     DateTitle
        MOVE.L  #17,-(SP)
        PEA     DatePromptBox
        MOVE    #-1,-(SP)
        _TextBox

        PEA     RatingTitle
        MOVE.L  #8,-(SP)
        PEA     RatingPromptBox
        MOVE    #-1,-(SP)
        _TextBox

        PEA     NumberTitle
        MOVE.L  #13,-(SP)
        PEA     NumberPromptBox
        MOVE    #-1,-(SP)
        _TextBox

        RTS

; ------------- Do the text edit functions ----------------------
DoEditing
        MOVE    WhatItem,D0     ;get set to figure out what was selected

        CMP     #3,D0           ;cut?
        BNE     DoEditing1
        MOVE.L  ActiveTextHandle,-(SP)
```

(continued)

```
        _TECut
        RTS

DoEditing1
        CMP     #4,DØ           ;copy?
        BNE     DoEditing2
        MOVE.L  ActiveTextHandle,-(SP)
        _TECopy
        RTS

DoEditing2
        CMP     #5,DØ           ;paste?
        BNE     DoEditing3
        MOVE.L  ActiveTextHandle,-(SP)
        _TEPaste
        RTS

DoEditing3
        CMP     #6,DØ           ;clear?
        BNE     DoEditing4      ;not a recognizable item
        MOVE.L  ActiveTextHandle,-(SP)
        _TEDelete

DoEditing4
        RTS

;----------------- Clear the NewRecord storage area ----------------------
ClearNewRecord
        LEA     NewRecordMask,AØ        ;all blanks
        LEA     NewRecord(A5),A1
        MOVE.L  #64,DØ
        _BlockMove
        RTS

;--------------- Move data from text edit records to data record -----------
MoveName
        CLR.L   -(SP)           ;space for CharsHandle result
        MOVE.L  NameTextHandle,-(SP)
        _TEGetText              ;get handle to text in Name edit record
        MOVE.L  (SP)+,A2        ;recover CharsHandle
        MOVE.L  (A2),AØ         ;source pointer for block move
        LEA     NewRecord+oTapeName(A5),A1      ;destination of block move
        MOVE.L  NameTextHandle,A3
        MOVE.L  (A3),A4
        MOVE    teLength(A4),DØ ;number of characters to move
        _BlockMove
        RTS

MoveProducer
        CLR.L   -(SP)
        MOVE.L  ProducerTextHandle,-(SP)
        _TEGetText                                              (continued)
```

Listing A.1 (continued)

```
        MOVE.L  (SP)+,A2
        MOVE.L  (A2),AØ
        LEA     NewRecord+oProducer(A5),A1
        MOVE.L  ProducerTextHandle,A3
        MOVE.L  (A3),A4
        MOVE    teLength(A4),DØ
        _BlockMove
        RTS

MoveDate
        CLR.L   -(SP)
        MOVE.L  DateTextHandle,-(SP)
        _TEGetText
        MOVE.L  (SP)+,A2
        MOVE.L  (A2),AØ
        LEA     NewRecord+oReleaseDate(A5),A1
        MOVE.L  DateTextHandle,A3
        MOVE.L  (A3),A4
        MOVE    teLength(A4),DØ
        _BlockMove
        RTS

MoveRating
        CLR.L   -(SP)
        MOVE.L  RatingTextHandle,-(SP)
        _TEGetText
        MOVE.L  (SP)+,A2
        MOVE.L  (A2),AØ
        LEA     NewRecord+oRating(A5),A1
        MOVE.L  RatingTextHandle,A3
        MOVE.L  (A3),A4
        MOVE    teLength(A4),DØ
        _BlockMove
        RTS

MoveNumber
        CLR.L   -(SP)
        MOVE.L  NumberTextHandle,-(SP)
        _TEGetText
        MOVE.L  (SP)+,A2
        MOVE.L  (A2),AØ
        LEA     NewRecord+oTapeNumber(A5),A1
        MOVE.L  NumberTextHandle,A3
        MOVE.L  (A3),A4
        MOVE    teLength(A4),DØ
        _BlockMove
        RTS

;--------------- Alert box processing for no selection criteria ------------
NoSelectionCriteria
        CLR     -(SP)           ;space for alert item result
        MOVE    #4,-(SP)        ;alert item ID
```

(continued)

```
        MOVE.L  #Ø,-(SP)        ;use standard filter procedure
        _Alert
        MOVE    (SP)+,DØ        ;pull result from stack
        RTS

;---------------- Display one record from array ----------------------
DisplayOneRecord
        JSR     DisplayWindows          ;clears out text edit records
        LEA     RecordCounter,AØ
        MOVE    (AØ),D5
        MULU    #64,D5

        MOVE.L  NameWindowPtr,-(SP)
        _SetPort
        LEA     TapeArray(A5),AØ
        ADD     D5,AØ
        MOVE.L  AØ,-(SP)                ;pointer to text
        MOVE.L  #3Ø,-(SP)               ;# of characters to get
        MOVE.L  NameTextHandle,-(SP)    ;edit record which will get characters
        _TEInsert                       ;incorporate text into record

        MOVE.L  ProducerWindowPtr,-(SP)
        _SetPort
        LEA     TapeArray(A5),AØ
        ADD     D5,AØ
        ADD.L   #oProducer,AØ
        MOVE.L  AØ,-(SP)
        MOVE.L  #2Ø,-(SP)
        MOVE.L  ProducerTextHandle,-(SP)
        _TEInsert

        MOVE.L  DateWindowPtr,-(SP)
        _SetPort
        LEA     TapeArray(A5),AØ
        ADD     D5,AØ
        ADD.L   #oReleaseDate,AØ
        MOVE.L  AØ,-(SP)
        MOVE.L  #4,-(SP)
        MOVE.L  DateTextHandle,-(SP)
        _TEInsert

        MOVE.L  RatingWindowPtr,-(SP)
        _SetPort
        LEA     TapeArray(A5),AØ
        ADD     D5,AØ
        ADD.L   #oRating,AØ
        MOVE.L  AØ,-(SP)
        MOVE.L  #4,-(SP)
        MOVE.L  RatingTextHandle,-(SP)
        _TEInsert
```

(continued)

Listing A.1 (continued)

```
        MOVE.L  NumberWindowPtr,-(SP)
        _SetPort
        LEA     TapeArray(A5),AØ
        ADD     D5,AØ
        ADD.L   #oTapeNumber,AØ
        MOVE.L  AØ,-(SP)
        MOVE.L  #4,-(SP)
        MOVE.L  NumberTextHandle,-(SP)
        _TEInsert

        RTS

; ------------ Retrieve and display an annotation ----------------------
DisplayAnnotation
        LEA     DataBuffer(A5),AØ
        MOVE.L  AØ,ioParamBlock+ioBuffer(A5)
        MOVE.L  #256,ioParamBlock+ioByteCount(A5)
        MOVE    #1,ioParamBlock+ioPosMode(A5)  ;read relative to start of file

        LEA     RecordCounter,AØ
        MOVE    (AØ),D5                        ;number of current record
        MULU    #64,D5                         ;offset into tape array
        ADD     #oAnnotNum,D5
        LEA     TapeArray(A5),AØ
        ADD.L   D5,AØ                          ;AØ has location of annot. number
        MOVE    (AØ),DØ                        ;retrieve annot. number
        MULU    #256,DØ                                ;offset into file
        MOVE.L  DØ,ioParamBlock+ioPosOffset(A5)
        LEA     ioParamBlock(A5),AØ
        _Read

        MOVE.L  AnnotationWindowPtr,-(SP)
        _SetPort

        LEA     DataBuffer(A5),AØ
        MOVE.L  AØ,-(SP)
        MOVE.L  #256,-(SP)
        MOVE.L  AnnotationTextHandle,-(SP)
        _TEInsert

        RTS

; ---------- Display and handle "Find and Wait" dialog box --------------
DisplayDialog3
        CLR.L   -(SP)           ;space for dialog pointer
        MOVE    #3,-(SP)        ;dialog ID
        PEA     DialogWindRec(A5)       ;storage for dialog record
        MOVE.L  #-1,-(SP)       ;put this dialog box in front
        _GetNewDialog

        MOVE.L  (SP)+,DialogWindPtr(A5)  ;recover dialog pointer
```

(continued)

```
        MOVE.L  DialogWindPtr(A5),-(SP)
        _SetPort

Dialog3a
        MOVE.L  #Ø,-(SP)        ;use standard event filter
        PEA     WhatItem        ;place to put number of item selected
        _ModalDialog            ;let system monitor dialog box

        MOVE    WhatItem,DØ
        CMP     #okButton,DØ    ;OK button pressed?
        BNE     Dialog3a

        MOVE.L  DialogWindPtr(A5),-(SP)  ;put dialog pointer on stack
        _CloseDialog            ;remove dialog

        RTS

; ------------ Display and handle "Find More?" dialog box ----------------
DisplayDialog2
        CLR.L   -(SP)           ;space for dialog pointer
        MOVE    #2,-(SP)        ;for dialog box #2
        PEA     DialogWindRec(A5)       ;storage for dialog record
        MOVE.L  #-1,-(SP)       ;put dialog box in front
        _GetNewDialog

        MOVE.L  (SP)+,DialogWindPtr(A5)  ;recover pointer

        MOVE.L  DialogWindPtr(A5),-(SP)  ;put back on stack
        _SetPort

Dialog2a
        MOVE.L  #Ø,-(SP)        ;use standard filter procedure
        PEA     WhatItem        ;space for item that was pressed
        _ModalDialog

        MOVE    WhatItem,D7
        CMP     #okButton,D7
        BEQ     Dialog2b

        CMP     #cancelButton,D7
        BNE     Dialog2a

Dialog2b
        MOVE.L  DialogWindPtr(A5),-(SP)
        _CloseDialog

        RTS                     ;if cancelled, returns to Select menu control

; ------------ Display and handle "No Find" dialog box --------------------
DisplayDialog1
        CLR.L   -(SP)           ;space for dialog pointer
        MOVE    #1,-(SP)        ;this is dialog box 1
```

(continued)

Listing A.1 (continued)

```
        PEA     DialogWindRec(A5)       ;storage for dialog record
        MOVE.L  #-1,-(SP)       ;put dialog box in front
        _GetNewDialog           ;get the dialog box

        MOVE.L  (SP)+,DialogWindPtr(A5)  ;recover pointer

        MOVE.L  DialogWindPtr(A5),-(SP)  ;put back on stack
        _SetPort

Dialog1a
        MOVE.L  #Ø,-(SP)        ;use standard filter procedure
        PEA     WhatItem        ;space for item that was pressed
        _ModalDialog

        MOVE    WhatItem,DØ
        CMP     #okButton,DØ
        BNE     Dialog1a

        MOVE.L  DialogWindPtr(A5),-(SP)
        _CloseDialog

        RTS

; ---------- Pointers and storage for the seven window records ----------

MainWindowPtr           DC.L    Ø
NameWindowPtr           DC.L    Ø
ProducerWindowPtr       DC.L    Ø
DateWindowPtr           DC.L    Ø
RatingWindowPtr         DC.L    Ø
NumberWindowPtr                 DC.L    Ø
AnnotationWindowPtr     DC.L    Ø

MainWindowStorage       DS      WindowSize
NameWindowStorage       DS      WindowSize
ProducerWindowStorage   DS      WindowSize
DateWindowStorage       DS      WindowSize
RatingWindowStorage     DS      WindowSize
NumberWindowStorage     DS      WindowSize
AnnotationWindowStorage DS      WindowSize

WhichWindowPtr          DC.L    Ø       ;place for FindWindow result

; ---------- Data Structures for TextEdit ----------

NameViewRect            DC      1,1,19,249
NameDestRect            DC      1,1,19,249
NameTextHandle          DC.L    Ø
NamePromptBox           DC      12,1Ø,32,2ØØ
NameTitle               DC      'Tape Name:'
```

(continued)

```
ProducerViewRect        DC      1,1,19,175
ProducerDestRect        DC      1,1,19,175
ProducerTextHandle      DC.L    Ø
ProducerPromptBox       DC      37,1Ø,57,2ØØ
ProducerTitle           DC      'Producer/Distributor:'

DateViewRect            DC      1,1,19,42
DateDestRect            DC      1,1,19,42
DateTextHandle          DC.L    Ø
DatePromptBox           DC      62,1Ø,82,2ØØ
DateTitle               DC      'Date of Release:'

RatingViewRect          DC      1,1,19,28
RatingDestRect          DC      1,1,19,28
RatingTextHandle DC.L   Ø
RatingPromptBox         DC      87,1Ø,1Ø7,2ØØ
RatingTitle             DC      'Rating:'

NumberViewRect          DC      1,1,19,35
NumberDestRect          DC      1,1,19,35
NumberTextHandle        DC.L    Ø
NumberPromptBox                 DC      112,1Ø,132,2ØØ
NumberTitle             DC      'Tape Number:'

AnnotationViewRect      DC      4,3,72,46Ø
AnnotationDestRect      DC      4,3,72,46Ø
AnnotationTextHandle    DC.L    Ø

ActiveTextHandle        DC.L    Ø       ;holds text handle of active text window for TEIdle
MainWindowRect          DC      Ø,Ø,24Ø,49Ø     ;for EraseRect
;---------------- Defintions for trapping events -----------------

everyEvent      DC.L    $ØØØØFFFF
EventRecord             ;where GetNextEvent Puts its result
What    DC      Ø
Message DC.L    Ø
When    DC.L    Ø
Point   DC.L    Ø
Modify  DC      Ø

;---------- These are the handles for the eight menus -------------

AppleHandle     DC.L    Ø
EditHandle      DC.L    Ø
OptionsHandle   DC.L    Ø
EnterHandle     DC.L    Ø
ChangeHandle    DC.L    Ø
DeleteHandle    DC.L    Ø
SelectHandle    DC.L    Ø
PrintHandle     DC.L    Ø
```

(continued)

Listing A.1 (continued)

```
WhichMenu       DC      Ø
WhatItem        DC      Ø

DeskAccName     DCB.W   16,Ø

TapeArray       DS.B    64ØØ

NewRecord       DS.B    64

NewRecordMask   DCB.B   64," "

TotalRecords    DC      Ø

AnnotRecMask    DCB.B   256," "

LastAnnotNumb   DC      Ø

RecordCounter   DC      Ø

StopNumber      DS.W    1

DialogWindRec   DS      dWindLen
DialogWindPtr   DS.L    1

; --------------- Data structures and storage for file operations -----------
DataBuffer      DS.B    256             ;need maximum 256 bytes for annotation

ioParamBlock    DS.B    ioQElSize       ;I/O parameter blocks are 5Ø bytes
fiParamBlock    DS.B    ioFQElSize      ;file info parameter blocks are 8Ø bytes
vParamBlock     DS.B    ioVQElSize      ;volume paramter blocks are 64 bytes

ReturnFlag      DS      1               ;source of call to SelectOneTitle

fiRefNum        DC      Ø               ;place for file reference number
; --------------- Data structures and constants for printing ------------------------
PrintRecordHandle       DC.L    Ø
PrinterStatusRec DS.B   iPrStatSize     ;printer status record
PrintLine               DS.B    1Ø2
PrintLineMask           DCB.B   1ØØ," "

PrPortPtr               DS.L    1
FontInfoStorage         DS.W    4               ;place to put font info for printing

PageHead                DC      'Video Tapes'
TitleHead               DC      'Title'
ProducerHead            DC      'Producer'
DateHead                DC      'Date'
RatingHead              DC      'Ratg'
NumberHead              DC      'Numb'

        END
```

Listing A.2 Resource File for the Video Tape Index Program

```
tape.index:TapesRsrc.REL

TYPE MENU                                   ;; Apple menu
  ,1
\14

  ,2                                        ;; Edit menu
Edit
Undo/Z
(-
Cut/X
Copy/C
Paste/V
Clear

  ,3                                        ;; Options menu
Options
Enter
Change
Delete
Select
Print
Quit/Q

  ,4                                        ;; Enter menu (add new titles)
Enter
Add/A
Quit/Q

  ,5                                        ;; Change menu (modify existing data)
Change
Find Record/F
Save Change/S
Abandon Change/A
Quit/Q

  ,6                                        ;; Delete menu (delete a tape master record)
Delete
Find Record/F
Delete/D
Cancel/C
Quit/Q

  ,7                                        ;; Select menu (search the tape master file)
Select
Display All
Display All Titles
Select One Title
Select by Producer
```

(continued)

Listing A.2 (continued)

```
Select by Date
Select by Rating
Select by Tape Number
Quit/Q

 ,8                                        ;; Print menu (print a couple of lists)
Print
Print All
Print All Titles
Quit/Q

TYPE WIND
 ,1                                        ;; Main window
Video Tape Index
40 10 300 500
visible NoGoAway
0
0

 ,2                                        ;; Tape name window
Tape Name
50 240 70 490
visible NoGoAway
2
0

 ,3                                        ;; Producer/Distributor window
Producer
75 240 95 415
visible NoGoAway
2
0

 ,4                                        ;; Date window
Date
100 240 120 283
visible NoGoAway
2
0

 ,5                                        ;; Rating window
Rating
125 240 145 269
visible NoGoAway
2
0
```

(continued)

```
 ,6                                          ;; Tape number window
Tape Number
15Ø 24Ø 17Ø 276
visible NoGoAway
2
Ø

 ,7                                          ;; Annotation window
Annotation
2Ø5 2Ø 28Ø 49Ø
visible NoGoAway
Ø
Ø

TYPE DLOG
 ,1                                          ;; None Found dialog box
Dialog box for "None Found" condition
1ØØ 3ØØ 17Ø 49Ø
Visibile NoGoAway
2
Ø
1

 ,2                                          ;; Find More dialog box
Dialog box for "One Found/Find More?" condition
1ØØ 3ØØ 17Ø 49Ø
Visible NoGoAway
2
Ø
2

 ,3                                          ;; One Found dialog box
Dialog box for "One Found" condition
1ØØ 3ØØ 17Ø 49Ø
Visible NoGoAway
2
Ø
3

TYPE ALRT
 ,4                                          ;; No Selection Criteria alert
1ØØ 3ØØ 17Ø 49Ø
4
7765

 ,5                                          ;; Ready Printer alert
5Ø 14Ø 12Ø 39Ø
5
4444
```

(continued)

Listing A.2 (continued)

```
 ,6                                          ;; File Error alert
5Ø 14Ø 12Ø 39Ø
6
5555

TYPE DITL
 ,1                                          ;; Item list for None Found dialog box
2

button
4Ø 11Ø 6Ø 17Ø


OK

staticText
1Ø 41 3Ø 149
None Found

 ,2                                          ;; Item list for Find More dialog box
3

button
4Ø 11Ø 6Ø 17Ø
OK

button
4Ø 2Ø 6Ø 8Ø
Cancel

staticText
1Ø 41 3Ø 149
Find More?

 ,3                                          ;; Item list for One Found dialog Box
1

button
4Ø 11Ø 6Ø 17Ø
OK

 ,4                                          ;; Item list for No Selection Criteria alert
2

button
4Ø 11Ø 6Ø 17Ø
OK

staticText
1Ø 5 3Ø 185
Selection criteria?
```

(continued)

```
,5                                          ;; Item list for Ready Printer alert
2

button
40 180 60 240
OK

staticText
10 10 30 240
Turn on printer. Press "Enter".

,6                                          ;; Item list for File Error Alert
2

button
40 180 60 240
OK

staticText
10 10 30 240
Unexpected file error!
```

APPENDIX B

SUMMARY OF OPERATING SYSTEM AND TOOLBOX ROUTINES DISCUSSED IN THIS BOOK

The names of ToolBox and operating system routines discussed in this book are presented below, grouped by function to help when you know what you want to do but not what you need to do it with. Each routine is followed by a short description of what it does. Once you know the name of the routine you wish to use, the quickest way to locate details about it is to look in the index under the name of the routine.

1. INITIALIZING THE SYSTEM

Calls to the initialization routines should be made at the beginning of every program in the order in which they are listed below:

InitGraf: Initializes QuickDraw. (Chapter 7)

InitFonts: Initializes the Font Manager. (Chapter 9)

FlushEvents: Flushes events from the event queue. (Chapter 8)

InitWindows: Initializes the window manager. (Chapter 7)

InitMenus: Initializes the menu manager. (Chapter 7)

InitDialogs: Initializes the Dialog Manager. (Chapter 9)

TEInit: Initializes Text Edit. (Chapter 9)

InitCursor: Initializes the arrow cursor.

1.a Managing the Cursor

GetCursor: Retrieves the 16 x 16 pixel image of a cursor from the system resource file. (Chapter 11)

SetCursor: Changes the shape of the cursor. (Chapter 11)

2. USING A RESOURCE FILE

OpenResFile: Opens a resource file for program use. This routine is needed when resource definitions are kept in a file separate from the application's source code. (Chapter 7)

3. CREATING WINDOWS

GetNewWindow: Creates a new window from parameters contained in a resource file template. (Chapter 7)

NewWindow: Creates a new window from parameters contained in the function call. (Chapter 7)

DrawGrowIcon: Draws a grow icon and the outline of scroll bars in a standard document window. (Chapter 7)

GetNewControl: Defines a control for one particular window, using parameters from a resource file. This routine is used to define scroll bars. (Chapter 7)

4. MANIPULATING WINDOWS

4.a Activating Windows

SelectWindow: Activates a window, making it the frontmost window on the screen. This is the preferred way to activate a window. (Chapter 7)

SetPort: Makes a window the current grafport. This is an essential routine, since the Macintosh can only draw in the current grafport. (Chapter 8)

4.b Manipulating Window Position in the Plane

BringToFront: Changes the position of a window in the plane, making it the frontmost window on the screen. This routines does not affect whether or not a window is visible and does not make it active. (Chapter 7)

SendBehind: Changes a window's position in the plane, sending it either behind all other windows on the screen or some other specific window on the screen. This routine does not affect whether or not a window is visible. (Chapter 7)

4.c Manipulating Window Appearance

SetWTitle: Changes the title of a window. (Chapter 7)

ShowWindow: Makes a previously invisible window visible. If the window is already visible, the routine has no effect. (Chapter 7)

HideWindow: Makes a previously visible window invisible. If the window is already invisible, the routine has no effect. (Chapter 7)

4.d Manipulating Window Regions

InvalRect: Incorporates a part of a window into the update region, indicating that something has disturbed the appearance of that part of the window and that it must be redrawn. (Chapter 8)

4.e Manipulating Controls

ShowControl: Makes a control visible. (Chapter 8)

HideControl: Makes a control invisible. (Chapter 8)

---

5. CLOSING WINDOWS

CloseWindow: Removes the window from the screen and deletes it from the application's window list. Should be used when storage for the window record was allocated by the application. (Chapter 7)

DisposWindow: Removes the window from the screen and deletes it from the application's window list. Should be used when storage for the window record was placed on the application heap. (Chapter 7)

6. CREATING MENUS

GetRMenu: Defines a menu, using parameters from a resource file. (Chapter 7)

AddResMenu: Adds resources of a given type to a menu. This routine is used primarily to add the desk accessories to an "Apple" menu. (Chapter 7)

7. MANIPULATING MENUS

7.a Managing the Menu Bar

InsertMenu: Inserts a menu into the menu list, but does not re-draw the menu bar. (Chapter 7)

DeleteMenu: Removes a menu from the menu list, but does not re-draw the menu bar. (Chapter 7)

DrawMenuBar: Draws the menu bar, displaying the titles of all menus currently in the menu list. (Chapter 7)

7.b Manipulating Menu Appearance

DisableItem: Disables either one menu item or an entire menu. Disabled items appear immediately, but the menu bar must be re-drawn before a disabled menu will appear with its title dimmed. (Chapter 7)

EnableItem: Enables either one menu item or an entire menu. Enabled items appear immediately, but the menu bar must be re-drawn before a newly enabled menu will appear with its title in boldface. (Chapter 7)

HiLiteMenu: Removes highlighting from a menu title. (Chapter 8)

8. IDENTIFYING EVENTS

GetNextEvent: Retrieves an event from the event queue. (Chapter 8)

8.a Mouse Down Events

FindWindow: Returns a code indicating the general location of where a mouse down event occurred. If the mouse down event was in a window, it also returns a pointer to that window. (Chapter 8)

MenuSelect: Returns the menu ID and the item number of a menu selection made with the mouse. (Chapter 8)

GetItem: Returns the text of a selected menu item. (Chapter 8)

FrontWindow: Returns a pointer to the frontmost window on the screen. (Chapter 8)

FindControl: Identifies which control, if any, was the site of a mouse down event. This routine also returns the part of the control that posted the event. (Chapter 8)

8.b Key Down Events

MenuKey: Returns the menu ID and menu item selection by the keyboard equivalent of a menu item. (Chapter 8)

8.c Update Events

EraseRect: Erases the contents of a rectangle. Can be used to clear the contents of a window before re-drawing them during the update process. (Chapter 8)

BeginUpdate: Called at the beginning of any code that updates a window. (Chapter 8)

EndUpdate: Called at the end of any code that updates a window. (Chapter 8)

9. HANDLING EVENTS

9.a The Desk Accessories

SystemTask: Updates the desk accessories. This routine must be called repeatedly and is therefore generally part of a main event loop. (Chapter 8)

OpenDeskAcc: Opens a desk accessory and turns its execution over to the system. (Chapter 8)

SysEdit: Handles editing requests in system windows, and in particular, the desk accessories. It should be called whenever an application detects an edit request. If the system cannot process the edit (i.e., the request wasn't for a system window), the function will return a result of false. In that case, the application can process the edit. (Chapter 8)

SystemClick: Handles any type of mouse down event in a system window (i.e., a desk accessory). (Chapter 8)

9.b Controls

TrackControl: Used to process mouse down events in scroll bars. If the mouse down event has occured in the thumb of a scroll bar, this routine will continue to drag that thumb as long as the mouse button is held down. If the mouse button was pressed in the up or down arrow, the routine will highlight the arrow until the mouse button is released. Returns a code for the part of the control posting the event. (Chapter 8)

9.c GoAway Boxes

TrackGoAway: Highlights the GoAway box as long as the mouse button is depressed in the box. Should be called whenever a mouse down event is detected in a GoAway box. (Chapter 8)

9.d Drag Regions

DragWindow: Drags an outline of a window around the screen until the mouse button is released. The window will be redrawn in its new location. Should be called whenever an application detects a mouse down event in a drag region. (Chapter 8)

9.e Grow Regions

GrowWindow: Drags an outline of the window about the screen as long as the mouse button is held down in the grow icon. Returns the coordinates of the new bottom right of the window. (Chapter 8)

SizeWindow: Re-draws a window with a new size, using the bottom right coordinates returned by **GrowWindow**. This routine only re-draws the outline of a window; it does not take care of controls or other window contents. (Chapter 8).

MoveControl: Moves a control to a new location in its window. (Chapter 8)

SizeControl: Changes the size of a control. (Chapter 8)

10. HANDLING TEXT

10.a Establishing a Text Edit Record

TENew: Creates a new text edit record. This routine attaches the text edit record to whatever window is the current grafport. (Chapter 9)

10.b Managing Text Edit Windows

TEIdle: Makes the straight-line cursor blink in the active text edit window. Must be called repeatedly for the cursor to blink regularly and should therefore be part of an event loop. (Chapter 9)

TEActivate: Activates a text edit window, making the straight-line cursor appear. (Chapter 9)

TEDeActivate: Deactivates a text edit window, removing the straight-line cursor. (Chapter 9).

TEUpdate: Re-draws the text specified by a boundary rectangle, generally the text edit window's view rectangle. (Chapter 9)

10.c Setting the Selection Range

TEClick: Positions the straight-line cursor in a text edit window based on the location of a mouse down event. The routine also takes care of extended selections made by dragging the mouse across text or by shift-clicking. (Chapter 9)

TESetSelect: Establishes the selection range in a text edit record based on starting and ending character positions passed to the routine as parameters. (Chapter 9)

10.d Character Display

TEKey: Inserts one character into a text edit record at the current insertion point and displays it on the screen. The character to be inserted generally comes from the keyboard. Therefore, this routine is called in response to a key down event that was not a keyboard equivalent for a menu selection. (Chapter 9)

TEInsert: Inserts one or more characters into a text edit record at the current insertion point and displays the new text on the screen. This routine is used, for example, to display text that has been read in from a disk file. (Chapter 9)

TESetJust: Sets the justification of the text in the current text edit record. The text edit window should be updated after changing the justification to re-draw the text. (Chapter 9)

10.e Editing

TECut: Deletes the text in the current selection range and copies it to the Clipboard. (Chapter 9)

TEDelete: Deletes the text in the current selection range. The text is not copied to the Clipboard. (Chapter 9)

TECopy: Copies the contents of the current selection range onto the Clipboard without deleting it from the text edit record. (Chapter 9)

TEPaste: Inserts the current contents of the Clipboard into a text edit record at the current selection point. (Chapter 9)

10.f Scrolling

TEScroll: Scrolls the text in a text edit window. (Chapter 9)

11. DIALOG BOXES

GetNewDialog: Creates a dialog box and displays it on the screen, using a template and an item list from a resource file. (Chapter 9)

CloseDialog: Removes a dialog box from the screen and deletes its data structures from memory. (Chapter 9)

ModalDialog: Monitors and handles events in modal dialog boxes. (Chapter 9)

12. ALERTS

Alert: Creates an alert from a template and item list in a resource file, monitors and handles events in the alert, and removes the alert from the screen when the user clicks on a push button. (Chapter 9)

13. PRINTING

NewHandle: Returns a handle to a block of memory in the application heap. This routine is used to allocate space for a print record. (Chapter 10)

DisposHandle: Releases the block of memory referenced by a handle. This routine is used to delete a printer record. (Chapter 10)

PrOpen: Opens the printer resource file. This call must be issued once, before any other Printing Manager calls. (Chapter 10)

PrClose: Closes the printer resource file. This call is issued once, at the end of all printing activity. (Chapter 10)

PrintDefault: Fills a printer record with default information stored in the printer resource file. (Chapter 10)

PrStlDialog: Displays the standard Style dialog box, allows the user to make selections within the dialog box, and fills the printer record with that information. Data from the dialog box is also stored in the printer resource file. (Chapter 10)

PrJobDialog: Displays the standard Job dialog box, allows the user to make selections within the dialog box, and fills the printer record with that information. Data from the dialog box is also stored in the printer resource file. (Chapter 10)

PrOpenDoc: Opens a printing port and makes it the current grafport. This routine is called once before beginning to print a document. (Chapter 10)

PrCloseDoc: Closes a printing port. If draft printing, it issues a form feed to the printer. If spool printing, it closes the spool file. This routine is called once at the end of printing a single document. (Chapter 10)

PrOpenPage: Opens a single page for printing. This routine is called before printing one page. (Chapter 10)

PrClosePage: Closes a single page. If draft printing, the routine issues a form feed to the printer. If printing with single sheets, it prompts the user to insert another sheet of paper. (Chapter 10)

PrPicFile: Images and prints a spool file. (Chapter 10)

14. MANAGING COORDINATES

GlobalToLocal: Translates a set of global screen coordinates into coordinates in the local coordinate system of the current grafport. (Chapter 8)

LocalToGlobal: Translates a set of coordinates expressed in the local coordinate system of the current grafport into global screen coordinates. (Chapter 9)

15. DRAWING

MoveTo: Moves the pen in the current grafport. If the application is printing, this routine affects the print head. (Chapter 10)

DrawChar: Draws a single character on the screen at the current pen position. (Chapter 6)

DrawString: Draws a string of characters, beginning at the current pen position and moving to the right. This routine does no text formatting. (Chapter 10)

DrawText: Draws a block of text that is stored in main memory, beginning at the current pen position and moving to the right. This routine does no text formatting. (Chapter 10)

TextBox: Draws a line of static text in a window. Though the text can be justified in its boundary rectangle, it is not stored in a text edit record and therefore cannot be edited. (Chapter 9)

16. MOVING TEXT

BlockMove: Moves a block of text stored in main memory to another main memory location. (Chapter 6)

17. STRING COMPARISON

IUMagString: Compares two strings of ASCII characters and returns a 0 if the two strings are equal, a −1 if the first string is less than the second and a +1 if the first string is greater than the second. (Chapter 6)

18. FONT CHARACTERISTICS

TextFont: Sets the text font. (Chapter 9)

TextFace: Sets the text style (e.g., boldface, underlined, etc.). (Chapter 9)

TextSize: Sets the size of the current text font. (Chapter 9)

GetFontInfo: Returns information about the current font in the current grafport. (Chapter 10)

19. FILE PROCESSING

Create: Creates a new disk file. This routine does not open a file. (Chapter 11)

GetFileInfo: Retrieves information stored by the Finder about a specific file. This routine is always called immediately after creating a file. (Chapter 11)

SetFileInfo: Sets information about a file for the Finder. The routine is generally called during the file creation sequence, immediately after **GetFileInfo**. (Chapter 11)

Write: Writes data from a data buffer in RAM onto a disk file. (Chapter 11)

Read: Reads data from a disk file into a data buffer in RAM. (Chapter 11)

Close: Closes a file. (Chapter 11)

SFGetFile: Displays the standard "get file" dialog box and allows the user to choose between the files listed. The user can also change disks and drives. The entire process is handled by this routine until the user selects "OK" or "Cancel". (Chapter 11)

SFPutFile: Displays the standard "save as" dialog box and allows the user to enter a file name. The user can also change disks and drives. The entire process is handled by this routine until the user selected "OK" or Cancel." (Chapter 11)

FlushFile: Forces the contents of the access path buffer to be written to disk. (Chapter 11)

20. ARITHMETIC

(All routines can be found in Chapter 12)

20.a Integer Binary/Decimal Conversions

NumToString: Converts an integer or longinteger into a string of ASCII characters.

StringToNum: Converts a string of ASCII characters in an integer or longinteger.

20.b Floating Point

The names of the FP68K and ELEMS68K routines are presented below as the macros defined for them in SANEMacs.Txt.

20.b.1 Addition (A := A + B)

FADDX: Add an extended source operand to an extended destination operand.

FADDD: Add a double precision source operand to an extended destination operand.

FADDS: Add a single precision source operand to an extended destination operand.

FADDC: Add a 64-bit (computational) integer source operand to an extended destination operand.

FADDI: Add an integer source operand to an extended destination operand.

FADDL: Add a longinteger source operand to an extended destination operand.

20.b.2 Subtraction (A := A – B)

FSUBX: Subtract an extended source operand from an extended destination operand.

FSUBD: Subtract a double precision source operand from an extended destination operand.

FSUBS: Subtract a single precision source operand from an extended destination operand.

FSUBC: Subtract a 64-bit integer source operand from an extended destination operand.

FSUBI: Subtract an integer source operand from an extended destination operand.

FSUBL: Subtract a longinteger source operand from an extended destination operand.

20.b.3 Multiplication (A := A * B)

FMULX: Multiply an extended source operand by an extended destination operand.

FMULD: Multiply a double precision source operand by an extended destination operand.

FMULS: Multiply a single precision source operand by an extended destination operand.

FMULC: Multiply a 64-bit integer source operand by an extended destination operand.

FMULI: Multiply an integer source operand by an extended destination operand.

FMULL: Multiply a longinteger source operand by an extended destination operand.

20.b.4 Division (A := A / B)

FDIVX: Divide an extended destination operand by an extended source operand.

FDIVD: Divide an extended destination operand by a double precision source operand.

FDIVS: Divide an extended destination operand by a single precision source operand.

FDIVC: Divide an extended destination operand by a 64-bit integer source operand.

FDIVI: Divide an extended destination operand by an integer source operand.

FDIVL: Divide an extended destination operand by a longinteger source operand.

20.b.5 Remainder (A := A mod B)

FREMX: Find the remainder of the division of an extended destination operand by an extended source operand.

FREMD: Find the remainder of the division of an extended destination operand by a double precision source operand.

FREMS: Find the remainder of the division of an extended destination operand by a single precision source operand.

FREMC: Find the remander of the division of an extended destination operand by a 64-bit integer source operand.

FREMI: Find the remainder of the division of an extended destination operand by an integer source operand.

FREML: Find the remainder of the division of an extended destination operand by a longinteger source operand.

20.b.6 Rounding

FRINTX: Round an extended operand to an integer.

FTINTX: Truncate an extended operand to an integer.

20.b.7 Arithmetic functions

FSQRTX: Find the square root of an extended operand. (A := sqrt(A))

FLOGBX: Find the base 10 logarithm of an extended operand. ($A := \log_{10}A$)

FSCALBX: Multiply an extended destination operand by 2 raised to an integer power. ($A := A * 2^B$)

FCPYSGNX: Replace an extended operand with the sign of the operand. (A: = sign of A)

FNEGX: Negate an extended operand ($A := -A$)

FABSX: Take the absolute value of an extended operand. ($A := |A|$)

20.b.8 Internal type conversion and arithmetic assignment (A := B)

FX2X: Move an extended source operand to an extended destination operand.

FD2X: Move a double precision source operand to an extended destination operand.

FS2X: Move a single precision source operand to an extended destination operand.

FI2X: Move an integer source operand to an extended destination operand.

FL2X: Move a longinteger source operand to an extended destination operand.

FC2X: Move a 64-bit integer source operand to an extended destination operand.

FX2D: Move an extended source operand to a double precision destination operand.

FX2S: Move an extended source operand to a single precision destination operand.

FX2I: Move an extended source operand to an integer destination operand.

FX2L: Move an extended source operand to a longinteger destination operand.

FX2C: Move an extended source operand to a 64-bit integer destination operand.

20.b.9 Binary to decimal conversions (A := B)

FX2DEC: Convert an extended operand to the canonical decimal format.

FD2DEC: Convert a double precision operand to the canonical decimal format.

FS2DEC: Convert a single precision operand to the canonical decimal format.

FC2DEC: Convert a 64-bit integer operand to the canonical decimal format.

FI2DEC: Convert an integer operand to the canonical decimal format.

FL2DEC: Convert a longinteger operand to the canonical decimal format.

20.b.10 Decimal to binary conversions (A := B)

FDEC2X: Convert from the canonical decimal format to an extended operand.

FDEC2D: Convert from the canonical decimal format to a double precision operand.

FDEC2S: Convert from the canonical decimal format to a single precision operand.

FDEC2C: Convert from the canonical decimal format to a 64-bit integer operand.

FDEC2I: Convert from the canonical decimal format to an integer operand.

FDEC2L: Convert from the canonical decimal format to a longinteger operand.

20.b.11 Comparisons (use in place of CMP)

FCMPX and **FCPXX:** Compare two extended operands and set the condition codes.

FCMPD and **FCPXD:** Compare an extended operand with a double precision operand and set the condition codes.

FCMPS and **FCPXS:** Compare an extended operand with a single precision operand and set the condition codes.

FCMPC and **FCPXC:** Compare an extended operand with a 64-bit integer operand and set the condition codes.

FCMPI and **FCPXI:** Compare an extended operand with an integer operand and set the condition codes.

FCMPL and **FCPXL:** Compare an extended operand with a longinteger operand and set the condition codes.

20.b.12 Branch on condition codes (use in place of Bcc instructions)

FBEQ and **FBEQS:** Branch if equal.

FBLT and **FBLTS:** Branch if less than.

FBLE and **FBLES:** Branch if less than or equal.

FBGT and **FBGTS:** Branch if greater than.

FBGE and **FBGES:** Branch if greater than or equal.

FBNE and **FBNES:** Branch if not equal.

20.b.13 Elementary functions

FLNX: Find the natural logarithm of an extended operand. (A := lnA)

FLOG2X: Find the base 2 logarithm of an extended operand. (A := $\log_2$A)

FLN1X: Find the natural logarithm of an extended operand plus 1. (A := ln (1 + A))

FLOG21X: Find the base 2 logarithm of an extended operand plus 1. (A := $\log_2$ (1 + A))

FEXPX: Raise **e** to an extended operand power. (A := e^A)

FEXP2X: Raise 2 to an extended operand power. (A := 2^A)

FEXP1X: Raise **e** to an extended operand power and subtract 1. (A := $e^A - 1$)

FEXP21X: Raise 2 to an extended operand power and subtract 1. (A := $2^A - 1$)

FXPWRI: Raise an extended operand to an integer operand power. (A := A^B)

FXPWRY: Raise an extended operand to an extended operand power. (A := A^B)

FCOMPOUND: Use extended operands to compute compound interest. (A := (1 + Rate) $^{\#Periods}$)

FANNUITY: Use extended operands to compute an annuity. (A := (1 − (1 + Rate)$^{-\#Periods}$)/ Rate)

FSINX: Find the sine of an extended operand. (A := sin(A))

FCOSX: Find the cosine of an extended operand. (A := cosine(A))

FTANX: Find the tangent of an extended operand. (A := tan(A))

FATANX: Find the arctangent of an extended operand. (A := atan(A))

FRANDX: Find the next random number, using an extended operand as a seed. (A := rand(A))

APPENDIX C

GLOSSARY

Absolute Address: A main memory address specified by its numeric address. For example, $001A is an absolute address. While an application can only work from absolute addresses, programmers can use symbolic addresses in their source code, leaving the translation to absolute addresses to the assembler and linker.

Access path: A data structure describing how the Macintosh should find a disk file. An access path is created every time a file is opened. The Macintosh will support 12 access paths at any one time, though only one access path per file can be open for writing.

Access path buffer: A RAM buffer that is used as temporary storage by the access path.

Active window: The front-most window on the screen. An application can only work in an active window. Active windows are highlighted in some way.

Address: The location of a byte in a computer's main memory. The bytes in a computer's main memory are numbered sequentially beginning with 0. Each byte therefore has a unique number known as its address.

Address register: A general purpose register within the Macintosh's microprocessor. The Macintosh has eight address registers, though some are used by the system for special purposes. A5 holds the start of the applications globals area; A7 is used as the stack pointer.

Addressing mode: A method for specifying the main memory address of a piece of data. The Macintosh has 13 addressing modes.

Alert: A Macintosh window that is displayed to warn the user that continuation of a particular action could cause damage or that some error has already occurred. Alerts contain text, icons, and buttons to either continue or cancel the action.

Applications globals area: A portion of RAM used for an application's data storage. The size of the application globals area is not fixed. Rather, it is set during the linking process so that only the exact amount of space the program requires will be allocated at run-time. Assembly language programmers should allocate space for all read/write data in the applications globals area.

Application heap: The portion of RAM available to an application program and its constants. Though it is possible to place read/write data storage in the application heap, it is better to avoid doing so whenever possible. (Interactions with the Printing Manager may cause exceptions to this rule.)

ASCII: The American Standard Code for Information Interchange. ASCII is a binary coding scheme that is used to represent characters within a computer. Standard ASCII requires 7 bits to represent the full range of alphanumeric characters. The Macintosh generates extra characters by using 8 bits.

Assembler: A program that translates a programmer's assembly language source code into machine language.

Assembler directive: An instruction in an assembly language source program that gives directions to the assembler. Assembler directives control the assembly process; they do not become a part of the object code.

Assembly language: A programming language that uses mnemonic codes to substitute for the machine language version of a computer's instruction set.

Asynchronous file operations: File operations that permit the application to continue with other activities while the file operation is in progress.

Band: A strip from a printed page. Since it takes a great deal of memory to image and print a spooled print file, each page is broken up into bands which can then be printed separately. Bands may run horizontally or vertically across the page, depending on the orientation of the printed page.

Binary: The base 2 numbering system used to represent quantities, instructions, and characters in a computer.

Bit: A contraction of "binary digit." A bit represents one binary place in a code or quantity. It can take only two values — 0 or 1.

Boot (a computer): To start the computer, either by turning on the power or pressing the Reset switch. It is also possible to reboot the Macintosh by issuing a RB (reboot) command to a debugger.

Boundary rectangle: A set of four coordinates that describe the top left and bottom right corners of a rectangle. The coordinates may be expressed in terms of the screen's global coordinate system or in terms of the local coordinate system of a specific window, depending on the situation. For example, window definitions require global coordinates, but control definitions require the local coordinates of the window in which the controls will appear.

Buffer: A temporary holding area for data. Buffers are generally used to reconcile the speed differences between slow I/O devices and the much faster CPU. For input, for example, a disk drive fills a main memory buffer at its own speed. The CPU can be doing other things while the disk is working. When the buffer is full, the CPU empties it at electronic speeds.

Bus: An electronic pathway that connects the parts of a computer. Buses carry data, addresses, and control signals between the CPU, main memory, and peripheral devices such as disk drives and printers.

Byte: Eight bits viewed as a whole.

Canonical decimal format: An intermediate numeric format used by the Macintosh. It is produced by scanning an ASCII string of characters. Numbers expressed in the canonical decimal format can then be converted into a variety of binary numbers which can be used in mathematical operations.

Clear: 1) Give a bit or a group of bits a value of 0-2) a text editing operation that deletes the contents of the current selection range from the document without affecting the clipboard.

Clipboard: A temporary storage area used by text editing routines to hold text from cut operations. Cut takes the contents of the current selection range and places it on the clipboard, deleting it from the document and erasing the previous contents of the clipboard. Copy also places the current selection range on the clipboard, but does not delete it from the document. Paste takes the contents of the clipboard and inserts it into the document at the current insertion point; the contents of the clipboard are not disturbed.

Compiled language: A programming language (usually a high-level language) that is translated to object code prior to run-time. Compiler output is a machine language file which generally must be linked to run-time libraries before execution.

Condition codes: see **Status register**.

Conditional branch: An assembly language instruction that checks one or more flags in the status register and executes a branch if the condition specified by the particular instruction is true. If the condition is false, program execution continues with the next sequential instruction. 68000 conditional branch instructions have the general form **Bcc**, where the **cc** is replaced with two letters that represent the condition to be tested.

Control: A graphic device that helps to regulate program function. Controls include scroll bars, push buttons, radio button, and check boxes.

Copy: A text editing operation that takes the contents of the current selection range and writes it to the clipboard. The document itself is unaffected.

CPU (central processing unit): The brain of a computer. The CPU is the site of instruction decoding and execution. When the CPU is placed on a single silicon chip, it is referred to as a microprocessor.

Creator: The type of application that created a file. A file's creator is a four-character string stored with the file itself. Unless a file type is explicitly set, an application created by the MDS will have a file type of APPL. The creator for all files created by such an an application will therefore be APPL.

Cursor: In general, some character on a computer screen (e.g., a blinking line, underbar, or box) that indicates where the next input will appear. On the Macintosh, the cursor is attached to the mouse. Moving the mouse moves the cursor. Macintosh cursors take a variety of shapes, including an arrow, an I-beam, and a wrist watch.

Cut: A text editing operation that takes the contents of the current selection range and copies it to the clipboard, at the same time deleting it from the document.

Data fork: The part of a Macintosh file that contains data.

Data register: A general purpose register within the Macintosh's microprocessor. The Macintosh has eight data registers.

Debugger: A program designed to aid a programmer in identifying logic errors within an assembly language program. A debugger permits step-by-step program execution, displays the contents of the CPU's registers, disassembles instructions, etc.

Decrement: To decrease by some fixed quantity. If the quantity is not specified, it is assumed to be 1.

Dialog box: A Macintosh window used to collect information from the user or to freeze program action until the user is ready to continue.

Direct access: A method of file processing. Files created for direct access have fixed field lengths, allowing an application to go directly to any record at any time, regardless of the location of the record most recently read or written. Records can be processed in random order.

Direct cursor addressing: Having the capability of moving the cursor anywhere on the screen or printed page at any time, regardless of the cursor's previous position.

Drag region: The title bar of a window except the GoAway box. It is used to move a window around the Macintosh screen.

Edit text: Text that can be edited using any of the Macintosh's editing routines: cut, copy, paste, or clear.

Effective address: The main memory location of an operand for an assembly language instruction. Effective addresses are specified by using one of the Macintosh's 13 addressing modes.

Equates file: A text file that contains a set of **EQU** statements. Each **EQU** associates a symbolic address with a constant that is useful in Macintosh programming.

Event: A system activity that the Macintosh can recognize. Events include pressing and releasing the mouse button, pressing and releasing keys, inserting disks, etc.

Event mask: A word whose bits can be selectively set to control which types of events are retrieved from the event queue.

Event queue: An ordered list of events as they occur. The event queue is maintained by the operating system in first in, first out order. In other words, the first event posted to the event queue will be the first event processed.

Excess notation: A method of storing floating point exponents. An excess value is selected so that when added to the smallest possible exponent, it will raise that exponent value to 0. All exponents are then stored with the excess value added to them. All exponents can therefore be kept as positive integers without having to resort to 2's complement representation.

Exponent: The power to which some base number is raised. For example, in the expression 10^{497}, 10 is the base number and 497 is the exponent.

Fixed point number: A number that includes a decimal point (or binary point if the number is in base 2) that does not move. For example, 3.44 is a fixed point number.

Floating point number: A number expressed as a mantissa multiplied by a base raised to some power. For example, 3.333 * 10^{99} is a floating point number. Because the exponent can change, the decimal point (or binary point, if the base is 2) is said to "float."

Fork: Part of a Macintosh file. Macintosh file's have two forks — a data fork for storing data and a resource fork for storing resources and program code.

GoAway box: A box that appears at the left of a title bar. Clicking the arrow cursor in the GoAway box will close the window.

Grafport: A contraction of "graphics port." A graphics port is a rectangle in which the Macintosh can draw. Grafports form the basis for Macintosh windows.

Hexadecimal: The base 16 numbering system. Since four binary digits can be represented by a single hexadecimal digit, hexadecimal is often used as a shorthand for binary.

High-level language: A programming language that looks very much like English. BASIC, Pascal, FORTRAN, PL/1, and COBOL are all high-level languages.

Highlighting: Changing the standard coloration of something on the Macintosh screen to draw attention to it in some way. For example, text editing selection ranges are highlighted by displaying them as white characters on a black background.

High-order: The upper-half of a group of bits. For example, in a word where the bits are numbered 0 through 15, bits 7 through 15 are the high-order byte. In a longword where the bits are numbered 0 through 31, bits 16 through 31 are the high-order word.

Hung: A state in which the computer appears to sit still and do nothing. Many things can cause a computer to hang, but most often it is some sort of infinite loop.

I/O Buffer: see **Buffer**

Icon: A small picture that the Macintosh uses to represent an object or program function.

Increment: To increase by some fixed quantity. If the quantity is not specified, it is assumed to be 1.

Insertion point: The place in a document where new characters and/or graphic images are inserted.

Instruction: A single command that a computer can understand and execute.

Instruction set: All the commands that a computer can understand and execute. Each type of microprocessor has its own unique instruction set.

Interpreted language: A programming language (usually a high-level language) that is translated to machine language while the program is being run. No permanent object code is ever generated. Statements that are executed repeatedly are translated each time they are executed.

Interrupt: A signal generated by a peripheral device such as a disk drive and sent to the CPU. The interrupt tells the CPU that the device is in need of attention. The CPU will stop whatever it is doing to take care of the device.

Keyboard equivalents: The pairing of the cloverleaf key with any other printing key on the keyboard as a substitute for using the mouse to make a selection from a pull-down menu.

Launch: To run a Macintosh application.

Least significant digit: In an integer, the digit in the one's place. When a number contains a factional portion, the least significant digit is the right-most non-zero digit.

Linker: A program that pulls together the various parts of an application to create an executable application. The Linker also completes the process of setting the size of the applications globals area.

Longword: On the Macintosh, a group of 32 bits.

Low-order: The lower-half of a group of bits. For example, in a word where the bits are numbered 0 through 15, bits 0 through 7 are the low-order byte. In a longword where the bits are numbered 0 through 31, bits 0 through 15 are the low-order word.

Machine language: A computer can only understand instructions that are written in machine language. Machine language consists of a sequence of binary codes. Since it is so very difficult for humans to write programs that are

comprised of nothing but a series of 0's and 1's, most programs are written in either assembly language or a high-level language. The programs must then be translated into machine language before they can be executed by a computer.

Macro: A short block of code defined within a program and given a name. The name of the macro is then used in the source program instead of the macro code. During assembly, the macro code is inserted everywhere the name of the macro appears.

Mantissa: The significant digits of a floating point number. The first digit of a mantissa will always be non-zero. For example, in the floating point number $3.9746123 * 10^{73}$, 3.9746123 constitutes the mantissa. The number, therefore, has eight significant digits.

Mark: A pointer in a Macintosh file that indicates the position of the next byte to be read from or written to.

Menu: A list of options from which a user can select. Macintosh menus descend, or "pull-down", from the menu bar.

Menu bar: The top line on the Macintosh screen. It contains the names of all menus currently available to the user. The left-most menu is the Apple menu which supports the standard desk accessories. Directly to its right will be found the File and Edit menus.

Menu list: A list maintained by the Macintosh that contains all menus that are displayed in the menu bar. Menus are displayed in their order in the list. An application can control which menus appear in the menu bar by inserting and deleting menus from the menu list.

Microcomputer: Commonly, a computer small enough to fit on a desk top. A microcomputer must have a microprocessor, RAM, enough ROM to boot the machine, buses for data and address transfer, a clock, and some provision for I/O.

Microprocessor: A CPU (central processing unit) contained on a single chip. The microprocessor is the place where instructions are decoded and executed. It is often called the "brain" of the computer.

Mnemonic: A group of two to five letters that stand for a machine language instruction. The collection of letters has some relationship to the name of the instruction. For example, **JSR** stands for Jump to Subroutine.

Modal dialog box: A dialog box that restricts the user to working within the box while the box is present on the screen, such as the dialog boxes that appear when a user selects Print from a File menu.

Modeless dialog box: A dialog box that permits the user to work outside the dialog box while the box is present on the screen. An example is the dialog box that appears when a user selects Find from a Search menu.

Most significant digit: The left-most non-zero digit in a number.

Object code: The machine language version of an assembly or high-level language program.

Octal: The base 8 numbering system. Since three binary digits can be represented by one octal digit, octal can be used as a shorthand for binary. It is less commonly used than hexadecimal.

Op code: A binary code that represents an assembly language instruction.

Operand: A piece of data required by an assembly language instruction.

Operating system: A program that controls the operation of the computer. Generally, operating systems for single-user microcomputers provide the means to boot the computer, execute programs, and manage files (delete, re-name, etc.).

Parameter: A piece of data used as input to or output from a Pascal subprogram.

Parse: To break a sentence down into its constituent parts. In computers, parsing generally refers to analyzing a program statement to determine its elements. It also refers to scanning and breaking down a string of ASCII characters so they can be transformed into some other format (i.e., the canonical decimal format).

Path reference number: A quantity that identifies an access path to a file.

Paste: A text editing operating that takes the contents of the clipboard and inserts it into a document at the current selection point. The contents of the clipboard are unaffected.

Patch: To modify existing program code by changing a small portion of it. Patching usually refers to making modifications to the binary (machine language) version of a program.

Pixel: Short for "picture element." A pixel is one dot on the Macintosh's screen.

Program counter: A 32-bit register in the Macintosh's microprocessor. The program counter always holds the main memory address of the next program instruction to be executed.

Prompt: A piece of static text that tells the user what data should be entered.

RAM (random access memory): A computer's main memory. An application can both read from and write to RAM. RAM is volatile — when electrical power is removed its contents are lost.

Region: An area within a grafport that can be bounded by a rectangle but is not necessarily rectangular in shape.

Register: A special storage location within a microprocessor. The Macintosh's general purpose registers are 32 bits wide; each can hold a longword.

Relocatable code: A block of object code that is independent of any fixed main memory location. Relocatable programs can theoretically be run regardless of where they are loaded into memory. The MDS Assembler creates a relocatable object code module which is then tied to a specific place in memory by the Linker.

Resource: An entity used by the Macintosh. In some instances, the Macintosh views the code of an application as a single resource; but more generally, the term refers to something much smaller, such as a window, a menu, an icon, a desk accessory, etc.

Resource file: A file that contains definitions and templates for resources. Resource files are created with a text editor and then translated to machine language by the resource compiler, RMaker.

Resource fork: The part of a Macintosh file that stores resource definitions and program code.

Resource template: An entry in a resource file that contains the parameters that describe a particular resource. The resource type must already have been defined. For example, the resource type WIND is pre-defined to describe a window. A resource file therefore contains only a window template — the data necessary to generate a window.

ROM (read only memory): A type of computer memory from which an application can only read. ROM cannot be modified and is non-volatile — it retains its contents when electrical power is removed.

Run-time library: A set of standard programs, usually handling I/O, that are used by compiled programs. The object code produced by compiler cannot be executed without first being linked to one or more run-time libraries.

Scroll: To move text or graphics so that a different portion of a large document appears in a window on the Macintosh screen.

Selection range: A group of contiguous characters in a block that will be affected

by editing operations such as cut, copy, and paste. The selection range is highlighted by displaying white characters on a black background.

Sequential access: A method of file processing. Files created for sequential access have either variable or fixed record lengths. The records are processed in order, generally beginning at the start of the file. Sequential processing proceeds either to the "next" or "prior" record; it is not possible to move randomly through the file.

Set: Give a bit or group of bits a value of 1.

Significant digits: The part of a number that conveys value rather than magnitude. For example, in the number 0.00009994, the significant digits are 9994. The leading zeros contribute only to the magnitude of the number, not to its exact value. The first significant digit in a number is most often the first non-zero digit from the left. Generally, the more significant digits retained in a number, the greater the accuracy of that number.

Source code: The version of a program created by a programmer, regardless of the language in which it is written. Source code must be translated to object code (machine language) before it can be executed.

Spooling: In general, using some form of auxiliary storage (usually a disk) as intermediate storage for an I/O operation. In particular, the Macintosh uses spooling for printing. An image of a printed document is stored on disk to be printed at a later time.

Stack: A special area in RAM used for temporary storage. The Macintosh's stack is 32 bits wide. Longwords are placed on top of one another on the stack; access is in last in, first out order. Many of the Macintosh's built-in routines take their parameters from the stack.

Stack pointer: A register that contains the address of the top of the stack (the address of the last longword placed on the stack). The Macintosh uses register A7 for that purpose.

Static text: Text that is for display purposes only. It cannot be edited.

Status register: A 16-bit register within the Macintosh's microprocessor. The bits in a status register function independently as flags to signal a variety of conditions within the computer. The flags in the status register are also referred to as "condition codes".

Symbolic address: In an assembly language program, a group of characters used in place of an absolute main memory address. Symbolic addresses can be attached to program instructions, constants, and storage locations. The

assembly and linking process translates the symbolic addresses into absolute addresses.

Synchronous file operations: File operations that force the application to wait for the file operation to finish before proceeding.

System byte: The high-order byte of the Macintosh's status register. Bits 8 through 15 of the status register are used only by the operating system and are not referenced by application programs.

System Dispatch Table: An array in RAM that contains the actual location of ToolBox and Operating System routines. When the Macintosh traps calls to those routines, it translates them into references to the System Dispatch Table where the address is found. The Table is kept in ROM but loaded into RAM at system start-up. Because the Table is in RAM when the system is running, it can be patched to install custom routines.

Title bar: The top of a window. The window's title is centered in the title bar. An optional GoAway box may appear at the very left.

ToolBox: A collection of programs supplied with the Macintosh that support graphics and the features of the Macintosh user interface. Most of the ToolBox is in ROM.

Trap: A function of the Macintosh operating system that catches ("traps") binary instruction codes that are not a part of the standard 68000 instruction set. The Macintosh uses the trap mechanism to extend the Macintosh's instruction set by adding instructions which call the ToolBox and operating system routines.

True magnitude form: A representation of an integer quantity where the binary value stored in the computer is the same as the actual value of the number.

Two's complement: The number which, when added to a binary number, will produce a result of 2.

Two's complement form: A representation of an integer quantity where the binary value stored in the computer is the two's complement of the actual value of the number.

Two's complement system: A method for representing integer quantities within a computer. Negative numbers are stored in their two's complement form; positive numbers are not converted but are left in their true magnitude form.

Unconditional branch: An assembly language instruction that executes a branch under all circumstances. No condition codes are checked. The 68000 has two unconditional branch instructions — **BRA** and **JMP**.

User byte: The low-order byte of the Macintosh's status register. An application often consults the bits in the user byte to determine the result of a particular program instruction.

Value parameter: A parameter that is used only as input to a Pascal program. Even the value of the parameter is changed in the subprogram, it will nonetheless retain its original value as far as the main program is concerned.

Variable parameter: A parameter that can be used for both input to and output from a Pascal subprogram. Any data that are to be returned to a main program must be declared as variable parameters. The only exception to this rule is for the results of functions, which in Pascal are returned across an assignment operator. Assembly language function results are either returned on the stack or in a data register.

Volume: Either a single floppy disk or a partition on a hard disk.

Window: A rectangle on the Macintosh screen. Windows are used to display text and graphics, to collect data essential to program function, and to warn the user about the consequences of specific actions. Virtually all user interaction with an application takes place within windows.

Word: On the Macintosh, a group of 16 bits. Word size does vary from computer to computer.

A P P E N D I X D

MATERIALS FOR FURTHER REFERENCE

To learn more about microcomputers and how they work:

Tocci, Ronald J. and Laskowski, Lester P. *Microprocessors and microcomputers: Hardware and Software*. 2nd ed. Prentice-Hall, 1982.

To learn more about the 68000 microprocessor and how to program it:

M68000 16/32-bit Microprocessor Programmer's Reference Manual. 4th ed. Prentice-Hall, 1984.

Kane, Gerry, Doug Hawkins and Lance Leventhal. *68000 Assembly Language Programming*. Osborne/Mc-Graw-Hill, 1981.

To learn more about the Macintosh ToolBox and operating system routines:

Inside Macintosh. Apple Computer, 1985.

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