Programming the
Macintosh
in Assembly Language
Programming the Macintosh in Assembly Language

Steve Williams
To Jim and Sylvia Williams
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Pacific Grove, California
Labor Day, 1985
INTRODUCTION

_Ideas control the world._

—James A. Garfield

This book is a “how-to” book; its goal is to teach you how to write assembly language programs for the Apple Macintosh computer. To do this, there are three areas of information you have to learn about:

1. Assembly language programming
2. Programming for the 68000 chip inside the Macintosh
3. The Macintosh Development System software

Because this is rather a large amount of material to cover in a single volume, I decided to provide standardized software that you can use in the early phases of learning to program. In this way you can learn a small part of the system without having to learn all of the mechanics necessary for writing a complete program. You can therefore write rather substantial programs without knowing how Macintosh applications manage windows, files, and other parts of the system. By the end of the book you will understand how the supplied software works, and you can then modify or rewrite it to suit your needs.

One of the most valuable aspects of this book is the example software, which includes listings for most common Macintosh functions. These listings provide a supplement to _Inside Macintosh_. The Apple documentation gives you a lot of detailed information about each system call, but it gives you little information on how to combine these calls to produce an application. I have tried to fill this gap.

Depending on your experience with assembly language programming and the 68000 chip, you may choose to direct your attention to specific chapters. Chapter 1 covers the basic computer hardware and software concepts, and describes how assembly language programs relate to their hardware environment. It provides common definitions for the terms that will be used throughout the book.

If you have prior assembly language experience but have never used the Motorola 68000, start with Chapter 2, which covers 68000 architecture. Chapter 3 continues this discussion by detailing first the instruction
classes, then the mechanics of developing a program, and finally the 68000 instruction set.

If you have prior experience with 68000 assembly language programming, read the section titled “Program Development Mechanics” in Chapter 3. This section describes how to use the Macintosh Development System software. Then go on to Chapter 4, which deals with elementary Macintosh programs, including terminal and file I/O operations.

Chapters 5 and 6 are more advanced. Chapter 5 covers advanced programming concepts required to write major applications, and Chapter 6 covers the differences between the Macintosh and conventional programming environments. Chapter 6 also includes a sample Macintosh application.

Chapter 7 describes the exception feature of the 68000 microprocessor and how it relates to the Macintosh. This information is necessary when you are writing programs that interact directly with the Macintosh hardware.

Chapter 8 describes the software used by the programs in this book to simplify writing Macintosh programs. It also contains helpful hints on how to reconfigure this software to add or remove features.

To obtain a disk containing the source files for all the programs in this book, send $19.95 plus $2.50 postage and handling in check or money order to this address:

MacDoodle Source Disk
P.O. Box 3262
Monterey, CA 93940

California residents add 6 percent sales tax. Make the check payable to MacDoodle Source Disk. Please allow 6–8 weeks for delivery.
Basic Concepts

The journey of a thousand miles begins with a single step.
—Lao Tzu

WHAT IS PROGRAMMING?

Machine-level computer programming has been called art, engineering, sorcery, and religion. It is all of these and more. Dealing with a computer at its own level can be a very rewarding (and frustrating) experience.

This book will introduce you to the joys and woes of this wondrous craft, using the Apple Macintosh as a vehicle. We have attempted to minimize the mathematics involved; anyone who can add, subtract, multiply, and divide can make full use of all the material presented here.

This chapter will introduce you to the concepts on which modern computing is founded: algorithms, elementary hardware operations, and the binary and hexadecimal number schemes.

As a start toward learning how to program, consider the process of starting an automobile engine:

1. Insert the key into the lock.
2. Turn the key past the ON position to the START position and hold.
3. If the motor does not crank, stop.
4. If the motor does catch, proceed to step 5. If the motor does not catch within 30 seconds, turn the key OFF and go to step 2.
5. Release the key back to the ON position, and stop.
This simple procedure has all of the same elements of a computer program:

- Step 1 is called an *initialization*. This is an action which is performed once at the start of a program.

- Steps 2 through 4 form a *loop*—a series of actions which is repeated until some condition is satisfied. (In this case, either the car starts or the battery expires.)

- Step 3 is an example of an *error condition*—some condition which causes the procedure to terminate in an abnormal fashion.

- Step 5 is the successful completion of the procedure.

**Algorithms**

The above procedure, in computer terminology, is called an *algorithm*. Algorithms are stepwise procedures which can be used to define the steps in programs. Any step-by-step description is an algorithm. Some examples from everyday life are kitchen recipes and directions for getting from one place to another.

You can see from these examples that not all algorithms can be made into computer programs. Even if an algorithm is suitable for transforming into a program, it must first be put into a form the computer can recognize. Computers cannot utilize even the simplest English.

**Programming Languages**

If you want a computer to carry out the steps you define in an algorithm, you must first translate the English description into a language that the computer can execute. Such a language is called a *programming language*. There are many such languages. The task to be performed generally dictates which language is to be used. Some examples of programming languages are:

- **BASIC** (Beginner's All-purpose Symbolic Instruction Code). BASIC is a very simple language to learn and to use. It is generally used for short, simple programs.

- **COBOL** (COmmon Business Oriented Language). COBOL is commonly used for business related software, such as payroll and other accounting applications.
• FORTRAN (FORmula TRANslation). FORTRAN is widely used in the scientific community for applications involving large numbers of calculations.

• Pascal (Named for the French mathematician Blaise Pascal). Pascal is often used in universities to teach budding computer scientists how to program.

• Assembly Language. Assembly language is the process of programming a computer at the level of individual machine instructions. This book describes the process of assembly language programming for the 68000 computer.

• Machine Language. Machine language deals with programming a computer at the instruction level, without assistance from development software. Machine language involves using a numeric language: the binary codes directly usable by the computer. This type of programming is incredibly tedious, and is only used for very specialized applications.

**Flowcharts**

A visual method of representing an algorithm is called flowcharting. A flowchart is a series of boxes which are connected by lines to show the possible paths of the algorithm. Flowcharting, like algorithm description, is not done in a computer language.

Flowcharts consist of three basic symbols:

• a square box which indicates an action to be performed

• a diamond shaped box which indicates a decision

• lines which connect the two.

There is an ANSI (American National Standards Institute) standard for flowchart symbols and flowchart layout.

A flowchart for our car-starting algorithm is shown in Figure 1.1.

A flowchart segment should fit on a single page. A flowchart for a computer program will require partitioning into several pages, interconnected by boxes. These boxes typically contain a number, indicating the mating connector on another page. Partitioning a large program flowchart into single-page segments is quite an involved process. It could require so much time that the exercise is not justified.
Figure 1.1 - Flowchart for car-starting algorithm
**HOW DOES A COMPUTER WORK?**

In order to learn programming, one must first understand how computer hardware functions. Figure 1.2 is a block diagram showing the major portions of a typical computer.

The *memory* contains the program which the computer follows, as well as the data on which the computer operates. In this simplified model of a computer, the box labeled *central processing unit* (CPU) is the "brains" behind the computer. The connection between the CPU and the computer's memory is known as the *memory bus*. *Input/output* (I/O) devices are the machines through which the computer interacts with the outside world. Examples of I/O devices are *cathode ray tube* (CRT) terminals (the computer's "TV screen"), floppy disk drives, and printers. The connection between the CPU and the I/O devices is called the *input/output bus*. Let us now examine each of these areas in detail.

**Memory**

Computer memory is a series of numbered slots, called *locations*, each of which contains a number. The number of the location is called its...
address (like a street number). The number contained within the slot is called the memory data or memory contents. There are two operations associated with a computer memory:

- Change the contents of a location to a specific value. This operation is called a memory write or a memory store. The contents of the location before the write are lost.

- Obtain the present contents of a location. This operation is called a memory read or a memory fetch. A memory read does not alter the contents of the location—subsequent reads with no intervening writes will return the same value.

For example, suppose we have a four location memory with the following values:

<table>
<thead>
<tr>
<th>Address</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>21</td>
</tr>
<tr>
<td>1</td>
<td>27</td>
</tr>
<tr>
<td>2</td>
<td>19</td>
</tr>
<tr>
<td>3</td>
<td>100</td>
</tr>
</tbody>
</table>

Note that memory addresses are always numbered sequentially, starting with zero. If we read location 2, we will get the result 19. Writing a 6 into location 1 gives the following values:

<table>
<thead>
<tr>
<th>Address</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>21</td>
</tr>
<tr>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>2</td>
<td>19</td>
</tr>
<tr>
<td>3</td>
<td>100</td>
</tr>
</tbody>
</table>

Note that the memory write did not affect any other location. For example, reading location 2 again would again yield 19. Reading location 1 will yield 6. The original contents of location 1 (before the write) have been discarded, and may not be retrieved.
Input/Output Devices

Input/output devices connect the computer to the outside world. These devices typically fall into one of two categories:

1. Low-speed, character-oriented devices used to interact directly with people. Examples of this type of device are CRT terminals, printers, and plotters.

2. High-speed, block-oriented devices used for bulk storage of programs or data. Devices in this category, such as disks, tapes, etc., are usually magnetic.

Character-oriented devices typically interact with human operators. This type of device usually transfers one character at a time. The Macintosh Imagewriter printer is an example of such a device. Any other external device that connects to one of the two serial ports on the back of the Macintosh, such as the modem, or a CRT used for debugging, is also a character device.

Many computer CRT terminals send and receive characters at 960 characters per second. Although this seems amazingly fast to a human sitting at a terminal, to a computer (which can handle millions of operations per second), it is extremely slow. When interacting with humans, the computer spends a tremendous amount of time just waiting for characters from the terminal.

Block-oriented devices such as disks and tapes, on the other hand, do not normally interact with humans. These devices typically handle multi-character blocks at a time, with a short interval between characters within a block, but a comparatively long interval between blocks.

Central Processing Unit

The CPU is the heart of the computer. It executes the programs and manipulates the input/output devices.

The organization of a typical CPU is shown in Figure 1.3.

The boxes on the top of the diagram are called registers. A register is a single memory location within the CPU which is used to store a temporary result. Different CPUs use different numbers and types of registers. The 68000 register set will be explained in detail in Chapter 2.

The CPU registers, which can be accessed much faster than main memory, are temporary memory locations used to facilitate program execution. There are usually a limited number of these registers.
The memory address and memory data registers are used to access memory. For example, to read memory, the correct address is placed in the memory address register, and then the data can be read from the memory data register. To write to memory, the data is placed in the memory data register, and then the address is placed in the memory address register.

The program counter is a special register that is used to keep track of the next instruction to be executed. This process is detailed in the next section.

The *Arithmetic and Logic Unit* (ALU) performs all of the basic arithmetic operations, such as addition, subtraction, etc. The data on which the ALU operates can come from any of the registers with a path into the top of the ALU: the CPU registers, memory data, or the program counter. The result of the operation can be placed back into any of the registers.

Fortunately, programming the machine does not require attention to the inner operations of the ALU. The control unit supervises the movement of data through the ALU, and defines certain basic machine functions called *instructions*.

![Figure 1.3 - CPU block diagram](image)
Stored Program Execution

The process of executing a program works like this:

1. Fetch memory at the address indicated by the program counter, and increment the program counter to the next instruction in memory. The program counter is said to "point to" (i.e., contain the address of) the next instruction.
2. Perform the instruction.
3. Go back to step 1.

To illustrate how all this works together, we will now write a short program to add two numbers together. For simplicity, we will define a computer: Our simple computer has one register, named A. The machine can execute the following instructions:

<table>
<thead>
<tr>
<th>Instruction</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>1nnn</td>
<td>Copy memory location nnn into A</td>
</tr>
<tr>
<td>2nnn</td>
<td>Add memory location nnn to A</td>
</tr>
<tr>
<td>3nnn</td>
<td>Copy A into memory location nnn</td>
</tr>
<tr>
<td>4000</td>
<td>Stop</td>
</tr>
</tbody>
</table>

Now suppose that the computer memory contains the following:

<table>
<thead>
<tr>
<th>Location</th>
<th>Contents</th>
<th>Instructions</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>1104</td>
<td>Load location 104 into A</td>
</tr>
<tr>
<td>101</td>
<td>2105</td>
<td>Add location 105 to A</td>
</tr>
<tr>
<td>102</td>
<td>3106</td>
<td>Store A into location 106</td>
</tr>
<tr>
<td>103</td>
<td>4000</td>
<td>Stop</td>
</tr>
<tr>
<td>104</td>
<td>0300</td>
<td>(Data)</td>
</tr>
<tr>
<td>105</td>
<td>0400</td>
<td>(Data)</td>
</tr>
<tr>
<td>106</td>
<td>0000</td>
<td>(Data)</td>
</tr>
</tbody>
</table>

If we then set the program counter to 100 and cause the computer to execute, the program will execute as follows:

1. The contents of memory location 104 (300) will be copied into register A.
2. The contents of location 105 (400) will be added to register A. Register A will then contain 700.

3. Register A will then be copied to memory location 106. This operation is called “Storing register A.”

4. The machine will stop.

Upon completion of the above program, Register A and memory location 106 will have been altered to contain the value 700. This example is a program which adds two memory locations together and stores the result in a third memory location.

Programming at its most basic level is the process of putting the right instructions (also called operations or op codes) into the proper memory locations. The above program is an example of machine language programming, where the programmer deals with the actual numeric values of the instructions, and memory locations are assigned by hand. This is a tedious process at best, and programs called “assemblers” have been developed to handle the drudgery involved. Programming using an assembler is commonly called assembly language programming. The example program above, might look like this in assembly language:

```
LOAD A,X
ADD A,Y
STORE A,Z
STOP
X: DC 300
Y: DC 400
Z: DC 0
```

The words LOAD, ADD, STORE and STOP are called mnemonics. A mnemonic is a symbolic representation of a machine instruction. X, Y, and Z are called labels. A label is a way to tag a memory location without knowing what the final memory address will be. The assembler or another tool called the linker will make the final address assignment.

Finally, the abbreviation “DC” is an assembler directive. DC stands for “Define Constant.” This directive tells the assembler to place a constant in memory at the location where the DC directive occurs.

Why is assembly language better than machine language? First, it is far more readable. Second, the task of changing an existing program is much simpler. Suppose that we wish to change our example program to add a
third number, \( W \), to \( X \) and \( Y \). To add this to the assembly language version, we need add only two lines: an

\[
\text{ADD A,W}
\]

addition instruction, and a declaration for the new constant:

\[
\text{W: DC 50}
\]

To change the machine language version of the program, we must alter all of the instructions that reference memory, since the values to be added are now in a different place, as illustrated below:

<table>
<thead>
<tr>
<th>Location</th>
<th>Machine Language</th>
<th>Assembly Language</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>*1105</td>
<td>LOAD A,X</td>
</tr>
<tr>
<td>101</td>
<td>*2106</td>
<td>ADD A,Y</td>
</tr>
<tr>
<td>102</td>
<td>*2107 *</td>
<td>ADD A,W</td>
</tr>
<tr>
<td>103</td>
<td>*3108</td>
<td>STORE A,Z</td>
</tr>
<tr>
<td>104</td>
<td>4000</td>
<td>STOP</td>
</tr>
<tr>
<td>105</td>
<td>0300</td>
<td>X: DC 300</td>
</tr>
<tr>
<td>106</td>
<td>0400</td>
<td>Y: DC 400</td>
</tr>
<tr>
<td>107</td>
<td>*0050 *W: DC</td>
<td>50</td>
</tr>
<tr>
<td>108</td>
<td>0000</td>
<td>Z: DC 0</td>
</tr>
</tbody>
</table>

The asterisk character (*) shows lines that have been changed. Note that no machine language location contains the same value as it did in the previous example. In large programs, altering machine code is a tremendous chore.

**Data Representation**

The vast majority of computers represent numbers in a form involving only two possible values: ON and OFF. This is a property of the hardware used to implement the CPU, memory, and I/O devices. This two-value representation is called binary, or base 2.

**The Binary System**

The binary system represents a number as a string of two-valued quantities. Each such quantity is called a bit, which stands for Binary digiT. The
ON and OFF values for a bit are 1 and 0, respectively. A bit with a value of 1 is said to be set; a bit with a value of 0 is said to be clear.

Most computers in use today organize bits in groups of eight to form a quantity known as a byte. The bits in a byte are numbered from right to left, starting at zero. Each bit is assigned a value twice the value of its neighbor on the right. Bit 0, the rightmost bit, has the value 1. The values associated with the eight bits in a byte are shown in Table 1.1.

<table>
<thead>
<tr>
<th>Bit Number</th>
<th>Place Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>128</td>
</tr>
<tr>
<td>6</td>
<td>64</td>
</tr>
<tr>
<td>5</td>
<td>32</td>
</tr>
<tr>
<td>4</td>
<td>16</td>
</tr>
<tr>
<td>3</td>
<td>8</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 1.1 – Binary Bit Values

Using this table of binary values, the binary number 0010 1111 has the value of 47. This is how the value for our example would be calculated.

The decimal value of a binary number is equal to the bit number value times the place value, as shown in Figure 1.4.

The largest number that can be represented using eight bits is 1111 1111, which is decimal 255. It is the result of adding 128 + 64 + 32 + 16 + 8 + 4 + 2 + 1. For readability, we will write binary numbers as groups of four bits. In computerese, a four bit group, or one half of a byte, is called a nibble.

To represent numbers bigger than 255, two or more bytes are used. Common combinations are two bytes (16 bits), and four bytes (32 bits).
These quantities are called a *word* and a *longword*, respectively. Dealing with 16 and 32 digit numbers can be cumbersome, however, so an abbreviated form of binary representation called *hexadecimal* (or base 16) is often used.

**Hexadecimal Numbers**

In hexadecimal (hex) representation, a nibble is encoded as one hexadecimal digit.

These digits have values from 0 to 15. The values for 10 through 15 are represented by the letters A through F. Each digit in a hex number has a place value of sixteen times the value of its neighbor to the right. For instance, the number 22 hex is \((2 \times 16) + 2\), or 34.

**Converting Binary to Hex**

A hex number can be derived from a binary number by first grouping the binary number into groups of four bits (nibbles), and then computing

<table>
<thead>
<tr>
<th>Bit Number</th>
<th>7 6 5 4 3 2 1 0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bit Value</td>
<td>0 0 1 0 1 1 1 1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Bit Number</th>
<th>Binary Value</th>
<th>Place Value</th>
<th>Decimal Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>0</td>
<td>128</td>
<td>0</td>
</tr>
<tr>
<td>6</td>
<td>0</td>
<td>64</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td>32</td>
<td>32</td>
</tr>
<tr>
<td>4</td>
<td>0</td>
<td>16</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

**Figure 1.4** – Computing the decimal value of a binary number
the proper hex digit for each group using the 8-4-2-1 values for the bits in the group. For example, the number 0010 1111 in binary is 2F in hex:

\[
\begin{align*}
8421 & \quad 0010 \quad 1111 \\
& = (0 \times 8) + (0 \times 4) + (1 \times 2) + (0 \times 1) = 2 \\
& = (1 \times 8) + (1 \times 4) + (1 \times 2) + (1 \times 1) = F \ (15)
\end{align*}
\]

**Converting Hex to Binary**

Hex numbers can be converted to binary by first taking each hex digit and then expanding it into four binary bits using the hex, decimal, and binary values shown in Table 1.2.

<table>
<thead>
<tr>
<th>Hex Value</th>
<th>Decimal Value</th>
<th>Binary Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0000</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>0001</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>0010</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>0011</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>0100</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
<td>0101</td>
</tr>
<tr>
<td>6</td>
<td>6</td>
<td>0110</td>
</tr>
<tr>
<td>7</td>
<td>7</td>
<td>0111</td>
</tr>
<tr>
<td>8</td>
<td>8</td>
<td>1000</td>
</tr>
<tr>
<td>9</td>
<td>9</td>
<td>1001</td>
</tr>
<tr>
<td>A</td>
<td>10</td>
<td>1010</td>
</tr>
<tr>
<td>B</td>
<td>11</td>
<td>1011</td>
</tr>
<tr>
<td>C</td>
<td>12</td>
<td>1100</td>
</tr>
<tr>
<td>D</td>
<td>13</td>
<td>1101</td>
</tr>
<tr>
<td>E</td>
<td>14</td>
<td>1110</td>
</tr>
<tr>
<td>F</td>
<td>15</td>
<td>1111</td>
</tr>
</tbody>
</table>

*Table 1.2 - Hex, Decimal, and Binary Values*
When you use this table, the hex number 2F converts to the binary number 0010 1111.

Converting Hex to Decimal

To convert a hex number to a decimal number, first multiply each digit by its appropriate place value, and then add the resulting numbers. The place values for hex numbers are shown in Table 1.3.

<table>
<thead>
<tr>
<th>Digit</th>
<th>Place Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>16</td>
</tr>
<tr>
<td>2</td>
<td>256</td>
</tr>
<tr>
<td>3</td>
<td>4,096</td>
</tr>
<tr>
<td>4</td>
<td>65,536</td>
</tr>
<tr>
<td>5</td>
<td>1,048,576</td>
</tr>
<tr>
<td>6</td>
<td>16,777,216</td>
</tr>
<tr>
<td>7</td>
<td>268,435,456</td>
</tr>
</tbody>
</table>

*Table 1.3 – Hexadecimal Place Values*

The digit numbered 0 is the rightmost digit in a hex number. Each place value is derived by multiplying the previous place value by 16, starting with a value of 1 for the rightmost digit. The digit number is also known as a “power of 16.”

The hex number 54321 converts to its decimal value as shown in Figure 1.5, the hex number A25 converts to its decimal value as shown in Figure 1.6, and the hex number 1234 converts to the decimal value of 4660 as shown in Figure 1.7.
### Figure 1.5 – Converting the hex number 54321 to its decimal value

<table>
<thead>
<tr>
<th>Hex Digit</th>
<th>Place Value</th>
<th>Decimal Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>65,536</td>
<td>327,680</td>
</tr>
<tr>
<td>4</td>
<td>4,096</td>
<td>16,384</td>
</tr>
<tr>
<td>3</td>
<td>256</td>
<td>768</td>
</tr>
<tr>
<td>2</td>
<td>16</td>
<td>32</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>+ 1</td>
</tr>
</tbody>
</table>

 Converted decimal value = 344,865

### Figure 1.6 – Converting the hex number A25 to its decimal value

<table>
<thead>
<tr>
<th>Hex Digit</th>
<th>Place Value</th>
<th>Decimal Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>A(10)</td>
<td>256</td>
<td>2,560</td>
</tr>
<tr>
<td>2</td>
<td>16</td>
<td>32</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td>+ 5</td>
</tr>
</tbody>
</table>

 Converted decimal value = 2,597

### Figure 1.7 – Converting the hex number 1234 to its decimal value

<table>
<thead>
<tr>
<th>Hex Digit</th>
<th>Place Value</th>
<th>Decimal Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4096</td>
<td>4096</td>
</tr>
<tr>
<td>2</td>
<td>256</td>
<td>512</td>
</tr>
<tr>
<td>3</td>
<td>16</td>
<td>48</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>+ 4</td>
</tr>
</tbody>
</table>

 Converted decimal value = 4660

---

*Programming the Macintosh in Assembly Language*
Converting Decimal to Hex

Decimal numbers can be converted to hex numbers using the inverse of the above technique. To convert a decimal number to hex, first find the largest place value in Table 1.3 that divides into the number to be converted, then divide the decimal value by this number. The quotient of this division is the hex digit. Divide the remainder by the next smallest place value to obtain the next hex digit (even if it's zero). Divide this remainder by the next smallest place value to get the next digit, and so on.

To convert the decimal number 123,456 to hex, we start with a hex place value of 65,536 and divide this hex value into the decimal value of 123,456. The result of 1 is the first hex digit and the remainder (57,920) is the dividend for the next hex place value.

<table>
<thead>
<tr>
<th>Decimal Remainder</th>
<th>Hex Place Value</th>
<th>Hex Digit</th>
</tr>
</thead>
<tbody>
<tr>
<td>123,456</td>
<td>65,536</td>
<td>1</td>
</tr>
<tr>
<td>57,920</td>
<td>4,096</td>
<td>E (14 decimal)</td>
</tr>
<tr>
<td>576</td>
<td>256</td>
<td>2</td>
</tr>
<tr>
<td>64</td>
<td>16</td>
<td>4</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

Read the answer down the Hex Digit column: 1E240. The next remainder can be calculated on a decimal calculator as: Present decimal remainder – (place value × hex digit).

For example, the remainder 576 was calculated above by first dividing 4,096 into 57,920. The answer is 14, or a hex value of E. Then the hex place value was multiplied by 14, which equals 57,344. Finally, the remainder of 576 was arrived at by subtracting 57,344 from the previous remainder, 57,920.

There are several calculators on the market which will do hex and decimal conversions. If you are going to be writing a lot of machine code, a hex calculator will pay for itself in short order.

What’s in a K?

The hex number 400 translates to 1,024 in decimal. The term K (for “Kilo”) is used in computer terminology to represent multiples of 1,024. Memory and disk device capacities are expressed in units of kilobytes. For
instance, a 64 kilobyte (64K) memory contains $64 \times 1,024$, or 65,536 decimal (or 10000 hex) bytes of memory.

Similarly, the number 100000 hex (1,048,576 decimal) is the result of multiplying $1024 \times 1024$. This number is commonly abbreviated $M$ (for Mega). Megabyte units are used to describe the capacities of larger memory and disk devices. A 5-megabyte (commonly written 5Mb) disk therefore contains $5 \times 1,048,576$, or 5,242,880 bytes.

**Operations on Binary Numbers**

Since decimal, binary, and hex are simply alternate ways of representing numbers, the same operations that can be performed on decimal numbers can also be performed on binary or hex numbers. One can apply techniques similar to those used for decimal numbers for the addition, subtraction, multiplication, and division of hex and binary numbers. For programming, however, it is important to understand the operations a computer is capable of performing.

A computer's ALU is capable of performing a number of very simple operations on binary numbers. These include: One's complement, AND, OR, Exclusive OR, addition, two's complement, shifts and rotates. We will now explore these in greater detail.

**One's Complement**

One of the simpler operations on binary numbers is to take the one's complement: Simply invert the values of all the bits. All 0's become 1's and vice versa.

For example, complementing the number 0011 1100 (3C hex) produces 1100 0011 (C3 hex). Complementing 0000 0000 (00 hex) yields 1111 1111 (FF hex). Complementing the complement of a number yields the original number again.

**Binary AND**

Performing an AND operation on two binary numbers produces a third binary number with 1's in each bit position where the original numbers both had a 1. ANDing 0000 1101 (0D hex) with 1001 1001 (99 hex) yields 0000 1001 (09 hex).

The AND operation is commonly used to obtain a remainder for a division by a power of two (2, 4, 8, 16, etc.). To obtain such a remainder,
AND the number with the power of 2 minus 1. For example, to find the remainder when 0011 1101 (3D hex) is divided by 8, AND with 0000 0111 (07 hex). The result is 0000 0101 (05 hex). 3D hex is $3 \times 16 + 13$, or 61 decimal. Dividing by 8 yields 7, with a remainder of 5.

**Binary OR**

The OR operation takes two binary numbers and produces a third binary number that has a 1 where either of the original numbers had a 1. For example, ORing 1010 1010 (M hex) with 0101 0101 (55 hex) yields 1111 1111 (FF hex). (ANDing these two numbers gives all zeros.)

**Binary XOR**

The XOR (eXclusive OR) operation takes two binary numbers and produces a third binary number which has 1's in bit positions where one (not both) of the original numbers had a 1. For example, XORing 0101 0101 (55 hex) with 1111 1111 (FF hex) yields 1010 1010 (M hex). XORing a number with all 1's yields the 1's complement of the number. XORing a number with itself produces zero.

**Binary Addition**

Adding two binary numbers is similar to adding decimal numbers. You add each pair of digits, starting on the right, and carry any result over 1 to the next column. For example, adding 0011 1101 (3D hex) and 0001 0101 (15 hex) is done as follows:

<table>
<thead>
<tr>
<th>Carry</th>
<th>0011</th>
<th>1010</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0011</td>
<td>1101 (3D hex)</td>
</tr>
<tr>
<td>+0001</td>
<td>0101</td>
<td>1101 (15 hex)</td>
</tr>
</tbody>
</table>

| Sum   | 0101 | 0010 (52 hex) |

This procedure can be used for binary numbers of any length.

**2's Complement Arithmetic**

Subtraction involves a bit of magic. Negative numbers are stored in a form known as two's complement. The two's complement of a number is
obtained by taking the one's complement (as explained above), and adding 1 to it. For instance, the two's complement of 0000 0001 is:

<table>
<thead>
<tr>
<th>Original Number:</th>
<th>0000 0001</th>
<th>(01 hex)</th>
</tr>
</thead>
<tbody>
<tr>
<td>One's Complement:</td>
<td>1111 1110</td>
<td>(FE hex)</td>
</tr>
<tr>
<td>Add One:</td>
<td>+ 0000 0001</td>
<td>(01 hex)</td>
</tr>
</tbody>
</table>

| Two's Complement:| 1111 1111 | (FF hex) |

Adding the two's complement of a number is the same as subtracting the number. As an example, consider adding 1111 1111 (FF hex) to 0000 0010 (02 hex). The leftmost bit of a two's complement number will be a 0 if the number is positive (zero or greater), and a 1 if the number is negative (less than 0). For this reason, the leftmost bit is often called the sign bit.

<table>
<thead>
<tr>
<th>Carry</th>
<th>1111</th>
<th>1100</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0000</td>
<td>0010</td>
</tr>
<tr>
<td>+ 1111 1111</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Sum              | 0000 | 0001 | (01 hex) |

Note that the carry out of the high order bit position is discarded. This is due to the fact that all of the numbers kept in a computer have exactly the same number of bits (eight in this example). Note that the result of adding 02 hex and FF hex is 01. This is the same as subtracting 1 from 2. FF hex is the two's complement of 01 hex, as shown above.

Two's complement changes the range of numbers it is possible to represent using a given number of bits. For instance, without using the two's complement, we could represent from 0 to 255 with eight bits. Using two's complement, however, we can represent from -128 to +127.

The first case is called unsigned arithmetic, meaning that only positive numbers can be represented. The second case is called two's complement representation, meaning that both positive and negative numbers can be represented.
**Shifts and Rotates**

Two other operations commonly performed on binary numbers are shifts and rotates. These operations are similar to the old "bucket brigade" operation used in fighting fires. Bits are moved from one position to the next position. Shifts and rotates can occur in either direction.

There are two types of shifts: logical and arithmetic. In a logical shift operation, the bits are moved left or right as in Figure 1.8.

Zero bits are shifted into the bit vacated by the shift operation. The bit marked C is a special status bit in one of the CPU internal registers. This bit is called the Carry bit, and it receives the bit which would otherwise be lost.

An arithmetic left shift is the same as a logical left shift. An arithmetic right shift is similar to a logical right shift, except that the most significant bit is copied into itself. Both of these are shown in Figure 1.9.

The two left shifts differ only in the settings of the condition codes. These are explained in Chapter 2.

Rotates are similar to logical shifts, except that the Carry bit is shifted into the vacated bit, instead of a zero, as illustrated in Figure 1.10.

---

**Figure 1.8** – Logical left shift and logical right shift
Arithmetic Left Shift:

```
C → . . . → 0
```

Arithmetic Right Shift:

```
. . . → C
```

Figure 1.9 - Arithmetic left shift and arithmetic right shift

Left Rotate:

```
C ← . . .
```

Right Rotate:

```
. . . → C
```

Figure 1.10 - Left rotate and right rotate
Examples
The following examples assume that the Carry bit is initially zero. The original number is 1010 1010 (AA hex).

Logical Shifts:

<table>
<thead>
<tr>
<th>Times</th>
<th>Left</th>
<th>Right</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1010</td>
<td>1010</td>
</tr>
<tr>
<td>1</td>
<td>0101</td>
<td>0100</td>
</tr>
<tr>
<td>2</td>
<td>1010</td>
<td>1000</td>
</tr>
<tr>
<td>3</td>
<td>0101</td>
<td>0000</td>
</tr>
<tr>
<td>4</td>
<td>1010</td>
<td>0000</td>
</tr>
<tr>
<td>5</td>
<td>0100</td>
<td>0000</td>
</tr>
<tr>
<td>6</td>
<td>1000</td>
<td>0000</td>
</tr>
<tr>
<td>7</td>
<td>0000</td>
<td>0000</td>
</tr>
<tr>
<td>8</td>
<td>0000</td>
<td>0000</td>
</tr>
</tbody>
</table>

Arithmetic shifts:

<table>
<thead>
<tr>
<th>Times</th>
<th>Left</th>
<th>Right</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1010</td>
<td>1010</td>
</tr>
<tr>
<td>1</td>
<td>0101</td>
<td>0100</td>
</tr>
<tr>
<td>2</td>
<td>1010</td>
<td>1000</td>
</tr>
<tr>
<td>3</td>
<td>0101</td>
<td>0000</td>
</tr>
<tr>
<td>4</td>
<td>1010</td>
<td>0000</td>
</tr>
<tr>
<td>5</td>
<td>0100</td>
<td>0000</td>
</tr>
<tr>
<td>6</td>
<td>1000</td>
<td>0000</td>
</tr>
<tr>
<td>7</td>
<td>0000</td>
<td>0000</td>
</tr>
<tr>
<td>8</td>
<td>0000</td>
<td>0000</td>
</tr>
</tbody>
</table>

Rotates:

<table>
<thead>
<tr>
<th>Times</th>
<th>C</th>
<th>Left</th>
<th>Right</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>1010</td>
<td>1010</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>0101</td>
<td>0100</td>
</tr>
<tr>
<td>2</td>
<td>0</td>
<td>1010</td>
<td>1001</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>0101</td>
<td>0010</td>
</tr>
</tbody>
</table>
Shifts are very useful for multiplying and dividing. A logical shift left is the same as multiplying a number by 2, and a logical shift right is the same as dividing a number by 2. This is only true for unsigned numbers.

Arithmetic shifts, on the other hand, represent multiplication and division by 2 for two's complement numbers. The one exception is that dividing (shifting right) $-1$ yields $-1$ and not zero.

**Extensions**

When copying an 8-bit quantity into a 16-bit quantity, or when copying a 16-bit quantity into a 32-bit quantity, there is a possibility of losing the two's complement properties of the number.

To illustrate the problem, suppose we copy FF hex ($-1$ as an 8-bit number) to a 16-bit number. Copying only the lower 8 bits gives us 00FF hex, which is not $-1$, but 255! The way to fix this situation is to copy the sign bit (most significant bit) into all the “extra” bits in the larger number. This is called sign extension. If we sign extend FF hex into 16 bits, we get FFFF hex, which is $-1$ in two’s complement form.

**SUMMARY**

In this chapter we have learned basic concepts that are applicable to most computers on the market today. In the next chapters, we shall see how these concepts are applied to the Motorola 68000, the CPU chip used in the Macintosh.

**EXERCISES**

Use the following questions to help solidify your understanding of the material presented in Chapter 1. Answers to all exercise questions can be found in Appendix A.
1. Write an algorithm for converting a decimal number to hex.

2. Develop a flowchart for the algorithm in question 1.

3. Suppose the computer on page 9 has an additional instruction 5nnn, which subtracts the contents of memory location nnn from Register A. The assembly form of this instruction is $\text{SUB A,y}$ where y is a label on the memory location to be subtracted from A. Modify the example of the machine-language program to compute the difference between the contents of location 105 and the contents of location 104. Store the result in location 106. (Hint: You will have to load location 105 into Register A first. Why?)

4. Move the machine-language program you wrote in question 3 to run at address 200.

5. Give the assembly language equivalent of the program for question 3.

6. Write a new assembly language program that computes the sum of the first five integers. Use the labels A through E for the memory locations that contain the numbers to be added. Store the result in a separate memory location, labeled F.

7. Convert the following decimal numbers to their hex and binary equivalents.

   273
   421
   1024
   100

8. Convert the following hex numbers to their binary and decimal equivalents.

   ABE
   100
   64
   1024
   505
9. Give the one's and two's complements for each of the numbers in the previous question.

10. Perform the AND, OR, XOR, and addition operations on the following pairs of hex numbers. Use 16-bit operations. Give the carry out of the high order bit pairs for the addition operation.

A5A5 5A5A
FFFF 0001
1234 4321

11. Prepare shift and rotate tables similar to those in the text for the hex quantities FF and 55. Assume that the carry bit is initially zero.
An investment in knowledge always pays the best interest.
—Benjamin Franklin

INTRODUCTION

In this chapter, we will expand the general programming concepts presented in Chapter 1 to cover the architecture of the Motorola 68000, the CPU chip used by the Macintosh. The information specific to the 68000 is necessary in order to understand the instruction set contained in Chapter 3. Most computers can be categorized by the following criteria:

- The number and type of registers that may be used by the programmer in writing software.
- How data is organized in memory, and what data types are supported with hardware instructions.
- How memory is addressed by an instruction.
- Special hardware features, such as hardware support for stacks.

We will now explore each of these areas as it relates to the 68000.
**REGISTER SET**

One of the first questions you should ask when learning a new computer is “How many registers does it have?” Another important consideration is whether the registers can be used interchangeably or not. If the computer has many registers that can be used interchangeably, you will have a great deal of flexibility in handling intermediate values in a computation.

The number of registers in a computer also has an effect on program speed and size. Computations using a register are usually smaller and faster than computations involving a memory location. (This is due primarily to the nature of computer hardware). A machine with a large number of general-purpose registers is preferred over a machine with a small number of registers or a machine whose registers are restricted in function.

The 68000 architecture trades off some generality in order to gain a larger register set. There are two types of registers: *address registers* and *data registers*. Address registers are normally used to contain memory addresses, while data registers normally contain data. The two register classes are not used interchangeably.

**Address Registers**

There are eight address registers, numbered A0–A7. Each address register is a 32-bit quantity. Address registers can also be used as 16-bit quantities. When a 16-bit quantity is loaded into an address register, it is sign extended to become a 32-bit quantity, as shown in Figure 2.1. The notation A0.W is used to mean the word part of address register A0. (A0.L means the entire 32 bits stored in register A0.) The .B suffix is used to denote an 8-bit quantity. Address registers may not be used as 8-bit quantities, however.

![Figure 2.1 – Address register layout](image-url)
Register A7 is a special-purpose register. A7 is the hardware stack pointer used by 68000 exceptions and subroutine call instructions. This register points to memory used by programs for temporary storage of data. The concept of a stack is discussed later in this chapter.

Address registers are used as temporary locations for storing memory addresses. These registers can be used in instructions that reference memory in order to specify the address at which data is located. The upper byte of the register is presently ignored in such usage (by the 68000 and 68010 chips). This limits the amount of memory that you can use to 16 megabytes (16,772,216 bytes). Future processors in the 68000 family will not ignore this byte, so it should always be set to zero for compatibility.

**Data Registers**

The 68000 also has eight other registers, called data registers, numbered D0–D7. A data register can be used as an 8-bit, 16-bit, or 32-bit quantity, as shown in Figure 2.2. Unlike address registers, loading a data register with less than 32 bits does not cause a sign extension to occur into the remaining bits in the register. These remaining bits are left unchanged.

Data registers cannot be used to address memory in an instruction. These registers are used instead as temporary locations where data may be stored. Many instructions require one or more of the operands to reside in a data register.

**Figure 2.2** – Data register layout
Program Counter

A special 32-bit register called the program counter is used to control execution of the program in memory. The program counter always contains the memory address of the next instruction to be executed. As an instruction is executed, the program counter is advanced to point to the next instruction.

Certain instructions can be used to affect the contents of the program counter. These are:

- Instructions that alter the contents of the program counter unconditionally. These are called unconditional branches or jumps. Such an instruction is useful for programming loops, or for merging several alternative sections of the program into one common section.

- Instructions that alter the contents of the program counter based on the result of a previous instruction. These are called conditional branches, and enable the computer to make decisions. Using a conditional branch, either a portion of the program can be skipped or a previous portion repeated, based on the result of a previous computation.

- Instructions that cause a given section of code to be repeated a specific number of times, or until a condition is satisfied. Such instructions are called looping primitives.

- Instructions that are used to branch to another area of the program and then to return to the location following the original branch. This technique is known as a subroutine call. A subroutine call can be used to invoke a common function, such as an I/O routine, at many points in the program, using only a single copy of the instructions that perform the I/O.

As with address registers, the upper eight bits of the program counter are ignored by the 68000 and 68010 processors.

Status Register

The 68000 uses a special register, called the status register (SR) to store information about the status of the machine. This register is used by the conditional branch instructions to retrieve information about the last instruction.

The status register is a 16-bit quantity, organized as shown in Figure 2.3.
System Byte

Bits 15–8 are called the system byte, because the information contained here is not normally available to applications programs. The fields in the system byte are:

1. Bit 15 is a hardware aid for debuggers. It is called the trace bit. If bit 15 is set, an exception will take place at the end of each instruction. Exceptions are described in Chapter 7, Exception Processing. This feature is used by debuggers to regain control as each instruction is executed.

2. Bit 13 is used to regulate access to certain instructions and to the system byte of the status register. It is called the supervisor bit. If this bit is set, access is allowed. When the supervisor bit is set, the 68000 is said to be executing in supervisor mode. When the bit is reset, the 68000 is said to be executing in user mode. User mode software is prevented by the hardware from executing certain privileged instructions that might compromise the integrity of the system software. Access to the status register’s system byte is also prohibited when in user mode, ensuring that the user mode program cannot change the supervisor bit. All software on the Macintosh executes in supervisor mode, however, so all instructions can be used. Free access to the status register is permitted.

3. Bits 10–8 are called the interrupt mask. This feature is more fully explained in Chapter 7, which deals with 68000 exception conditions.

The system byte of the status register is of concern only to systems software programmers. We will deal more extensively with this topic in later chapters.
User Byte

The lower byte of the status register is called the user byte. The user byte contains a set of bits known as condition codes, which are bit flags used to record the outcome of the last arithmetic operation performed. The user byte can be accessed at any time regardless of machine state. The bits defined in the user byte are:

- The C (carry) bit carries out the high-order bit position of an arithmetic operation. For example, when two 8-bit numbers are added, the C bit is the ninth bit of the result. This bit also receives bits that are shifted out of a number during shift or rotate operations.

- The V (overflow) bit is set whenever an operation yields a result that cannot be properly represented. For example, when adding the bytes 7F hex and 01 hex, the result, 80 hex, is not properly represented in eight bits. (Remember, 80 hex is -128 decimal in two’s complement notation.) The V bit would be set following such an operation.

- The Z (Zero) bit is set if the result of an operation is zero.

- The N (Negative) bit is set if the high order bit of a result is set. (In two’s complement, the high order bit of a number is set if the number is less than zero.)

- The X (extended) bit is a copy of the carry bit, but it is not affected by every instruction that affects the carry bit. The purpose of this bit is to facilitate multiprecision instructions. The X bit is affected only by instructions that can be used for multiprecision operations. This allows you to intermix other instructions between multiprecision operations without having to preserve the carry bit.

The descriptions of the instruction set in Chapter 3 describe how the condition codes are used by each operation. Since the lower half of the status register contains nothing but the condition codes, it is sometimes called the condition code register (CCR).

DATA ORGANIZATION IN MEMORY

The 68000 instruction set supports several data formats: binary, BCD, and floating point.
**Bytes, Words, and Longwords**

Binary data items can be 8, 16, or 32 bits long. These data types are known as *bytes*, *words*, and *longwords*, respectively. Most instructions that operate on binary data support any of these three data lengths. For example, the MOVE instruction, which transfers a binary data item from one place to another, has three forms:

- MOVE.B moves a byte of data
- MOVE.W moves a word of data
- MOVE.L moves a longword of data

Note the use of the suffixes .B, .W, and .L to denote data length. If no suffix is given, .W is usually assumed.

When a word or a longword is stored in memory, the bytes are stored in order of decreasing magnitude. The most significant bits are stored at the lowest address, and the least significant bits are stored at the highest address. For example, when a 16-bit word is stored at location 1000, the most significant byte is at location 1000, and the least significant byte at 1001. When the longword 01234567 (hex) is stored at address 1000, memory appears as shown in Figure 2.4.

<table>
<thead>
<tr>
<th>Address</th>
<th>Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000</td>
<td>0000 0001 (01 hex)</td>
</tr>
<tr>
<td>1001</td>
<td>0010 0011 (23 hex)</td>
</tr>
<tr>
<td>1002</td>
<td>0100 0101 (45 hex)</td>
</tr>
<tr>
<td>1003</td>
<td>0110 0111 (67 hex)</td>
</tr>
</tbody>
</table>

*Figure 2.4 – Memory with longword stored at address 1000*
We emphasize this point because all computers do not store multibyte binary quantities in the same way. In particular, the 8080/Z-80, 6502, and 8086/8088 family of microprocessors store words and longwords in ascending order, so that the low byte is stored at the lowest address and the high byte at the highest address. Which order is "correct" is largely a matter of taste, but you should be aware that the difference exists.

**BCD**

A special form of binary numbers, called *binary coded decimal* (BCD), is often used for digital displays and input devices. The familiar displays on digital clocks and electronic calculators are universally based on BCD. Most computer-based laboratory and factory instruments also use BCD.

BCD is basically hexadecimal without the codes for 10–15 (i.e., A–F). Each nibble represents a digit in a decimal number. Thus, two decimal digits are stored in a byte. The 68000 has instructions for the addition and subtraction of BCD numbers.

BCD is especially useful in commercial applications, such as accounting. Many such applications require only addition and subtraction of numbers in character format. To convert these numbers to binary for calculation and then convert them back to character format for output requires much multiplication and division, which are comparatively slow operations for most computers. Using BCD avoids these expensive operations, and provides quick conversion to and from character format. In many applications, BCD is much more efficient than binary.

**Floating Point**

Scientific applications require a large range of possible values. For example, to represent Avogadro's number (a common quantity in chemical calculations, roughly 6 followed by 23 zeros) would require ten bytes of storage. To hold the result of the multiplication of two such numbers would require twice this much storage. Then there is the problem of representing fractional numbers, which none of the data representations thus far have addressed.

The clean solution to these problems is found in *floating point numbers*. Floating point numbers are a computerized form of scientific notation, which is taught in grade school mathematics. In scientific notation, a number is written as a quantity between 0 and 10 times 10 to the appropriate power. For example, the quantity 1,935,000,000 is written as \( 1.935 \times 10^{12} \). The quantity \( 0.000001349 \) is written as \( 1.349 \times 10^{-6} \).
Scientific notation is extremely useful in a computer. Allocating a fixed number of bits to the exponent and fraction parts of a number yields a very useful approximation to both very large and very small numbers. The 68000, like most microprocessors, does not directly support floating point with instructions. However, there is an additional feature which can be added to provide hardware support for floating point.

The 68000 add-on is called the 68881 Floating Point Processor. It provides hardware instructions to manipulate floating-point numbers. The 68881 uses a floating-point format known as The Institute of Electrical and Electronic Engineers (IEEE) format, named for the organization that proposed the format as a standard. IEEE format provides the following floating point format:

<table>
<thead>
<tr>
<th>S</th>
<th>Exp</th>
<th>Fraction</th>
</tr>
</thead>
</table>

The field labeled S is the sign bit for the entire number. If this bit is set, the number is negative. If the bit is not set, the number is positive.

The field labeled Exp is the exponent; it is seven bits long (for normal floating point) or 15 bits long (for extended floating point). The exponent field indicates the exponent of 2 by which the fractional part of the number is multiplied. To allow for negative exponents, a quantity called the exponent bias is subtracted from the exponent before it is used. This number is decimal 64 for 7-bit exponents and 16384 for 15-bit exponents. The 7-bit exponent range is 00 hex (−64) to 7F hex (+63). Thus, the range of representation is $2^{63}$ (approximately $9.2234 \times 10^{18}$) to $2^{-64}$ (approximately $5.421 \times 10^{-20}$).

The fraction part of a standard floating-point number is 24 bits, or six to seven decimal digits. This limits the number of significant digits the floating-point number can contain. A limit of six digits means that the computer cannot correctly subtract 1 from 10,000,000, for example.

The Macintosh supports a software implementation of floating point known as “SANE” (Standard Apple Numeric Environment). This format provides three forms of floating-point numbers:

1. *Single precision*, which represents numbers in 32 bits, with a 7-bit exponent and a 24-bit fraction.
2. *Double precision*, which represents numbers in 64 bits, with a 7-bit exponent and a 56-bit fraction.
3. *Extended precision*, which represents numbers in 80 bits, with a 15-bit exponent and a 64-bit fraction.
These formats are compatible with the IEEE standard used by the 68881 hardware chip. The remainder of this book will deal with integer arithmetic.

ASCII

The final form of data storage is known as ASCII or character format. ASCII stands for American Standard Code for Information Interchange. This code assigns a numeric value for each character. These values are used to represent characters in memory and during I/O. The current ASCII standard for the United States defines 128 characters, with values from 0–127. The characters are stored one per byte in memory. The eighth bit is used for additional characters in Europe and Japan. For a complete list of United States ASCII values, see Appendix B.

Multicharacter sequences, called strings, are stored in multiple consecutive bytes in memory. The 68000 provides no instructions explicitly for string manipulation; sequences of byte instructions must be used instead. There are three common types of string storage you may employ:

- Use a fixed length for each string to be stored. This has the advantage of being easy to program, but wastes memory if string length tends to vary. This technique is usually used by the FORTRAN and COBOL languages.

- Prefix each string with a character count. This is more difficult to program, but wastes less memory. If the character count is stored in a byte at the beginning of the string, then strings are limited to 255 characters. Using a word (i.e., two bytes) allows 65,535 characters in a string. This is the technique usually used by the Pascal and BASIC languages.

- Terminate the string with some flag value, usually zero. This technique is used by the C language. Problems arise, however, if strings are processed in a manner other than sequentially from beginning to end.

ADDRESSING MODES

A computer instruction must specify two things:

1. What operation to perform, such as addition or subtraction.
2. On what data to perform the operation. Data for instructions is usually found either in registers or memory.
A portion of the instruction, called the op code, indicates the operation to perform. The simple example in Chapter 1 used the first digit of the instruction as the op code. Data was in the machine's single register and a memory location. The memory location was identified by the address contained in the last three digits of the instruction.

Real computers are seldom so simple. In the 68000, instructions specify operands by one of three techniques:

1. Some instructions imply the use of certain operands, usually a register, such as the status register or the Program Counter (PC).
2. Some instructions work only on registers. The register number is contained in the instruction itself.
3. Most 68000 instructions specify operands with a technique called an effective address. This is a generalized technique for addressing the registers and memory.

**Effective Address**

An effective address is specified by six bits in the instruction (usually the lowest six bits). The bit values indicate how to find the data for the instruction. Figure 2.5 shows how these bits are arranged into two groups of three bits.

The mode bits determine the meaning of the entire field. Three bits give eight possible combinations. Values 0–6 mean that a register is to be used, either as the operand, or to determine the address of the operand in memory. If the mode field is 7 (i.e., all 1's), then the entire six bits of the effective address field is used to specify the mode.

In the following examples, we will illustrate the addressing modes using the MOVE.L instruction, which moves a longword from one operand to another. Both operands have the effective address format. We will use the D0.L data register as the destination operand, and vary the source operand to illustrate the various addressing modes. Figure 2.6 shows the format of a MOVE.L instruction.

![Figure 2.5 - Format of an effective address](image-url)
The Source and Destination fields are used to select the source and destination operands. Since the register and mode fields are three bits wide, it is difficult to look at the hex representation of an instruction and determine the assembly language equivalent. This process is known as disassembly. 68000 instructions in general are difficult to disassemble by hand. Fortunately, most debuggers perform disassembly, so this problem is not as severe as it could be.

### Data Register Direct Addressing

<table>
<thead>
<tr>
<th>Addressing Mode Field:</th>
<th>000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Register Field:</td>
<td>000-111 (Data Register Number)</td>
</tr>
<tr>
<td>Assembler Syntax:</td>
<td>Dn (n is 0-7)</td>
</tr>
</tbody>
</table>

**Description**

Data register direct addressing is indicated by an effective address mode field of 000 (binary). The register field contains a number from 000 to 111 (0-7), which indicates a data register. In data register direct addressing, the data register (indicated by the register field) contains the operand.

**Example**

The instruction `MOVE.L D1,D0` causes the contents of data register D1 to be copied into data register D0. After the instruction executes, the two registers contain the same information. Figure 2.7 shows the format of this instruction.

When only a word or byte is transferred, the contents of the upper bytes of the data register are unchanged. Figure 2.8 shows examples of the MOVE instruction with a byte, a word, and a longword.

---

**Figure 2.6 – Format of a MOVE.L instruction**

- **Source**
- **Destination**

---

**Table 2.1**

<table>
<thead>
<tr>
<th>Bit</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **Reg**
- **Mode**
- **Reg**

Expression: `← Destination → ← Source →`
**Address Register Direct Addressing**

Addressing Mode Field: 001  
Register Field: 000–111 (Address Register Number)  
Assembler Syntax: An (n is 0–7)

**Description**

Address register direct addressing is indicated by an effective address mode field of 001 (binary). The register field contains a number from 000
to 111 (0–7), which indicates an address register. In address register direct addressing, the address register indicated by the register field contains the operand.

**Example**

The instruction `MOVE.L A1,D0` causes the contents of address register A1 to be copied into data register D0. After the instruction executes, the two registers contain the same information. Figure 2.9 shows the format of this instruction.

Transfers involving an address register are restricted to word or long size. Byte operations are not allowed. When transferring a word to an address register, bit 15 (the sign bit of a word) is extended throughout the upper word of the address register. Figure 2.10 gives several examples of address register direct addressing.

![Figure 2.9 - Format of MOVE.L A1,D0 instruction](image)

<table>
<thead>
<tr>
<th>Instruction</th>
<th>Before</th>
<th>After</th>
</tr>
</thead>
<tbody>
<tr>
<td>MOVE.W A1,D0</td>
<td>D0=FFFFFFFF</td>
<td>D0=FFFF4567</td>
</tr>
<tr>
<td></td>
<td>A1=01234567</td>
<td>A1=01234567</td>
</tr>
<tr>
<td>MOVE.W D0,A1</td>
<td>D0=01234567</td>
<td>D0=01234567</td>
</tr>
<tr>
<td></td>
<td>A1=FFFFFFFF</td>
<td>A1=00004567</td>
</tr>
<tr>
<td>MOVE.W D0,A1</td>
<td>D0=0000FFFF</td>
<td>D0=0000FFFF</td>
</tr>
<tr>
<td></td>
<td>A1=00000000</td>
<td>A1=FFFFFFFF</td>
</tr>
<tr>
<td>MOVE.L A1,D0</td>
<td>D0=FFFFFFFF</td>
<td>D0=01234567</td>
</tr>
<tr>
<td></td>
<td>A1=01234567</td>
<td>A1=01234567</td>
</tr>
</tbody>
</table>

*Figure 2.10 – Examples of address register direct addressing*
**Address Register Indirect Addressing**

Addressing Mode Field: 010  
Register Field: 000–111 (Address Register Number)  
Assembler Syntax: (An) (n is 0–7)

**Description**

Address register indirect addressing is indicated by an effective address mode field of 010 (binary). The register field contains a number from 000 to 111 (0–7), which indicates an address register.

In address register indirect addressing, the address register indicated by the register field is the address of a memory location that contains the operand. The register is said to point to (contain the address of) the operand. Address register indirection is denoted by enclosing the address register name in parentheses. For example, (A0) denotes indirection on address register A0. Word or longword references require that the address contained in the address register must be even.

**Example**

The instruction `MOVE.L (A1),D0` causes the contents of the memory location pointed to by address register A1 to be copied into data register D0. After the instruction executes, data register D0 and the memory location contain the same information. Figure 2.11 shows the format of this instruction.

The instruction works as shown in Figure 2.12. $1000$ indicates the contents of the longword in memory at address 1000 hex.

![Figure 2.11 - Format of MOVE.L (A1),D0 instruction](image-url)
Address Register Indirect Addressing with Post-increment

Addressing Mode Field: 011  
Register Field: 000–111 (Address Register Number)  
Assembler Syntax: (An)+ (n is 0–7)

Description

Address register indirect addressing is indicated by an effective address mode field of 011 (binary). The register field contains a number from 000 to 111 (0–7), which indicates an address register. In address register indirect addressing, the address register indicated by the register field contains the address of a memory location that contains the operand. The register is said to point to (contain the address of) the operand.

The address register is incremented after the data has been obtained from memory. The increment is based on the length of the data item referenced by the instruction. Thus, for a MOVE.B instruction, the address register would be incremented by one. For a MOVE.W instruction, the address register is incremented by two. For a MOVE.L instruction, the address register is incremented by four.

Address register indirection with post-increment is denoted by enclosing the address register name in parentheses followed by a plus (+) symbol. For example, (A0)+ denotes post-increment indirection on address register A0. Word or longword references require that the address contained in the address register must be even.

Example

The instruction MOVE.L (A1)+,D0 causes the memory location pointed to by address register A1 to be copied into the contents of data register
DO. After the instruction is executed, data register D0 and the memory location contain the same information. Address register A1 is incremented by 4. Figure 2.13 shows the format of this instruction.

The instruction works as shown in Figure 2.14. $1000$ indicates the contents of the longword in memory at address 1000 hex.

A special case occurs when the address register specified is A7, which is the hardware stack pointer. Byte operations on address register A7 cause an increment by two rather than one. This ensures that the stack pointer always contains an even address.

![Figure 2.13 – Format of the MOVE.L (A1)+, D0 instruction](image)

<table>
<thead>
<tr>
<th>Instruction</th>
<th>Before</th>
<th>After</th>
</tr>
</thead>
<tbody>
<tr>
<td>MOVE.L (A1)+, D0</td>
<td>D0=FFFFFFFF</td>
<td>D0=01234567</td>
</tr>
<tr>
<td></td>
<td>A1=00001000</td>
<td>A1=00001004</td>
</tr>
<tr>
<td></td>
<td>$1000=01234567$</td>
<td>$1000=01234567$</td>
</tr>
</tbody>
</table>

![Figure 2.14 – An example of the MOVE.L (A1)+, D0 instruction](image)
Address Register Indirect Addressing with Pre-decrement

Addressing Mode Field: 100
Register Field: 000-111 (Address Register Number)
Assembler Syntax: – (An) (n is 0-7)

Description

Address register indirect addressing with pre-decrement is indicated by an effective address mode field of 100 (binary). The register field contains a number from 000 to 111 (0-7), which indicates an address register. In address register indirect addressing, the address register indicated by the register field contains the address of a memory location that contains the operand. The register is said to point to (contain the memory address of) the operand.

The address register is decremented before the data is obtained from memory. The decrement is based on the length of the data item referenced by the instruction. Thus, for a MOVE.B instruction, the address register is decremented by one. For a MOVE.W instruction, the address register is decremented by two. For a MOVE.L instruction, the address register is decremented by four.

Address register indirection with pre-decrement is denoted by enclosing the address register name in parentheses preceded by a minus (−) symbol. For example, −(A0) denotes pre-decrement indirection on address register A0. Word or longword references require that the address contained in the address register must be even.

Example

The instruction MOVE.L −(A1),D0 causes address register A1 to be decremented by four. The contents of the memory location pointed to by address register A1 are copied into data register D0. After the instruction executes, data register D0 and the memory location would contain the same information. Figure 2.15 shows the format of this instruction.

The instruction works as shown in Figure 2.16. $1000$ indicates the contents of the longword in memory at address 1000 hex.

A special case occurs when the address register specified is A7, which is the hardware stack pointer. Byte operations on address register A7 cause a decrement by two rather than one. This ensures that the stack pointer always contains an even address.
Address Register Indirect Addressing with Displacement

Addressing Mode Field: 101
Register Field: 000–111 (Address Register Number)
Assembler Syntax: x(An) (x is 16 bits, n is 0–7)

Description
Address register indirect addressing with displacement is indicated by an effective address mode field of 101 (binary). The register field contains a number from 000 to 111 (0–7), which indicates an address register. In this type of addressing, the address register indicated by the register field is added to the sign-extended 16-bit number following the instruction. The result is the address of a memory location that contains the operand.
Address register indirect addressing with displacement is denoted by enclosing the address register name in parentheses preceded by a 16-bit constant. For example, 8(A0) denotes the memory location whose address is the contents of A0 plus 8. Word or longword references require that the address generated must be even.

**Example**

The instruction MOVE.L 4(A1),D0 causes the contents of the memory location pointed to by address register A1 plus 4 to be copied into data register D0. After the instruction executes, data register D0 and the memory location contain the same information. Figure 2.17 shows the format of this instruction.

The instruction works as shown in Figure 2.18. $1004$ indicates the contents of the longword in memory at address 1004 hex.

![Figure 2.17 - Format of the MOVE.L 4(A1),D0 instruction](image)

<table>
<thead>
<tr>
<th>Instruction</th>
<th>Before</th>
<th>After</th>
</tr>
</thead>
<tbody>
<tr>
<td>MOVE.L 4(A1),D0</td>
<td>D0=FFFFFFF</td>
<td>D0=01234567</td>
</tr>
<tr>
<td></td>
<td>A1=00001000</td>
<td>A1=00001000</td>
</tr>
<tr>
<td></td>
<td>$1004=01234567</td>
<td>$1004=01234567</td>
</tr>
</tbody>
</table>

*Figure 2.18 - An example of the MOVE.L 4(A1),D0 instruction*
Note that displacement values greater than 7FFF (hex) subtract from rather than add to the value in the address register. This is due to the sign extension.

**Address Register Indirect Addressing with Index**

- **Addressing Mode Field:** 110
- **Register Field:** 000-111 (Address Register Number)
- **Assembler Syntax:**
  - x(An,Dn.L) (x is 8 bits, n is 0-7)
  - x(An,Dn.W)
  - x(An,An.W)
  - x(An,An.L)

**Description**

Address register indirect addressing with index is indicated by an effective address mode field of 110 (binary). The register field contains a number from 000 to 111 (0-7), which indicates an address register. In address register indirect addressing with index, the address register indicated by the register field is added to the contents of another register, plus a sign-extended 8-bit displacement. The sum of these three quantities is the address of a memory location that contains the operand.

The second register is called the *index register*, and may be either a data register or an address register. The size of the index register may be either a word or a longword. Word quantities are sign-extended before use.

Indexed address register indirect addressing is denoted by enclosing the index and address register names in parentheses preceded by an 8-bit constant. The desired size of the index register is defined by using the .L or .W suffixes on the register name. For example, 4(A0,D0.L) denotes the memory location whose address is the contents of data register D0 and the contents of address register A0 plus 4. Word or longword references require that the address so generated must be even.

The information concerning the index register and 8-bit displacement is contained in the 16-bit quantity that follows the instruction. This is called an *extension word*, and is in the format shown in Figure 2.19.

The bit labeled A is 1 if the index register is an address register, and 0 if the index register is a data register. Bits 14–12 contain the register number. The bit labeled L is a 1 if the index register is a long quantity, and 0 if the index is a word.
Example

The instruction \texttt{MOVE.L 4(A1,A2.L),D0} causes the contents of the memory location pointed to by the sum of address registers A2 and A1 plus 4 to be copied into data register D0. After the instruction executes, data register D0 and the memory location contain the same information. Figure 2.20 shows the format of this instruction.

Figure 2.21 shows how the instruction works. $2004$ indicates the contents of the longword in memory at address 2004 hex.


<table>
<thead>
<tr>
<th>Instruction</th>
<th>Before</th>
<th>After</th>
</tr>
</thead>
<tbody>
<tr>
<td>MOVE.L 4(A1,A2.L),D0</td>
<td>D0=FFFFFFF</td>
<td>D0=01234567</td>
</tr>
<tr>
<td></td>
<td>A1=00001000</td>
<td>A1=00001000</td>
</tr>
<tr>
<td></td>
<td>A2=00001000</td>
<td>A2=00001000</td>
</tr>
<tr>
<td></td>
<td>$2004=01234567</td>
<td>$2004=01234567</td>
</tr>
</tbody>
</table>

*Figure 2.21 – An example of the MOVE.L 4(A1,A2.L),D0 instruction*

**Absolute Short Addressing**

Addressing Mode Field: 111  
Register Field: 000  
Assembler Syntax: x (x is a 16-bit constant)

*Description*

Mode 7 with a register field of zero indicates that the word following the instruction is an absolute 16-bit address. The address is sign-extended before use, so that address specifications 8000 hex and above refer to addresses FFFF8000 and above. Remember, however, that the high byte of the address is presently discarded. The sign extension means that short addressing is useful only for the first 32,768 (32K) bytes of memory.

*Example*

The instruction MOVE.L $1000,D0 causes the contents of memory location 1000 (hex) to be copied into data register D0. (Many 68000 assemblers use the $ prefix to indicate hex numbers.)  
Figure 2.22 shows the format of this instruction.  
Figure 2.23 shows how the instruction works.  
$1000 indicates the contents of the longword in memory at the address 1000 hex.
Figure 2.22 – Format of MOVE.L $1000,D0 instruction with 16-bit address

<table>
<thead>
<tr>
<th>Instruction</th>
<th>Before</th>
<th>After</th>
</tr>
</thead>
<tbody>
<tr>
<td>MOVE.L $1000,D0</td>
<td>D0= FFFFFFFF</td>
<td>D0= 01234567</td>
</tr>
<tr>
<td></td>
<td>$1000= 01234567</td>
<td>$1000= 01234567</td>
</tr>
</tbody>
</table>

Figure 2.23 – An example of the MOVE.L $1000,D0 instruction with 16-bit address

**Absolute Long Addressing**

- Addressing Mode Field: 111
- Register Field: 001
- Assembler Syntax: x (x is a 32-bit constant)

**Description**

Mode 7 with a register field of one indicates that the longword following the instruction is an absolute 32-bit address. Remember that the high byte of the address is presently discarded.
Example

The instruction `MOVE.L $10000,D0` causes the contents of the memory location specified by the address of the instruction plus 102 hex to be copied into data register D0. Figure 2.24 shows the format of this instruction. Figure 2.25 shows how the instruction works.

$10000$ indicates the contents of the longword in memory at address 10000 hex. Many 68000 assemblers use the prefix $\$ $ to indicate hex numbers.
**Program Counter with Displacement**

Register Field: 010  
Assembler Syntax: \( x(\text{PC}) \) (\( x \) is a 16-bit constant)

**Description**

Mode 7 with a register field of two indicates that the word following the instruction is a displacement to be added to the program counter in order to obtain a memory address. The displacement is sign-extended before the addition takes place. Thus, it is possible to address memory in a range from \(-32,768\) to \(+32,767\) bytes relative to the present instruction. The value used for the program counter is the address of the displacement word.

The program counter with displacement is denoted as \( xxxx(\text{PC}) \), where \( xxxx \) is a constant 16-bit number.

**Example**

The instruction \texttt{MOVE.L } \$100(\text{PC}),D0\texttt{ } causes the contents of the memory location specified by the address of the instruction plus 102 hex to be copied into data register \( D0 \). Figure 2.26 shows the format of this instruction.

Suppose the first word of the instruction is at location 1000 hex. Figure 2.27 shows how the instruction would work.

\$1102 indicates the contents of the longword in memory at address 1102 hex. Many 68000 assemblers use the prefix \$ to indicate hex numbers.

![Figure 2.26 - Format of the MOVE.L$100(\text{PC}),D0 instruction](image)
Program Counter with Index

Addressing Mode Field: 111
Register Field: 011
Assembler Syntax: x(PC,Dn.L) (x is 8 bits, n is 0–7)
                     x(PC,Dn.W)
                     x(PC,An.W)
                     x(PC,An.L)

Description

Mode 7 with a register field of 3 indicates that the memory address is to be constructed using the value of the program counter, an index register, and a sign-extended 8-bit displacement. This mode is similar to the address register with index mode instruction. The same format extension word is required. Figure 2.28 shows the format of this instruction.

The program counter with index is denoted as xxx(PC,xr.s), where xxx is a constant 8-bit number, and xr.s is a register name with size specification. For example, indexing with the word contained in DO and a displacement of 10 hex is written $10(PC,D0.W).

Example

The instruction MOVE.L $10(PC,A1.L),DO causes the contents of the memory location at the address of the instruction plus the contents of A1 plus 12 hex to be copied into data register D0. Figure 2.29 shows the format of this instruction.
Suppose the first word of the instruction is at location 1000 hex. Figure 2.30 shows how the instruction would work.

$2012$ indicates the contents of the longword in memory at address 2012 hex.

---

**Figure 2.28** - Format of program counter with index extension word

---

**Figure 2.29** - Format of MOVE.L $10(PC,A1.L),D0$ instruction

---

<table>
<thead>
<tr>
<th>Instruction</th>
<th>Before</th>
<th>After</th>
</tr>
</thead>
<tbody>
<tr>
<td>MOVE.L $10(A1.L,PC),D0$</td>
<td>D0 = $FFFFFFFF$</td>
<td>D0 = 01234567</td>
</tr>
<tr>
<td></td>
<td>$2102 = 01234567$</td>
<td>$2102 = 01234567$</td>
</tr>
<tr>
<td></td>
<td>A1 = 00001000</td>
<td>A1 = 00001000</td>
</tr>
</tbody>
</table>

**Figure 2.30** - An example of the MOVE.L $10(PC,A1.L),D0$ instruction
Immediate Mode

Addressing Mode Field: 111 (Source only)
Register Field: 100
Assembler Syntax: #x (x is 8, 16, or 32 bits)

Description

Mode 7 with a register field of 4 indicates that the source data for an instruction is contained in the word or longword (depending on the size of the instruction) that follows the instruction. Byte data for an immediate mode instruction is contained in the low-order byte of the word following the instruction.

Immediate mode is denoted by #(constant) where (constant) is a hex or decimal number. Many assemblers allow symbols to be defined for use as immediate quantities. (See the section on assemblers in Chapter 3 for additional information.)

Example

The instruction MOVE.L #$10002000,D0 causes the long constant 10002000 (hex) to be loaded into data register D0. The previous contents of D0 are lost. Figure 2.31 shows the format of this instruction. Figure 2.32 shows how this instruction works.

![Figure 2.31 - Format of the MOVE.L #$10002000,D0 instruction](image)
### Status Register Addressing

**Addressing Mode Field:** 111 (Destination only)

**Register Field:** 100

**Assembler Syntax:**
- SR
- CCR

**Description**

Mode 7 with a register field of 4, when used as a destination field on some instructions, indicates that the operation is to be performed on the status register. The And Immediate (ANDI), Exclusive Or Immediate (EORI), and Or Immediate (ORI) instructions are the only operations that can use this addressing mode.

When the instruction specifies a byte length, then only the user byte of the status register is affected. When a word length instruction is used, then both the system and user bytes are affected. The System bit in the status register must be set to 1 in the latter case.

The assembler recognizes the special labels SR (for the whole status register) and CCR (for the user byte). CCR is an acronym for Condition Code Register. Only the condition codes are stored in the status register user byte.

**Example**

The ORI #5,CCR instruction sets both the carry (C) and zero (Z) flags. Figure 2.33 shows the format of this instruction. Figure 2.34 shows how the instruction works.

---

**Figure 2.32** – An example of the MOVE.L #$10002000,D0 instruction

<table>
<thead>
<tr>
<th>Instruction</th>
<th>Before</th>
<th>After</th>
</tr>
</thead>
<tbody>
<tr>
<td>MOVE.L #$10002000,D0</td>
<td>D0 = 01234567</td>
<td>D0 = 10002000</td>
</tr>
</tbody>
</table>

---

**Table 2.32** – Addressing mode for the status register

<table>
<thead>
<tr>
<th>Addressing Mode Field</th>
<th>Register Field</th>
<th>Assembler Syntax</th>
</tr>
</thead>
<tbody>
<tr>
<td>111</td>
<td>100</td>
<td>SR, CCR</td>
</tr>
</tbody>
</table>
STACKS AND STACK FRAMES

Many commercial microcomputers today (including the 68000) have a feature called a stack. A stack is a storage technique similar to the spring-loaded platforms used for plates in a cafeteria line. The last byte, word, or longword, placed on the stack is the first data item to be removed. This storage scheme is called Last-In-First-Out (LIFO). The act of placing a new data item on the stack is known as a push. Removing a data item is commonly called a pop.

How a Stack Works

Stacks are implemented on the 68000 using the pre-decrement and post-increment addressing modes. An address register (called the stack pointer)
is used to indicate the top of the stack's position in memory. Data items are pushed onto the stack using the \(-(\text{An})\) addressing mode, and popped using the \((\text{An})+\) addressing mode, as illustrated in Figure 2.35.

The stack pointer always contains the address of the element on top of the stack. Subsequent push operations cause items to be stored at lower addresses. Pop operations cause the stack pointer to be incremented toward higher addresses. The stack is said to “grow toward lower addresses” on the 68000.

### 68000 Hardware Stack

Register A7 on the 68000 is called the hardware stack pointer. This register is used by the 68000 hardware for addressing memory that contains temporary data items. Most 68000 assemblers take the symbol SP (for Stack Pointer) as an alternative to A7 in register specifications.

There are two stack pointers on the 68000: one for when the processor is in user mode (called USP) and one for when the processor is in supervisor mode (called SSP).

<table>
<thead>
<tr>
<th>Address</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>n−3</td>
<td></td>
</tr>
<tr>
<td>Pushes</td>
<td>n−2</td>
</tr>
<tr>
<td>(-(\text{An}))</td>
<td>n−1</td>
</tr>
<tr>
<td>((\text{An}))</td>
<td>n</td>
</tr>
<tr>
<td>Stack Top</td>
<td>Item 1</td>
</tr>
<tr>
<td>n+1</td>
<td>Item 2</td>
</tr>
<tr>
<td>Pops</td>
<td>n+2</td>
</tr>
<tr>
<td>((\text{An})+)</td>
<td>n+3</td>
</tr>
<tr>
<td>Item 3</td>
<td></td>
</tr>
<tr>
<td>Item 4</td>
<td></td>
</tr>
</tbody>
</table>

*Figure 2.35 – 68000 stack operations*
A special instruction, **MOVE USP**, allows the supervisor program to access the USP. The user mode program is not allowed access to the SSP. The present Macintosh runs in supervisor mode and does not use user mode.

Typically, the stack is used for information that will be required again later. For example, there is a common programming technique called a *subroutine*.

**Subroutines**

Subroutines are small programs in themselves that can be used as units of other, larger programs. Typical subroutines include I/O routines and common calculations, such as taking the square root of a number.

The 68000 supports instructions known as *subroutine calls*. These instructions place the address of the next instruction on the stack and the address of the subroutine into the program counter (PC). In this way, the next instruction to be executed becomes the first instruction in the subroutine. When the subroutine has completed processing, it executes a *return* instruction, which restores the address currently on top of the stack back into the PC. This causes the program to resume execution at the instruction that immediately follows the subroutine call.

Subroutines are powerful programming tools. A subroutine is essentially an extension to the instruction set of the machine. The programmer can treat subroutine calls as if they were sophisticated machine instructions.

**Exceptions**

A concept similar to the subroutine call is the 68000 exception mechanism. The 68000 allows the suspension of a program and subsequent resumption of the same program through a technique known as an exception. (This same technique is called an *interrupt* on other machines.)

An exception causes the status register and program counter to be pushed onto the stack. A special instruction allows restoration of the program counter/status register combination at a later point. This mechanism is described in detail in Chapter 7, Exception Programming.

**Stack Implemented in Software**

You can implement a stack using any address register. All that is required is to place the address of the end of the area to be used as a stack into the address register. The pre-decrement and post-increment addressing modes can then be used to push and pop data items from this software stack.
Stack Frames

Stacks are convenient for allocating temporary memory areas. The 68000 supports a hardware mechanism for allocating scratchpads called a stack frame.

The 68000 LINK and UNLK (unlink) instructions allocate and free temporary memory at the top of the stack. An additional address register, called the frame pointer, is used to point to the area allocated on the stack. References to the stack frame use the address register with displacement addressing mode. The frame pointer rather than the stack pointer is used to address the frame so that subsequent stack PUSH and POP operations will not affect the offsets of individual components of the frame.

SUMMARY

The important points that we have covered in this chapter are:

- The 68000 has sixteen registers: eight data registers and eight address registers. Data registers may be used as bytes, words, or longwords. Address registers may be used only as words or longwords. In addition, loading a word into an address register causes the word to be sign-extended to 32 bits.

- There are two special registers: the program counter (PC) and the status register (SR). The program counter contains the address of the next instruction to be executed. The status register contains machine status bits. The upper eight bits of the status register, called the system byte, may not be accessed by ordinary programs. The lower eight bits of the status register, called the condition code register (CCR), contain status bits (condition codes) that indicate the result of the last instruction executed.

- The 68000 supports three principle numeric data types: binary, BCD, and floating-point. Binary data may be used in units of 8 bits (a byte), 16 bits (a word), and 32 bits (a longword). These lengths are indicated on register and instruction names by the suffixes .B, .W, and .L. BCD is a method of storing two decimal digits per byte. Floating-point is a method of representing very large or very small numbers without requiring undue amounts of memory.

- The 68000 supports fourteen distinct methods of specifying data in an instruction. These are called addressing modes. They are listed in Table 2.1.
### Syntax

<table>
<thead>
<tr>
<th>Syntax</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dn</td>
<td>Data register direct</td>
</tr>
<tr>
<td>An</td>
<td>Address register direct</td>
</tr>
<tr>
<td>(An)</td>
<td>Address register indirect</td>
</tr>
<tr>
<td>(An)+</td>
<td>Address register indirect post-increment</td>
</tr>
<tr>
<td>−(An)</td>
<td>Address register indirect pre-decrement</td>
</tr>
<tr>
<td>w(An)</td>
<td>Address register with displacement</td>
</tr>
<tr>
<td>b(An,Rn)</td>
<td>Address register with index</td>
</tr>
<tr>
<td>w(.W)</td>
<td>Absolute short</td>
</tr>
<tr>
<td>l(.L)</td>
<td>Absolute long</td>
</tr>
<tr>
<td>w(PC)</td>
<td>PC with displacement</td>
</tr>
<tr>
<td>b(PC,Rn)</td>
<td>PC with index</td>
</tr>
<tr>
<td>#x</td>
<td>Immediate</td>
</tr>
<tr>
<td>SR</td>
<td>Status register (Privileged)</td>
</tr>
<tr>
<td>CCR</td>
<td>Condition code register</td>
</tr>
</tbody>
</table>

b is a byte constant.
w is a word constant.
l is a long constant.
x can be any of these.
n is a register number, 0–7.
R is a register specifier, either A or D.

### Table 2.1 – Addressing Modes of the 68000

- The post-increment and pre-decrement addressing modes are used to implement data structures called stacks. Stacks are organized in a last-in first-out (or LIFO) scheme in which the last data item to be put on is the first one taken off. Register A7 is used by the 68000 instructions to refer to a special stack called the hardware stack.
• Special 68000 instructions exist that allocate and free temporary scratchpad memory areas on the hardware stack. These scratchpad areas are known as stack frames.

Chapter 3 will build on this background to present the 68000 instruction set and the mechanics of writing 68000 assembly language programs.

EXERCISES

1. Given the following conditions:
   • DO = 00008000
   • A0 = 00001000
   • A7 = 00010000

   What are the results of the following instructions?
   MOVE.B D0,A0
   MOVE.W D0,A0
   MOVE.B D0,(A0)+
   MOVE.B D0,-(A7)

   Give the new contents of all registers and memory locations that change. Use the same starting conditions for all the instructions.

2. The ADD binary instruction can add an effective address operand to a data register. The format of this instruction is shown in Figure 2.36.

   ![Figure 2.36 – ADD binary instruction format](image)

   The Size field is 00 for byte, 01 for word, and 10 for long data. Modify the examples for the addressing modes (except for the status register mode) to use this instruction.
3. The 68000 pre-decrement and post-increment addressing modes are normally used for stacks that grow toward lower addresses. Can these addressing modes be used to implement a stack (in software) that grows toward higher addresses? If so, how would such a stack differ from a normal one? How could the 68000 addressing modes be altered to support such stacks?
INTRODUCTION

This chapter covers the mechanics of program generation and the details of the 68000 instruction set. It is probably not necessary to study each instruction in detail, but you should pay attention to the section on the mechanics of program generation. This information is vital to understanding the instruction descriptions.

INSTRUCTION CLASSES

The 68000 instructions fall into eight classifications:

- Data movement
- Integer arithmetic
- Logical
- Shift and rotate
- Bit manipulation
- BCD
- Program control
- System control

We will now describe each of these classes in detail.
Data Movement

Data movement instructions transport data from one location in the 68000 to another. Normally, these instructions move from one to four bytes of data between two registers, a register and memory, or between two memory locations.

This category of 68000 instructions includes:

- The EXG (EXchanGe) instruction. Exchanges the contents of two registers.
- The LEA (Load Effective Address) instruction. Calculates a memory address and places it in an address register.
- The LINK instruction. Allocates a stack frame.
- The MOVE instruction. Transfers one register or memory location to another.
- The MOVEM (Move Multiple) instruction. Transfers multiple registers to or from memory.
- The MOVEP (Move Peripheral) instruction. Transfers data to or from an 8-bit peripheral.
- The MOVEQ (Move Quick) instruction. Loads a data register with a constant.
- The PEA (Push Effective Address) instruction. Calculates a memory address, and pushes it onto the hardware stack.
- The SWAP instruction. Swaps the words in a data register.
- The UNLK (UNLinK) instruction. Deallocates a stack frame.

Integer Arithmetic Operations

Integer arithmetic instructions perform basic two's complement operations on binary data. This class of instructions includes:

- The ADD, ADDA, ADDI, ADDQ, and ADDX instructions. Used for two's complement addition.
- The CLR instruction. Moves zero into an operand.
- The CMP, CMPA, CMPI, and CMPM instructions. Compares two quantities.
• The DIVS and DIVU instructions. Perform signed and unsigned integer division.

• The EXT instruction. Sign extends a byte to a word quantity or a word to a long quantity.

• The MULS and MULU instructions. Used for signed and unsigned multiplication operations.

• The NEG and NEGX operations. Form the two's complement of a number.

• The SUB, SUBA, SUBI, SUBQ, and SUBX instructions. Used for two's complement subtraction.

• The TAS (Test and Set) instruction. Used to synchronize multiple processors.

• The TST instruction. Compares an operand to zero.

**Logical Operations**

The logical operation instruction group performs bit-wise Boolean operations on binary numbers. This class of instructions includes:

• The AND and ANDI instructions. Perform a Boolean AND operation on two binary integers.

• The OR and ORI instructions. Perform a Boolean OR operation.

• The EOR and EORI instructions. Perform a Boolean exclusive OR operation.

• The NOT instruction. Perform a one's complement operation.

**Shift and Rotate Operations**

The shift and rotate instructions perform arithmetic and logical shifts, as well as rotates with and without an auxiliary Carry bit. This group contains:

• The ASL and ASR instructions. Arithmetic left and right shift operations.

• The LSL and LSR instructions. Logical left and right shift operations.
• The ROL and ROR instructions. Left and right rotates without an auxiliary Carry bit.
• The ROXL and ROXR instructions. Left and right rotates through an auxiliary Carry bit.

**Bit Manipulation Operations**

The bit-manipulation instructions operate on single bits within a byte. This instruction class contains:

• The BTST instruction. Tests a single bit.
• The BSET instruction. Tests a single bit and then sets the bit.
• The BCLR instruction. Tests a single bit and then clears the bit.
• The BCHG instruction. Tests a single bit and then inverts (complements) the bit.

**Binary Coded Decimal Instructions**

The binary coded decimal (BCD) instructions manipulate numbers in BCD format. This group contains:

• The ABCD instruction. Performs BCD add operations.
• The SBCD instruction. Performs BCD subtract operations.
• The NBCD instruction. Performs BCD negation.

**Program Control Instructions**

The program control instructions alter the instruction flow through a program segment. This group contains:

• The Bcc instruction group of fifteen conditional-branch instructions. Conditionally alter the flow of instructions.
• The DBcc instruction group, consisting of sixteen looping-primitive instructions.
• The Scc instruction group of sixteen conditional-set instructions. Set a byte depending on the settings of the condition code.
• The BSR and JSR subroutine call instructions.
• The RTS subroutine return instruction.
• The JMP absolute jump instruction.
• The RTR instruction. Restores the program counter and condition codes from the stack.

**System Control Operations**

System control instructions alter the state of the 68000 hardware environment.

Many of these instructions are "privileged," meaning that they require that the 68000 be executing in supervisor mode. This instruction class contains:

• The MOVE USP instruction. Allows a supervisor mode program access to the user mode stack pointer.
• The RESET instruction. Resets external devices.
• The RTE instruction. Returns from an exception condition. (Exceptions are described in Chapter 7.)
• The STOP instruction.Suspends instruction processing until an external event occurs.
• The CHK and TRAPV instructions. These instructions detect catastrophic program errors.
• The TRAP group of sixteen instructions. Provide a method for a user mode program to call a supervisor mode program.

All Macintosh software runs in supervisor mode, so there is no restriction on the instructions your programs can execute. You should, however, exercise care in using privileged instructions. Improper use of these instructions may cause the system to crash, forcing you to reboot.

**PROGRAM DEVELOPMENT MECHANICS**

The process of writing an assembly language program for the Macintosh is illustrated in the following four steps:

1. Key in the program using EDIT (the text editor). The disk file that results is called the assembly source (.asm) file.
2. Transform the program into machine code using the assembler program. The machine-code file produced by the assembler is called an object (.rel) file. The assembler can also produce a listing (.lst) file that contains the instructions from the source file along with the machine code in the object file (produced in hexadecimal).

3. Before the program can be executed, the Macintosh Development System requires that the object output of the assembler be processed by a program called a linker or linkage editor. Many large programs are split into separate source files, assembled separately, and then combined with the linker. This process results in a file that is ready to be loaded into memory and executed. This file is called a load file, executable file, or a load module. The load file produced by the linker shows up as an "application" in the Macintosh Finder.

4. The load file produced by the above steps is then loaded into memory and executed.

This process is illustrated in Figure 3.1.

Usually, the programmer needs to repeat each of these steps many times. Often, the file must be edited many times before it assembles without errors. Then, the assembled file still may not link properly, necessitating more editing and assembling. Finally, the successfully linked file may not run properly.
This is the time to check for bugs, or errors in the program. Finding bugs in object programs is more of an art than a science. Fortunately, there are tools that make the task easier. One is the popular method of printing out values within the program by inserting a temporary printing code. The second, and more valuable tool, is the interactive debugger. This program allows you to stop at certain points in the program and look at the values that are currently in the registers and in memory. Many debuggers also allow you to specify labels contained in the program source file.

There are several assembly language development packages available for the Macintosh. In this book, we will use the Macintosh Development System from Apple.

**Editing**

Developing programs requires only a simple editor. There are many to choose from, and determining which is the best one is a matter of personal preference.

The Macintosh editor is called EDIT; it operates only on files known as textfiles. The source file for the assembler must be a textfile. You can also create textfiles using MacWrite with the Text Only option on the Save menu. Other examples of textfiles include the listing file produced by the assembler, the MAP file produced by the linker, and the information saved by MacTerminal from an interactive session with another computer. You can use EDIT to inspect, alter, or print any textfile.

EDIT is a mouse-driven, multiwindow, screen-oriented editor. You can edit multiple files, arranging and sizing the display for each file on the screen. You can even cut information from one file and paste it into another.

**Backups**

Maintaining backup copies of source files is essential because of the possibility of a hardware or software failure. While hardware failures are comparatively rare, they still occur from time to time. Software and media failures are all too common. Power failures can also destroy disk files. There is a bit of conventional engineering wisdom known as Murphy's Law:

> If anything can go wrong, it will.

You will find that this law applies to programming as well. Most programmers keep two backup copies in case the machine crashes while
making a backup. (If this occurs, it is possible to destroy both the original and the backup.) Recovery from such a disaster is extremely painful. Unfortunately, most people have to learn this lesson the hard way, as Ben Franklin said:

*Experience is a dear school, but fools will learn at no other.*

Don’t be one of them! Back up your files!

**Source File Format**

The source file that you input to the assembler consists of lines of text. Each line in the source file can be classified as one of the following four things:

- **A comment line.** Comments in the Macintosh assembler are denoted by placing a semicolon (;) as the first character on the line. Comments can also be placed at the end of any other line.
- **A 68000 instruction.** Instruction lines consist of an optional label, followed by an instruction mnemonic, followed by one or more operands. Spaces or tabs are required between the label, mnemonic, and operand fields. Commas are used to separate multiple operands. The assembler does not allow spaces between operands.
- **A macro invocation.** Macros are predefined sequences of source lines that are invoked by a single source line.
- **An assembler directive.** Directives are a means of telling the assembler how you want your program treated. The Macintosh assembler has the following directives:

1. **STRING_FORMAT.** This directive controls how the assembler handles text in quotes.
2. **IF, ELSE, and ENDIF.** These directives include or ignore part of a program, depending on the result of an expression. This feature is called *conditional assembly*. Programs that require source changes to work in different environments often use conditional assembly to generate multiple versions of the program from a single source file.
3. **INCLUDE.** This directive causes the entire contents of a file to be used in the assembly at the point where the INCLUDE directive occurs.
4. **MACRO and .MACRO/.ENDM.** These directives define a set of source lines to be used by a macro invocation.
5. **EQU.** This directive allows you to create a symbolic name for a constant value.

**Assembling**

The Macintosh assembler takes a textfile as input and produces a machine-code (object) file and an optional program listing file. There are a set of file-name conventions that must be followed. For an application named “Program”, the assembly source file is named “Program.asm”. The object file produced by the assembler is called “Program.rel”, and the listing file is called “Program.lst”. The Macintosh ignores case differences in file names, so these names can be any combination of uppercase and lowercase letters.

**Linking**

After obtaining an error-free assembly, you must link the object file in order to make it executable. For the linker to work, you must write a textfile, called a *linker command file*, containing the names of the files to be linked. The file names must be listed one per line, ending with a line containing a dollar sign ($) as the first character. If your application is named “Program”, the linker command file is usually called “Program.link”.

For example, assume you want to link five object files, named File1.rel through File5.rel. You could create a file called Files.link, containing the following:

```
file1
file2
file3
file4
file5
$
```

When the linker runs, it places the executable program in a file called File1.

**EXEC**

For applications involving more than one source file or long assembly and link times, you can automate the assembly and link process. The Macintosh Development System includes an application called *EXEC* that executes commands contained in a textfile. This textfile must consist of
lines of text in the following format:

```
application    file   program1   program2
```

The command file must have a "job" extension, and you must separate all of the fields with a single tab character. EXEC interprets two consecutive tab characters as a blank field. Application is the name of a program to be run, and File is the file the program should operate on. If the application completes without error, Program1 is run. If the application terminates because of errors, Program2 is run. Normally, Program1 is EXEC and Program2 is EDIT. If the application terminates with no errors, EXEC runs again and starts the next application. In an error situation, running EDIT allows you to make corrections to the file causing the error. You can then use EXEC's Resume and Redo Last option to retry the failing step.

For instance, if you want to assemble the five text files File1.asm through File5.asm and then link them using the linker command file Files.link, you could use a file named Files.job, which contains the following lines of text:

```
assembler file1.asm   executor editor
assembler file2.asm   executor editor
assembler file3.asm   executor editor
assembler file4.asm   executor editor
assembler file5.asm   executor editor
linker files.link     executor editor
```

If an error is detected during, say, the assembly of File3.asm, the editor is automatically invoked as if you had opened File3.asm from the Finder. After fixing the problem with the editor, you could select EXEC from the editor's Transfer menu. Once inside EXEC, you could select Resume and Redo Last from the File menu. EXEC would then resume the job stream, starting by reassembling File3.asm.

**Debugging**

The application or load file created by the linker can be executed in the same way as any other Macintosh application: by selecting the application icon in the Finder, in the Open Application menu of EXEC, or in the Transfer menu in the linker. But what if the file doesn't execute correctly? How do you figure out what is wrong?

When something goes wrong, use the interactive debugger. The Macintosh has three interactive debuggers: one that uses the bottom of the screen as a debugging "window," one that uses an external serial terminal, and one that uses another Macintosh. These debuggers are called
MacsBug, TermBug, and MacDB, respectively. A special version of MacsBug, called MaxBug, can be used on a Macintosh with 512K of memory. (This machine is known affectionately as a “Fat Mac.”) MaxBug allows you to use the whole screen for debugging and to switch back and forth from the debugging screen to the application screen. All of these debugging programs allow you to interact with an executing program so that you can identify any problem areas.

The Macintosh debuggers all provide the following features:

- The ability to examine and change the contents of a machine register or a memory location.
- The ability to start execution at a desired location, and stop execution at one of several points (commonly called breakpoints).
- The ability to execute a single instruction at a time. This is commonly called tracing, because it is the Trace bit in the status register that provides this capability.

To use a debugger, you must first install the one you want to use in the system. Then you must activate the debugger after the program you want to debug has been loaded into memory. Installing the debugger is described below. To activate the debugger after the test program has been loaded, place an illegal instruction as the first instruction of the program. This causes the debugger to be activated as soon as the program starts execution.

You can also activate a debugger by using the interrupt button on the side of the Macintosh. (You should install one if you haven’t already—it is very useful in assembly language programming.)

**Installing the Debugger**

The two one-machine debuggers, MacsBug and TermBug, are installed by copying the desired debugger to a file named MacsBug on the startup disk. When the system boots, the debugger is loaded automatically. The message “MacsBug installed” should appear below the “Welcome to Macintosh” message printed when the system boots. MacsBug (which needs no additional hardware) occupies 16K of memory. TermBug (which uses an external terminal) requires about 10K of memory. You can change the debugger name in the boot record with the application “Boot Config”.

To install the MacDB (two-machine) debugger, run a serial cable between the machines. Then run MacDB in one machine and a program called a “debug nub” in the target machine. The machine running
MacDB will accept debugging commands for the application running in the target machine.

**Example—Summing the First Five Integers**

To illustrate how to use the Macintosh programming tools, let's write a simple program that sums the first five integers and stores the result in memory. We need to write an assembly source file, a linker control file, and an EXEC job file. These files are shown on the screen in Figure 3.2.

The first line of the Sum5.asm file generates an illegal instruction that causes the debugger to gain control. Subsequent lines accumulate the sum of the numbers 1 through 5, stored in memory locations A through E, in register D0.W. The LEA instruction causes A0 to point to memory location F. D0 is then stored there. The RTS instruction returns control to the Finder.

The files on disk before assembly and linking are shown in Figure 3.3. The disk with the assembler, linker, and EXEC utility is called “MDS1 Backup” in this example. Invoking EXEC on the file Sum5.job causes the program to be assembled and linked, producing the files shown in Figure 3.4.

The assembler listing file for Sum5 is shown in Listing 3.1. The first column of numbers contains the decimal line number of the source line.

![Figure 3.2 - Creating the Sum5 source files](image-url)
in the source file. The second column of numbers contains the hexadecimal address of each instruction, relative to the first instruction in the file.

Figure 3.3 - The Sum5 source files on disk

Figure 3.4 - The Sum5 object files on disk
The binary machine code generated appears next, followed by the line from the source file. Locations marked "xxxx" are addresses that must be processed by the linker. The Macintosh assembler uses the PC-relative addressing mode for labels on instructions or DC (Define Constant) assembler directives. This is why the LEA instruction is necessary—PC-relative addressing cannot be used on a destination memory operand.

To execute the program, we used TermBug and captured the output and keyboard input in a file. The debugging session is shown in Listing 3.2.

```
1 0000 FF01  DC.W  $FF01
2 0002 303A xxxx(R)  MOVE.W A,D0 ; Load First Number
3 0006 D07A xxxx(R)  ADD.W  B,D0 ; Add second number
4 000A D07A xxxx(R)  ADD.W  C,D0
5 000E D07A xxxx(R)  ADD.W  D,D0
6 0012 D07A xxxx(R)  ADD.W  E,D0
7 0016 41C0 xxxx(PX)  LEA  F,A0 ; A0 -> Answer
8 001A 3080  MOVE.W D0,(A0) ; Store Result
9 001C 4E75  RTS  ; Back to Finder
10 001E 0001  A: DC.W  1 ; Data Follows
11 0020 0002  B: DC.W  2
12 0022 0003  C: DC.W  3
13 0024 0004  D: DC.W  4
14 0026 0005  E: DC.W  5
15 0028 0000  F: DC.W  0 ; Space for Answer
```

Listing 3.1 - The Sum5 assembly listing file

```
1111 ERR
>TD
00004F9A:  $$$$  
PC=00004F9A  SR=00002004  
D0=00000000  D1=00000000  D2=00000000  D3=FFFEFEFE  
D4=00001200  D5=00003EFF  D6=0000FFFF  D7=00000000  
A0=00015D24  A1=00017E44  A2=00016ED2  A3=00017E46  
A4=00006124  A5=00017E24  A6=00016D92  A7=00017D20  
>DM 4F9A 30
004F9A  FF 01 30 3A 00 1A D0 7A 00 18 D0 7A 00 16 D0 7A 00 ...O...z...z...z
004FAA  00 14 D0 7A 00 12 41 FA 00 10 30 80 4E 75 00 01 ...z...A...0.Nu...
```

Listing 3.2 - The Sum5 debugging session
Listing 3.2 – The Sum5 debugging session (continued)
The debugger first printed out

1111 ERR

indicating that an illegal instruction with the first four bits equal to F hex caused the debugger to gain control. This is the result of executing the instruction

\texttt{DC.W \$FF01}

at the beginning of the program.

The debugger prints a "\texttt{>}" (greater than) character as an input prompt. The TD (Total Display) command causes the debugger to print the instruction to be executed next, together with the contents of all the registers. The first instruction printed out as "\texttt{$$$$}" because \texttt{\$FF01} is an illegal instruction.

Next, we used the DM (Display Memory) command to list the program. With the Macintosh, you don't know where the program will be placed in memory, so you must use the address contained in the PC when the illegal instruction is attempted. This is 4F9A. From the assembly listing, we see that the program is 28 (hex) bytes long. The command

\texttt{DM 4F9A 30}

<table>
<thead>
<tr>
<th>Address</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>004F9A</td>
<td>FF 01 30 3A 00 1A D0 7A 00 18 D0 7A 00 16 D0 7A</td>
</tr>
<tr>
<td>004FAA</td>
<td>00 14 D0 7A 00 12 41 FA 00 10 30 80 4E 75 00 01</td>
</tr>
<tr>
<td>004FBA</td>
<td>00 02 00 03 00 04 00 05 00 <em>0</em> 00 00 16 30 00 01</td>
</tr>
</tbody>
</table>

\textbf{Listing 3.2 – The Sum5 debugging session (continued)}
causes 30 (hex) bytes to be listed starting from address 4F9A. The data listed corresponds to the machine code in the assembly listing.

Next, we used the IL (Instruction List) command to disassemble the instructions. The command

IL 4F9A 9

disassembles nine instructions starting at location 4F9A. Note that all memory locations are referenced as

* + hex number

indicating PC-relative addressing.

When the 68000 encounters an illegal instruction, the PC does not advance to point to the next instruction, as it normally does. This means that in order to execute the next instruction, we must advance the program counter by hand. The debugger command

PC 4F9C

causes the program counter to point to the first real instruction. You must do this every time you use the illegal-instruction technique to debug a program. Later versions of MDS do this automatically.

Next, we use the T (Trace) command to execute each instruction in the program. Note that the status register displayed after the instruction is executed has the Trace bit (15) and the Supervisor bit (13) set.

Prior to executing the RTS instruction, we redisplay the program in hex. Note that location 4FC2 has been changed. The debugger G (Go) command returns control to the Finder.

**DDT-68K**

In explaining the 68000 instruction set, we will make use of the CP/M-68K debugger, DDT-68K. We also use CP/M to execute the instructions. This system allows us to use absolute addressing for memory operands, which the Macintosh does not allow. Using absolute addresses makes it much easier to determine a memory operand's location in the examples.

This debugger is called a hex debugger because it lacks the ability to use labels from the source program. A debugger that can use these labels is called a symbolic debugger. (A later version of DDT-68K provides symbolic capability.) The Macintosh single-machine debuggers MacsBug and TermBug are hex debuggers. The Fat Mac debugger, MaxBug, and the two-machine debugger, MacDB, both have symbolic capability.
We will use the following commands from DDT-68K:

- The Lxxxxx,yyyyy command. This causes memory locations xxxxx through yyyyy to be displayed as 68000 instruction mnemonics.

- The Dxxxxx,yyyyy command. This causes memory locations xxxxx through yyyyy to be displayed in hex.

- The Sxxxxx command. This causes memory location xxxxx to be displayed for possible modification. Pressing Return causes the debugger to prompt for the next command.

- The G,xxxxx command. This starts program execution at the location contained in the program counter and stops program execution immediately before the instruction at xxxxx.

- The T command. The next instruction is executed, using the Trace bit hardware mechanism.

**DDT-68K Example**

Suppose that we wish to execute the source file shown in Listing 3.3 under CP/M-68K. This is the same program as the Macintosh example.

```
.text
*****************************************************************************
* This program adds the first five integers and stores the result in memory.
*****************************************************************************
start: move.w a,d0     Load first number
add.w b,d0
add.w c,d0
add.w d,d0
add.w e,d0
move.w d0,f     Store answer
rts               Return to CP/M
.data
a:   dc.w 1     Numbers to add
b:   dc.w 2
c:   dc.w 3
d:   dc.w 4
e:   dc.w 5
f:   dc.w 0     Answer goes here
.end

Listing 3.3 - The Sum5 source file for CP/M-68K
```
Note that the LEA instruction is not required. The CP/M-68K assembly listing file is shown in Listing 3.4.

The first number on each line is the number of the line in the source file, starting with 1. The assembler reports errors by line number.

The second number is the hex offset at which the present line is assembled. When added to the load address of the text (instructions), data (initialized data), or bss (uninitialized data) segment as appropriate, this number yields the absolute memory address of the instruction or data described by the line.

The third number in each line is the actual hex contents of the memory location when the program is loaded into memory. Addresses may not be relocated to their final value until load time. The assembly listing reflects addresses as they are known to the assembler.

The linker relocates all addresses to the values that they will have at execution time. Later, when the program is loaded into memory, it may be relocated yet again if the base address of the program does not match the address to which it was linked. By the time the program begins execution, however, all addresses are absolute.

The source line as it appears in the file comes next. Source lines that begin with an asterisk (*) are placed in the listing file as is. Such a line is

```
.text

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

* This program adds the first
* five integers and stores the
* result in memory

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

start: move.w a,d0    Load first number
        add.w b,d0
        add.w c,d0
        add.w d,d0
        add.w e,d0
        move.w d0,f    Store answer
        rts            Return to CP/M

.data

a:   dc.w 1     Numbers to add
b:   dc.w 2

.c:

c:   dc.w 3

.d:

d:   dc.w 4

e:

e:   dc.w 5

.f:

f:   dc.w 0    Answer goes here

.end
```

Listing 3.4 - The CP/M-68K Sum5 assembly listing file
called a comment line. Comments serve only to help the human reader understand the program.

Other lines consist of an optional label, an opcode or directive, and one or more operands. Additional text on the line following the operands is regarded as comments by the assembler. At least one space is required between the end of the last operand and the beginning of the comment. The leading asterisk is not required for a comment at the end of a line.

A label on a line establishes a symbolic name for a memory location. A label must be the first word on a line, and must be terminated by a colon (or by a space or tab if the label starts in column 1). The label may then be referred to by instructions that reference memory. The memory locations a: through f: in Listing 3.4 illustrate this usage. These labels are tags for the memory locations referenced by the program's MOVE and ADD instructions.

The linker produces an executable file called test.68k. To run the program under the debugger, we type:

```
A>ddt test.68k
```

**DDT-68K**  
Copyright 1982, Digital Research

```
text base = 00000500 data base = 00000526 bss base = 00000532  
text length = 00000026 data length = 00000000 bss length = 00000000  
base page address = 00000400 initial stack pointer = 0001A2B8
```

This information indicates that the program is loaded into memory starting at 500 hex (text base). The data section of the program begins at address 526 hex (data base). From the assembly listing, we can see that the text portion is 26 bytes long. We can now use the debugger to list out the program in 68000 mnemonics with the I (el) command:

```
-1500,524  
00000500 move $526,D0  
00000506 add $528,D0  
0000050C add $52A,D0  
00000512 add $52C,D0  
00000518 add $52E,D0  
0000051E move D0,$530  
00000524 rts
```

The data area is between addresses 526 and 532. The data base printed out by DDT (526) and data length (0c), when added together, produce the first address beyond the data area (532). We can display the data area
with the Display Words (dw) command:

\[-\text{dw}526,532\]

\[00000526\ 0001\ 0002\ 0003\ 0004\ 0005\ 0000\ \ldots\ldots\ldots\ldots\]  

The Trace (t) command is used to execute each instruction. DDT shows the registers before the instruction is executed, as shown below:

\[\begin{array}{c}
\text{PC} = 00000500 \\
\text{USP} = 0001A2B0 \\
\text{SSP} = 00002000 \\
\text{ST} = 0000 = > \text{IM} = 0 \\
\hline
\text{D} & 0000000D & 0000000D & 0000000D & 0000000D & 0000000D & 0000000D \\
\text{A} & 000000A0 & 000000A1 & 000000A2 & 000000A3 & 000000A4 & 000000A5 & 000000A6 & 0001A2B0 \\
\end{array}\]

\[-\text{t}\]  

\[\begin{array}{c}
\text{PC} = 00000506 \\
\text{USP} = 0001A2B0 \\
\text{SSP} = 00002000 \\
\text{ST} = 0000 = > \text{IM} = 0 \\
\hline
\text{D} & 0000000D & 0000000D & 0000000D & 0000000D & 0000000D & 0000000D \\
\text{A} & 000000A0 & 000000A1 & 000000A2 & 000000A3 & 000000A4 & 000000A5 & 000000A6 & 0001A2B0 \\
\end{array}\]

\[-\text{t}\]  

\[\begin{array}{c}
\text{PC} = 00000512 \\
\text{USP} = 0001A2B0 \\
\text{SSP} = 00002000 \\
\text{ST} = 0000 = > \text{IM} = 0 \\
\hline
\text{D} & 0000000D & 0000000D & 0000000D & 0000000D & 0000000D & 0000000D \\
\text{A} & 000000A0 & 000000A1 & 000000A2 & 000000A3 & 000000A4 & 000000A5 & 000000A6 & 0001A2B0 \\
\end{array}\]

\[-\text{t}\]  

\[\begin{array}{c}
\text{PC} = 00000518 \\
\text{USP} = 0001A2B0 \\
\text{SSP} = 00002000 \\
\text{ST} = 0000 = > \text{IM} = 0 \\
\hline
\text{D} & 0000000D & 0000000D & 0000000D & 0000000D & 0000000D & 0000000D \\
\text{A} & 000000A0 & 000000A1 & 000000A2 & 000000A3 & 000000A4 & 000000A5 & 000000A6 & 0001A2B0 \\
\end{array}\]

\[-\text{t}\]  

\[\begin{array}{c}
\text{PC} = 00000524 \\
\text{USP} = 0001A2B0 \\
\text{SSP} = 00002000 \\
\text{ST} = 0000 = > \text{IM} = 0 \\
\hline
\text{D} & 0000000D & 0000000D & 0000000D & 0000000D & 0000000D & 0000000D \\
\text{A} & 000000A0 & 000000A1 & 000000A2 & 000000A3 & 000000A4 & 000000A5 & 000000A6 & 0001A2B0 \\
\end{array}\]

\text{rtn}

Notice how the value of register D0 changes as each number is added. To make the actions of the instructions easier to identify, we will underline registers that change in presenting examples. Just before returning to
CP/M, look at the answer in memory. (Location 530 hex corresponds to
the label f: in the assembly listing.)

- dw530,532
  00000530 000F
- g
  A>

**INSTRUCTIONS**

The rest of this chapter is devoted to presenting the details of the
Motorola 68000 instruction set. For ease of reference, the instructions are
listed in alphabetical order. For each instruction, the following items are
provided:

- A verbal description of what the instruction does.
- Which addressing modes are allowed. (Very few of the instruc-
tions allow all addressing modes.)
- What data sizes (byte, word, long) are allowed.
- Condition codes affected by executing the instruction.
- The layout of the machine code.
- Where possible, an example of how this instruction might be
  used. We will use the DDT-68K debugger to illustrate the results
  of executing the instruction.

**Effective Address Operands**

Most instructions that reference memory do so by means of an effective
address operand. Effective address operands consist of a 3-bit mode field
and a 3-bit register field. These operands are discussed in detail in Chapter 2.
The notation used in the instruction descriptions for an effective address
operand is <ea>. For each effective address operand in an instruction,
the instruction discussion will present a table of addressing modes that are
permitted with the operand.
The ABCD (Add BCD with extend) instruction adds two bytes in BCD (Binary Coded Decimal) format. The destination operand is replaced with the sum of the source and destination bytes.

Addressing Modes Allowed:

<table>
<thead>
<tr>
<th>Dn</th>
<th>An</th>
<th>(An)</th>
<th>(An) +</th>
<th>− (An)</th>
<th>x(An)</th>
<th>x(An,xr.s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>x.w</td>
<td>x.l</td>
<td>x(PC)</td>
<td>x(PC,xr.s)</td>
<td>#x</td>
<td>SR</td>
<td>CCR</td>
</tr>
<tr>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

There are only two forms of this instruction:

1. Add data register to data register (Dn addressing modes). The low-order bytes of two data registers are added and the result stored in the destination register.

2. Add memory to memory. This form of the instruction is designed for adding multiple bytes in memory. The only valid addressing mode is − (An). Since the 68000 stores BCD data with the most significant byte first, one must start at the highest address (where the least significant byte is located) and work down to add multi-byte quantities. (Hence the use of pre-decrement addressing.) Each instruction sets the X-bit if there was a carry out of the most significant BCD digit in the byte. Then the X-bit is added into the next byte.

Data Sizes: Byte only

Condition Codes Affected:

X Set by carry out of the most significant BCD digit.
N Undefined.
Z Cleared if the result is not zero. Unchanged otherwise.
V  Undefined.
C  Set by carry out of the most significant BCD digit.

The Z-bit is cleared if the result was not zero. Not setting the bit when the result of the present byte is zero allows the Z-bit to be accurate after a series of ABCD instructions is executed. The Z-bit must be set initially in such a case. (Comparing a register to itself is an easy way to set the Z-bit.) The N and V bits are undefined as a result of this instruction.

Assembler Syntax:  
\[
\text{ABCD} \quad \text{Dx,Dy}
\]
\[
\text{ABCD} \quad -(\text{Ax}), -(\text{Ay})
\]

Machine Code Format:

<table>
<thead>
<tr>
<th>Bit</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>D. Reg</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>F</td>
<td>S. Reg.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The D. Reg and S. Reg fields specify the destination and source register numbers. If the F (format) bit is 0, then the registers are data registers. If the F bit is a 1, then the registers are address registers and the pre-decrement addressing mode is used.

Example:
This example adds two values in data registers:

PC = 0000050C USP = 0001598C SSP = 0007BF08 ST = 0000 = >IM = 0
D 00000099 00000001 00000000 00000000 00000000 00000000 00000000 00000000
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001598C
abcd.b D1,D0
- t
PC = 0000050E USP = 0001598C SSP = 0007BF08 ST = 0011 = >IM = 0  EXT CRY
D 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001598C

Since we added 1 to 99, the result is zero, with the EXT (extend) bit set in the status register. The next example adds two two-byte BCD numbers in memory. The addresses in registers A0 and A1 point to the ends of the BCD numbers.

PC = 0000051E USP = 0001598C SSP = 0007BF08 ST = 0000 = >IM = 0
D 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
A 0000082A 0000082C 00000000 00000000 00000000 00000000 00000000 0001598C
abcd.b - (A0), -(A1)
Show the operands before the first add:

\[-\text{dw}828,82c\]
\[00000828 \text{ 0099 } 0001\]
\[-t\]

PC = 00000520 USP = 001598C SSP = 0007BF08 ST = 0011 = >IM = 0 EXT CRY
D 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
A 00000829 0000082B 00000000 00000000 00000000 00000000 00000000 0001598C
abcd.b –(A0), –(A1)

Now look at the operands:

\[-\text{dw}828,82c\]
\[00000828 \text{ 0099 } 0000\]
\[-t\]

PC = 00000522 USP = 001598C SSP = 0007BF08 ST = 0000 = >IM = 0
D 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
A 00000828 0000082A 00000000 00000000 00000000 00000000 00000000 0001598C

Now look at the results:

\[-\text{dw}828,82c\]
\[00000828 \text{ 0099 } 0100\]

This example adds 99 to 1 to become 100. (The second operand is destroyed.) The memory displays show exactly what happens at each step of the process. Notice how the Extend bit gives the carry between the two add operations.
ADD Instruction

The ADD (Add binary) instruction adds two operands together and stores the result in the destination operand. There are two forms of this instruction:

1. Add an effective address operand to a data register.
2. Add a data register to an effective address operand.

Addressing Modes Allowed:
All addressing modes except SR and CCR are allowed when the effective address specifies a source operand:

<table>
<thead>
<tr>
<th>Dn</th>
<th>An</th>
<th>(An)</th>
<th>(An) +</th>
<th>− (An)</th>
<th>x(An)</th>
<th>x(An,xr.s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>x.w</td>
<td>x.l</td>
<td>x(PC)</td>
<td>x(PC,xr.s)</td>
<td>#x</td>
<td>SR</td>
<td>CCR</td>
</tr>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

When the effective address field is the destination, then the following addressing modes are allowed:

<table>
<thead>
<tr>
<th>Dn</th>
<th>An</th>
<th>(An)</th>
<th>(An) +</th>
<th>− (An)</th>
<th>x(An)</th>
<th>x(An,xr.s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>x.w</td>
<td>x.l</td>
<td>x(PC)</td>
<td>x(PC,xr.s)</td>
<td>#x</td>
<td>SR</td>
<td>CCR</td>
</tr>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

Using a data register as a destination requires the register destination form of the instruction.
Data Sizes: byte, word, long
Using an address register as the source is valid only for word and long data lengths.

Condition Codes Affected:

- **X** Set by the carry-out of the most significant bit. Cleared otherwise.
- **N** Set if high-order bit of result was 1. Cleared otherwise.
- **Z** Set if result was zero. Cleared otherwise.
- **C** Set by the carry-out of the most significant bit. Cleared otherwise.
- **V** Set if operation resulted in overflow condition. Cleared otherwise.

Assembler Syntax: ADD  \( Dn, <ea> \)
ADD  \(<ea>, Dn \)

Machine Code Format:

<table>
<thead>
<tr>
<th>Bit</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The Register field gives the data register that must be one of the operands. The D-bit is 0 if the Register field is the destination operand. The D-bit is 1 if the effective address is the destination.

The Size field is 00 for byte, 01 for word, and 10 for long operands.

Example:

\[ PC = 00000530 \quad USP = 0001598C \quad SSP = 0007BF08 \quad ST = 0000 = > IM = 0 \]
\[ D 0000FFFF \quad 0000FFFF \quad 00000000 \quad 00000000 \quad 00000000 \quad 00000000 \quad 00000000 \quad 0001598C \]
add $82C,D0

Examine the Memory Operand:

\[-dw82c,82e\]
\[0000082C 0001\]
\[-t\]

\[ PC = 00000536 \quad USP = 0001598C \quad SSP = 0007BF08 \quad ST = 0015 = > IM = 0 \quad EXT \ ZER \ CRY \]
\[ D 00000000 \quad 0000FFFF \quad 00000000 \quad 00000000 \quad 00000000 \quad 00000000 \quad 00000000 \quad 0001598C \]
Notice that the result of adding \(-1\) and \(1\) is zero. (This was a word operation.) The Z-bit was set by this operation. We will now add the same two numbers with an ADD.L instruction.

\[
\text{add.I } \$82E, \text{D1}
\]

Examine the Memory Operand:

\[
-\text{dl82e,832}
\text{0000082E 00000001} \ldots
-\text{t}
\]

PC = 0000053C USP = 0001598C SSP = 0007BF08 ST = 0000 = >IM = 0
D 00000000 00010000 00000000 00000000 00000000 00000000 00000000 00000000
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001598C
**ADDA Instruction**

The ADDA instruction does a binary ADD operation to an address register. In order to allow address computations to be freely intermixed with data operations, this instruction does not affect the condition codes.

**Addressing Modes Allowed:**

<table>
<thead>
<tr>
<th>Dn</th>
<th>An</th>
<th>(An)</th>
<th>(An) +</th>
<th>− (An)</th>
<th>x(An)</th>
<th>x(An, xr.s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>x.w</td>
<td>x.l</td>
<td>x(PC)</td>
<td>x(PC, xr.s)</td>
<td>#x</td>
<td>SR</td>
<td>CCR</td>
</tr>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

The effective address must be the source operand.

**Data Sizes:** word, long

The ADDA operation always affects all 32 bits of the destination address register.

**Condition Codes Affected:** None

**Assembler Syntax:** ADDA <ea>, An

**Machine Code Format:**

The Register field gives the address register that is to be used as the destination operand. The S-bit is 1 for long operands and 0 for word operands.
Example:

PC = 00000548  USP = 0001598C  SSP = 0007BF08  ST = 0000 = >IM = 0
D 00000000  00000000  00000000  00000000  00000000  00000000  00000000  00000000
A 0000FFFF  00000000  00000000  00000000  00000000  00000000  00000000  0001598C
adda $830,A0
− dw830,832
00000830 0001
− t
PC = 0000054E  USP = 0001598C  SSP = 0007BF08  ST = 0000 = >IM = 0
D 00000000  00000000  00000000  00000000  00000000  00000000  00000000  00000000
A 00010000  00000000  00000000  00000000  00000000  00000000  00000000  0001598C

Notice that the operation size was a word, but the result was a long.
**ADDI Instruction**

The ADDI instruction adds a constant to an effective address operand. The source operand is always immediate.

**Addressing Modes Allowed:**

<table>
<thead>
<tr>
<th>Dn</th>
<th>An</th>
<th>(An)</th>
<th>(An) +</th>
<th>– (An)</th>
<th>x(An)</th>
<th>x(An,xr.s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>x.w</td>
<td>x.l</td>
<td>x(PC)</td>
<td>x(PC,xr.s)</td>
<td>#x</td>
<td>SR</td>
<td>CCR</td>
</tr>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

**Data Sizes:** byte, word, long

**Condition Codes Affected:**

- X  Set on carry out of high-order bit.
- N  Set if high bit of result is set.
- Z  Set if result is zero.
- C  Set on carry out of high-order bit.
- V  Set on overflow condition.

**Assembler Syntax:** ADDI  #x,<ea>

Most assemblers automatically choose the ADDI instruction if the source operand of an ADD instruction is immediate (and not 1 to 8). Therefore, ADDI need not be used; simply use ADD.
### Machine Code Format:

<table>
<thead>
<tr>
<th>Bit</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **Size**: 00 for byte operations, 01 for word operations, and 10 for long operations.

**Example:**

PC = 00000560 USP = 0001598C SSP = 0007BF08 ST = 0000 = >IM = 0
D 00007FFF 0000FFFF 00000000 00000000 00000000 00000000 00000000 00000000
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000

addi #$10,00

- **t**

PC = 00000566 USP = 0001598C SSP = 0007BF08 ST = 0000 = >IM = 0
D 0000800F 0000FFFF 00000000 00000000 00000000 00000000 00000000 00000000
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000

This instruction adds 10 hex to the contents of register D0.L.

- **t**

PC = 0000056A USP = 0001598C SSP = 0007BF08 ST = 0011 = >IM = 0 NEG ZER OFL CRY
D 0000800F 0000FFFF 00000000 00000000 00000000 00000000 00000000 00000000
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000

addi #$10,D1

- **t**

PC = 0000056E USP = 0001598C SSP = 0007BF08 ST = 0011 = >IM = 0 EXT CRY
D 0000800F 0000000F 00000000 00000000 00000000 00000000 00000000 00000000
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000

This instruction adds 10 hex to register D1.W. (Note that $-1 + 10 = 10$)
ADDQ Instruction

The ADDQ instruction adds a three-bit immediate value to an effective address operand. This allows adding a small number to a register or memory address using a small, fast instruction.

Addressing Modes Allowed:

<table>
<thead>
<tr>
<th>Dn</th>
<th>An</th>
<th>(An)</th>
<th>(An)+</th>
<th>− (An)</th>
<th>x(An)</th>
<th>x(An,xr.s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>x.w</td>
<td>x.1</td>
<td>x(PC)</td>
<td>x(PC,xr.s)</td>
<td>#x</td>
<td>SR</td>
<td>CCR</td>
</tr>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

Data Sizes: byte, word, long

When an address register is used as the destination, only word and long sizes are allowed.

Condition Codes Affected:

X  Set on carry-out of high-order bit position.
N  Set if high-order bit of result is set.
V  Set on overflow.
Z  Set if result is zero.
C  Set on carry-out of high-order bit position.

No condition codes are affected if an address register is used as the destination operand.

Assembler Syntax: ADDQ  #<data>,<ea>
#<data> is a constant number between 1 and 8.
Most assemblers automatically choose the ADDQ instruction if the source operand of an ADD instruction is an immediate value from 1 to 8.

Machine Code Format:

<table>
<thead>
<tr>
<th>Bit 15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>Data</td>
<td>0</td>
<td>Size</td>
<td>Effective</td>
<td>Address</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Data is a three-bit immediate field, with 000 representing 8, 001–111 representing 1–7. Size is 00 for a byte operation, 01 for a word, and 10 for a long operation.

Example:

PC = 00000580 USP = 0001598C SSP = 0007BF08 ST = 0000 = >IM = 0
D 00007FFF 00000000 00000000 00000000 00000000 00000000 00000000 00000000
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001598C
addq.1 #$1,D0
-t
PC = 00000582 USP = 0001598C SSP = 0007BF08 ST = 0000 = >IM = 0
D 00008000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001598C

This example adds 1 to register D0.
ADDX Instruction

The ADDX (ADD eXtended) instruction provides multiple precision ADD operands. Integers of any length can be added using the ADD and ADDX instructions. This makes it possible to represent numbers much larger than the 32-bit longword allows. The X (extended) condition code bit serves as a carry across the 32-bit boundary.

There are two forms of this instruction:

1. Add a data register to a data register.
2. Add a memory location to a memory location. The – (An) addressing mode must be used for both the source and destination in this form of the instruction.

Addressing Modes Allowed:

<table>
<thead>
<tr>
<th>Dn</th>
<th>An</th>
<th>(An)</th>
<th>(An) +</th>
<th>– (An)</th>
<th>x(An)</th>
<th>x(An,xr.s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>x.w</td>
<td>x.l</td>
<td>x(PC)</td>
<td>x(PC,xr.s)</td>
<td>#x</td>
<td>SR</td>
<td>CCR</td>
</tr>
<tr>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

Data Sizes: byte, word, long

Condition Codes Affected:

- X Set on carry-out of high-order bit.
- N Set if result was negative.
- Z Cleared if result is not zero. Unchanged otherwise.
- C Set on carry-out of high-order bit.
- V Set on overflow condition.

The Z-bit is not set if the result was zero. It is cleared if the result was not zero. This property of the instruction allows the Z bit to correctly indicate the result of a multiprecision addition operation. The Z-bit must be set before the ADD begins, however. (This can be done with a MOVE to
CCR, or by comparing a register to itself. The latter instruction is two bytes shorter.)

Assembler Syntax: ADDX \(D_y, D_x\)

\(\text{ADDX} \rightarrow (A_y), \rightarrow (A_x)\)

Machine Code Format:

<table>
<thead>
<tr>
<th>Bit</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reg. Rx</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Size</td>
<td>0</td>
<td>0</td>
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<td></td>
<td></td>
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<td></td>
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<tr>
<td>T</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Reg. Ry</td>
<td></td>
<td></td>
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<td></td>
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<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The Reg. Rx and Reg. Ry fields contain the destination and source register numbers, respectively. The size field is 00 for a byte operation, 01 for a word operation, and 10 for a long operation. The T-bit (type) is 0 for the data register to data register form of the instruction. The Reg. Rx and Reg. Ry fields identify data registers in this case. The T-bit is 1 for the memory to memory form of the instruction. The Rx and Ry fields identify the address registers used by this form of the instruction.

Example:

This example adds the 64-bit quantity in \((D_0, D_1)\) to the 64-bit quantity in \((D_2, D_3)\). The even numbered registers contain the high order part of the number.

\[\begin{align*}
\text{PC} &= 00000596 \quad \text{USP} = 0001598C \quad \text{SSP} = 0007BF08 \quad \text{ST} = 0000 \quad >\text{IM} = 0 \\
D &= 00000000 \quad \text{FFFFFFFFFF} \quad 00000000 \quad \text{FFFFFFFFFF} \quad 00000000 \quad 00000000 \quad 00000000 \quad 00000000 \\
A &= 00000000 \quad 00000000 \quad 00000000 \quad 00000000 \quad 00000000 \quad 00000000 \quad 00000000 \quad 0001598C \\
\text{add} \cdot \text{I} \\n\text{D}_1, \text{D}_3 \\
- t
\end{align*}\]

\[\begin{align*}
\text{PC} &= 00000598 \quad \text{USP} = 0001598C \quad \text{SSP} = 0007BF08 \quad \text{ST} = 0019 \quad >\text{IM} = 0 \quad \text{EXT NEG CRY} \\
D &= 00000000 \quad \text{FFFFFFFFFF} \quad 00000000 \quad \text{FFFFFFFFFF} \quad 00000000 \quad 00000000 \quad 00000000 \\
A &= 00000000 \quad 00000000 \quad 00000000 \quad 00000000 \quad 00000000 \quad 00000000 \quad 00000000 \quad 0001598C \\
\text{add} \cdot \text{x} \cdot \text{I} \\nD_0, D_2 \\
- t
\end{align*}\]

\[\begin{align*}
\text{PC} &= 0000059A \quad \text{USP} = 0001598C \quad \text{SSP} = 0007BF08 \quad \text{ST} = 0000 \quad >\text{IM} = 0 \\
D &= 00000000 \quad \text{FFFFFFFFFF} \quad 00000001 \quad \text{FFFFFFFFFF} \quad 00000000 \quad 00000000 \quad 00000000 \quad 00000000 \\
A &= 00000000 \quad 00000000 \quad 00000000 \quad 00000000 \quad 00000000 \quad 00000000 \quad 00000000 \quad 0001598C
\end{align*}\]

The quantities \((0, \text{FFFFFFFFFF})\) and \((0, \text{FFFFFFFFFF})\) when added together become \((1, \text{FFFFFFFFFF})\). Note the action of the X (extended) condition code bit. The low-order registers \((D_1 \text{ and } D_3)\) were added first. Although the low-order registers both contained negative numbers, the final result was positive.
**AND Instruction**

The AND instruction performs a bit-wise AND operation. There are two forms of this instruction:

1. AND the contents of an effective address with a data register, leaving the results in the data register.
2. AND the contents of a data register and an effective address, leaving the results in the effective address.

Addressing Modes Allowed:

**Effective address as Source:**

<table>
<thead>
<tr>
<th>Dn</th>
<th>An</th>
<th>(An)</th>
<th>(An) +</th>
<th>− (An)</th>
<th>x(An)</th>
<th>x(An, xr.s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>x.w</td>
<td>x.l</td>
<td>x(PC)</td>
<td>x(PC, xr.s)</td>
<td>#x</td>
<td>SR</td>
<td>CCR</td>
</tr>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

**Effective address as Destination:**

<table>
<thead>
<tr>
<th>Dn</th>
<th>An</th>
<th>(An)</th>
<th>(An) +</th>
<th>− (An)</th>
<th>x(An)</th>
<th>x(An, xr.s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>x.w</td>
<td>x.l</td>
<td>x(PC)</td>
<td>x(PC, xr.s)</td>
<td>#x</td>
<td>SR</td>
<td>CCR</td>
</tr>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

Data Sizes: byte, word, long
Condition Codes Affected:

- **X** Not affected.
- **N** Set if most significant bit of result is set. Cleared otherwise.
- **Z** Set if result is zero. Cleared otherwise.
- **C** Always cleared.
- **V** Always cleared.

Assembler Syntax: `AND <ea>,Dn
AND Dn,<ea>`

Machine Code Format:

```
<table>
<thead>
<tr>
<th>Bit</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>
```

The Register field specifies the Data register used by the instruction, regardless of whether the register is the source or the destination. The D-bit determines the direction of the instruction. If the D-bit is zero, then the Data register is the destination. If the D-bit is one, then the effective address operand is the destination. The Size field specifies the data size: 00 for byte, 01 for word, and 10 for long.

Example:

This example shows the machine operation when two data registers are ANDed together.

```
PC = 000005AC USP = 0001598C SSP = 0007BF08 ST = 0000 > IM = 0
D AAAAAAAA 01234567 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
and.l D1,D0
PC = 000005AE USP = 0001598C SSP = 0007BF08 ST = 0000 > IM = 0
D 00220022 01234567 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000

The long quantities AAAAAAAA and 01234567 are ANDed to become 00220022.
```
ANDI Instruction

The ANDI instruction performs a bit-wise AND between an immediate operand (always the source) and an effective address operand (always the destination).

Addressing Modes Allowed:

Destination only. Source is always immediate.

<table>
<thead>
<tr>
<th>Dn</th>
<th>An</th>
<th>(An)</th>
<th>(An) +</th>
<th>− (An)</th>
<th>x(An)</th>
<th>x(An,xr.s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>x.w</td>
<td>x.l</td>
<td>x(PC)</td>
<td>x(PC,xr.s)</td>
<td>#x</td>
<td>SR</td>
<td>CCR</td>
</tr>
</tbody>
</table>

Using the status register (SR) as the destination requires that the 68000 executes in Supervisor state. Attempting to execute this form of the instruction in User mode causes a privilege violation exception. (See Chapter 7 on Exception Programming.)

Data Sizes: byte, word, long

Condition Codes Affected:

X Not affected.
N Set if the high-order bit of the result is set. Cleared otherwise.
Z Set if the result is zero. Cleared otherwise.
C Always cleared.
V Always cleared.

The condition codes are cleared according to bits 4–0 of the operand if either the status register (SR) or the condition code register (CCR) is used as the destination. The normal condition code settings do not apply for these addressing modes.

Assembler Syntax: ANDI #<data>,<ea>
Machine Code Format:

<table>
<thead>
<tr>
<th>Bit</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
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<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Size</th>
<th>Effective Address</th>
</tr>
</thead>
</table>

- Mode → Reg. →

Word data: 16 bits

Byte Data: 8 bits

Long data: 16 bits plus previous word

The Size field determines the data size used by the instruction. Size is 00 for byte operation, 01 for word, and 10 for long. Byte and word operations are followed by a word of immediate data. (Byte operations use only the low eight bits of this word.) Long operations are followed by two words (32 bits) of immediate data.

Examples:

The first example ANDs an immediate quantity with a data register.

PC = 000005BA
USP = 0001598C
SSP = 0007BF08
ST = 0000 = >IM = 0
D 55555555
A 00000000
andi #$1234,DO

PC = 000005BE
USP = 0001598C
SSP = 0007BF08
ST = 0000 = >IM = 0
D 55551014
A 00000000
move #$1F,CCR

The next example shows the effect of ANDing to the condition code register (CCR). First, we set all the condition codes using the MOVE to CCR instruction:

PC = 000005BE
USP = 0001598C
SSP = 0007BF08
ST = 0000 = >IM = 0
D 55551014
A 00000000
move #$1234,D0

PC = 000005BE
USP = 0001598C
SSP = 0007BF08
ST = 0000 = >IM = 0
D 55551014
A 00000000
move #$1F,CCR

-t
Next, we AND the condition code register with 11 hex. This leaves the X and C bits set, and clears the other condition codes.

```assembly
andi.b #$11,ccr
-t
```

```
PC = 000005C6 USP = 0001598C SSP = 0007BF08 ST = 0011 => IM = 0 EXT CRY
D 55551014 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001598C
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001598C
```
The ASL instruction performs an arithmetic left shift on a data register or memory operand. There are three forms of this instruction:

1. Shift a data register to the left by a constant contained in the instruction. Shifts from one to eight bits can be accomplished using this form of the instruction.

2. Shift a data register to the left by the number of bits contained in another data register.

3. Shift a memory word left by one bit only.

Addressing Modes Allowed: Memory form only

<table>
<thead>
<tr>
<th>Dn</th>
<th>An</th>
<th>(An)</th>
<th>(An) +</th>
<th>(An)</th>
<th>x(An)</th>
<th>x(An, xr.s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>x.w</td>
<td>x.l</td>
<td>x(PC)</td>
<td>x(PC, xr.s)</td>
<td>#x</td>
<td>SR</td>
<td>CCR</td>
</tr>
</tbody>
</table>

Data Sizes: byte, word, long

Data size is restricted to word for the form of the instruction that is in memory.

Condition Codes Affected:

- **X** Set according to the last bit shifted out of the operand. Unaffected if the shift count is zero. (This is possible only in the second form of the instruction.)
- **N** Set if the most significant bit of the result is set. Cleared otherwise.
- **Z** Set if the result is zero. Cleared otherwise.
- **C** Set according to the last bit shifted out of the operand. Unaffected if the shift count is zero.
- **V** Set if the most significant bit is changed at any time during the shift operation. Cleared otherwise.
Assembler Syntax: ASL  #<count>,Dy  
   ASL  Dx,Dy  
   ASL  <ea>

Machine Code Format:

Data Register as destination:

<table>
<thead>
<tr>
<th>Bit</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>Immed.</td>
<td>1</td>
<td>Size</td>
<td>T</td>
<td>0</td>
<td>0</td>
<td>Register</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Memory location as destination:

<table>
<thead>
<tr>
<th>Bit</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>Effective</td>
<td>Address</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The T-field determines the form of the register-destination form of the instruction. If T is 0, then the Immediate field contains the shift count, with 000 binary representing a count of 8. If T is 1, then the register number that contains the shift count is contained in the Immediate field.

Example:

PC = 000005D2 USP = 0001598C SSP = 0007BF08 ST = 0000 = >IM = 0
D 01234567 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001598C
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001598C
asl #8,D0
-t
PC = 000005D4 USP = 0001598C SSP = 0007BF08 ST = 0013 = >IM = 0 EXT OFL CRY
D 01236700 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001598C
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001598C

Notice that the upper half of the register destination is unchanged when a word shift is performed. The sign bit of the word is also changed during the shift, resulting in an overflow condition.
This is a long shift with the count specified in a register.
The ASR instruction performs an arithmetic right shift on a data register or memory operand. There are three forms of this instruction:

1. Shift a data register to the right by a constant contained in the instruction. Shifts from one to eight bits can be accomplished using this form of the instruction.

2. Shift a data register to the right by the number of bits contained in another data register.

3. Shift a memory word right by one bit only.

Addressing Modes Allowed: Memory form only

<table>
<thead>
<tr>
<th>Dn</th>
<th>An</th>
<th>(An)</th>
<th>(An) +</th>
<th>− (An)</th>
<th>x(An)</th>
<th>x(An,xr.s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>x.w</td>
<td>x.l</td>
<td>x(PC)</td>
<td>x(PC,xr.s)</td>
<td>#x</td>
<td>SR</td>
<td>CCR</td>
</tr>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

Data Sizes: byte, word, long
Data size is restricted to word for the form of the instruction that is in memory.

Condition Codes Affected:

- **X**: Set according to the last bit shifted out of the operand. Unaffected if the shift count is zero. (That is possible only in the second form of the instruction.)
- **N**: Set if the most significant bit of the result is set. Cleared otherwise.
- **Z**: Set if the result is zero. Cleared otherwise.
- **C**: Set according to the last bit shifted out of the operand. Cleared if the shift count is zero.
- **V**: Always cleared.
Assembler Syntax: ASR  #<count>,Dy  
     ASR  Dx,Dy  
     ASR  <ea>

Machine Code Format:

Data Register as destination:

| Bit 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|--------|----|----|----|----|----|---|---|---|---|---|---|---|---|---|---|---|
| 1      | 1  | 1  | 0  |    |    |   |   |   |   |   |   |   |   |   |   |

Memory location as destination:

| Bit 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|--------|----|----|----|----|----|---|---|---|---|---|---|---|---|---|---|---|
| 1      | 1  | 1  | 0  | 0  | 0  | 0 | 0 | 1 | 1 |    |   |   |   |   |   |   |

The T-field determines the form of the register-destination form of the instruction. If T is 0, then the Immediate field contains the shift count, with 000 binary representing a count of 8. If T is 1, then the register number which contains the shift count is contained in the Immediate field.

Example:

PC = 000005EE USP = 0001598C SSP = 0007BF08 ST = 0000
D 01234567 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001598C
asr #8,D0  
−t
PC = 000005F0 USP = 0001598C SSP = 0007BF08 ST = 0000
D 01230045 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001598C
asr #1,D0

This instruction shifts register D0 to the right by 8. The upper half of the register is unaffected because the operation is a word operation.
- t
PC = 000005FE USP = 0001598C SSP = 0007BF08 ST = 0008 = >IM = 0 NEG
D FFF8123 00000010 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001598C
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001598C

Notice the sign extension due to the upper bit of register D0 being propagated by the right shift.
Branch instructions are a vital part of machine-language programs. They provide a way of interrogating the condition codes and executing two or more alternate sets of instructions based on the results of the interrogation. The Bcc group of instructions is the method by which the 68000 performs this function. There are fifteen combinations of the condition codes that may be tested. Each of these has a two-letter mnemonic that takes the place of the cc in Bcc.

The permissible branch instructions are:

- **BCC** Branch if the C-bit (carry) is clear.
- **BCS** Branch if the C-bit (carry) is set.
- **BEQ** Branch on Equal. This instruction branches if the Z (Zero) bit is set.
- **BGE** Branch on Greater than or Equal. This instruction branches if the N (negative) and V (overflow) bits are either both set or both clear. BGE is used for two's complement binary numbers.
- **BGT** Branch on Greater Than. This instruction branches if
  - The N and V bits are both set AND the Z-bit is clear, or,
  - The N, V, and Z bits are all clear.
- **BHI** Branch on Higher than. This instruction branches if the C and Z bits are both clear. BHI is similar to BGT, except it is used for unsigned numbers.
- **BLE** Branch on Less than or Equal. This instruction branches if
  - The Z-bit is set, or,
  - The N-bit is set AND the V-bit is clear, or,
  - The N-bit is clear AND the V-bit is set.
  The BLE instruction is used for two's complement binary numbers.
- **BLS** Branch on Lower or Same. This instruction branches if either the C or Z bits are set. BLS is similar to BLE, except it is used for unsigned numbers.
- **BLT** Branch on Less Than. This instruction branches if
  - The N-bit is set and the V-bit is clear, or,
  - The N-bit is clear and the V-bit is set.
- **BMI** This instruction branches if the N-bit is set.
BNE  Branch on Not Equal. This instruction branches if the Z-bit is clear.
BPL  Branch on Plus. This instruction branches if the N-bit is clear.
BVC  Branch on V Clear. This instruction branches if the V-bit is clear, indicating no overflow.
BVS  Branch on V Set. This instruction branches if the V-bit is set, indicating overflow.
BRA  Branch Always. This instruction always branches, regardless of the setting of the condition codes.

The Condition Code Summary is shown in Table 3.1.

<table>
<thead>
<tr>
<th>Condition Codes</th>
<th>Branch Instructions That Succeed</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>Z</td>
</tr>
<tr>
<td>0 0 0 0</td>
<td>x</td>
</tr>
<tr>
<td>0 0 0 1</td>
<td>x</td>
</tr>
<tr>
<td>0 0 1 0</td>
<td>x</td>
</tr>
<tr>
<td>0 0 1 1</td>
<td>x</td>
</tr>
<tr>
<td>0 1 0 0</td>
<td>x</td>
</tr>
<tr>
<td>0 1 0 1</td>
<td>x</td>
</tr>
<tr>
<td>0 1 1 0</td>
<td>x</td>
</tr>
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<td>0 1 1 1</td>
<td>x</td>
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<td>x</td>
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<td>1 0 1 0</td>
<td>x</td>
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<td>x</td>
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<td>1 1 1 0</td>
<td>x</td>
</tr>
<tr>
<td>1 1 1 1</td>
<td>x</td>
</tr>
</tbody>
</table>

*Table 3.1 - Condition Code Summary*
Addressing Modes Allowed:

There is a special addressing mode for branch instructions. Branches can either have a byte or word displacement that is sign extended to a long and added to the PC (Program Counter) to perform the branch. (This is done only if the condition is satisfied.)

Data Sizes: byte, word

Condition Codes Affected: None

Assembler Syntax: Bcc.S <label>  Byte displacement
              Bcc.W <label>  Word displacement

<label> is a label contained in the instruction area of the program (.text area on UNIX and CP/M-68K). The .S and .W suffixes are used to denote the two possible displacement sizes (short and word). Many assemblers perform this selection automatically.

Machine Code Format:

<table>
<thead>
<tr>
<th>Bit</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
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<th>6</th>
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<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Condition</th>
<th>8-bit displacement</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0 0 0 1</td>
<td></td>
</tr>
</tbody>
</table>

16-bit displacement if 8-bit displacement = 0

The Condition is a four-bit encoding of the branch condition. The conditions are shown in Table 3.2.

The combination 0001 for condition is used to denote the BSR (Branch to Subroutine) instruction, rather than a conditional branch.

The 8-bit displacement field is an 8-bit field that gives a two’s complement number to be added to the PC if the branch is successful. The PC always contains the address of the word that follows the first word of the branch instruction. If the 8-bit displacement is zero, then the word following the branch instruction contains a 16-bit displacement to be added to the PC.

One-word (8-bit) displacements give a branch range of -128 to +126 bytes away from the branch instruction. With a 16-bit displacement, this range is expanded to -32768 to +32766 bytes. The displacement must always be even. (Instructions must begin on a word boundary.)
A one-word (8-bit displacement) branch to the next instruction is impossible. The displacement would have to be zero, and the next word (i.e., the first word of the next instruction) would be taken as a 16-bit branch offset. The Bcc instruction cannot be configured to yield a one word no operation (an instruction that does nothing).

Example:

PC = 00000606 USP = 0001598C SSP = 0007BF08 ST = 0000 => IM = 0
D 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
beq $60A
-1606,60e
00000606 beq $60A
00006068 moveq #$FF,D0
00000660A bne $60E
0000060C moveq #$FE,D0
00000660E nop

In this segment of sample code, there are two conditional branches, a BNE and a BEQ. The BEQ will not be taken, since the Z-bit is not set at the beginning. Thus, the first MOVEQ instruction will be executed. The Z-bit will remain clear as a result of this instruction. The BNE will be taken, and register D0 will have a value of FFFFFFFF.
The next example illustrates an anomaly of the 68000 instruction set. The CMP instruction is used to set the condition codes as if the two operands were subtracted. The operands remain unaffected. However, the comparison CMP D0,D1 followed by a BGT instruction will branch if register D1 is greater than register D0 (i.e., the operands of the compare instruction must be read backwards).

In this code segment, D0 (−1) and D1 (1) are compared. If D1 is greater than D0 (and it is), the first ADDQ instruction will be skipped. The BHI instruction is the unsigned version of a BGT. In this case, −1 (actually 2^{32} − 1, or about 4 billion) is greater than 1, so the branch will not be taken. (Since we skipped the first ADDQ instruction, the condition codes at the time of executing the BHI are the result of the CMP.L instruction.) Register D2 will have a value of 1.
- t
PC = 00000618 USP = 0001598C SSP = 0007BF08 ST = 0001 = >IM = 0 CRY
D FFFFFFFF 00000001 00000000 00000000 00000000 00000000 00000000 00000000 0001598C
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001598C
bgt $61C
- t
PC = 0000061C USP = 0001598C SSP = 0007BF08 ST = 0001 = >IM = 0 CRY
D FFFFFFFF 00000001 00000000 00000000 00000000 00000000 00000000 00000000 0001598C
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001598C
bhi $620
- t
PC = 0000061E USP = 0001598C SSP = 0007BF08 ST = 0001 = >IM = 0 CRY
D FFFFFFFF 00000001 00000000 00000000 00000000 00000000 00000000 00000000 0001598C
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001598C
addq #$1,D2
- t
PC = 00000620 USP = 0001598C SSP = 0007BF08 ST = 0000 = >IM = 0
D FFFFFFFF 00000001 00000000 00000000 00000000 00000000 00000000 00000000 0001598C
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001598C
The BCHG (test a Bit and ChAnGe) instruction inverts a single bit in an effective address operand. The Z-bit is set according to the state of the bit before the inversion.

The bit number is contained either in a register or in an immediate field inside the instruction itself. The operation is restricted to long data for a data register destination, and to byte data for memory locations. Bits are numbered from 0, with bit 0 being the least significant bit in a byte (or long).

Addressing Modes Allowed:

<table>
<thead>
<tr>
<th>Dn</th>
<th>An</th>
<th>(An)</th>
<th>(An) +</th>
<th>− (An)</th>
<th>x(An)</th>
<th>x(An,xr.s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>x.w</td>
<td>x.l</td>
<td>x(PC)</td>
<td>x(PC,xr.s)</td>
<td>#x</td>
<td>SR</td>
<td>CCR</td>
</tr>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

Data Sizes: byte, long

Condition Codes Affected:

X Not affected.
N Not affected.
Z Set if the bit was zero before being inverted. Cleared otherwise.
C Not affected.
V Not affected.

Assembler Syntax: BCHG Dn,<ea>
BCHG #<data>,<ea>
Machine Code Format:

Bit Number Dynamic:

<table>
<thead>
<tr>
<th>Bit</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
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<th>0</th>
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</thead>
<tbody>
<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Register</td>
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<td>1</td>
<td></td>
<td></td>
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Bit Number Static:

<table>
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<tr>
<th>Bit</th>
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</thead>
<tbody>
<tr>
<td></td>
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<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The Register field indicates the data register in which the bit number resides for the Bit Number Dynamic form of the instruction. In the Bit Number Static case, bits 5–7 of the extension word are ignored for data register destinations. For memory locations, bits 4 and 3 are also ignored. (Bit numbers in a long range from 0–31, and in a byte from 0–7.)

Example:

PC = 00000628 USP = 0001598C SSP = 0007BF08 ST = 0000 = >IM = 0
D 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
bchg #$0,D0
- t
PC = 0000062C USP = 0001598C SSP = 0007BF08 ST = 0004 = >IM = 0 ZER
D 00000001 00000000 00000000 00000000 00000000 00000000 00000000 00000000
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000

This example inverts bit 0 of register D0. The Z-bit is set after the instruction, indicating that the bit was clear before the instruction.
The BCLR (test a Bit and CLeaR) instruction clears a single bit in an effective address operand. The Z-bit is set according to the state of the bit before the instruction.

The bit number is either contained in a register, or in an immediate field inside the instruction itself. The operation is restricted to long data for a data register destination, and to byte data for memory locations. Bits are numbered from 0, with bit 0 being the least significant bit in a byte (or long).

Addressing Modes Allowed:

<table>
<thead>
<tr>
<th>Dn</th>
<th>An</th>
<th>(An)</th>
<th>(An) +</th>
<th>−(An)</th>
<th>x(An)</th>
<th>x(An,xr.s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>x.w</td>
<td>x.l</td>
<td>x(PC)</td>
<td>x(PC,xr.s)</td>
<td>#x</td>
<td>SR</td>
<td>CCR</td>
</tr>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

Data Sizes: byte, long

Condition Codes Affected:

- X Not affected.
- N Not affected.
- Z Set if the bit was zero before being cleared. Cleared otherwise.
- C Not affected.
- V Not affected.

Assembler Syntax: BCLR Dn,<ea>  
BCLR #<data>,<ea>
Machine Code Format:
Bit Number Dynamic:

<table>
<thead>
<tr>
<th>Bit</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
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<th>9</th>
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<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>R</td>
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<td>1</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

Bit Number Static:

<table>
<thead>
<tr>
<th>Bit</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The Register field indicates the data register in which the bit number resides for the Bit Number Dynamic form of the instruction. In the Bit Number Static case, bits 5–7 of the extension word are ignored for data register destinations. For memory locations, bits 4 and 3 are also ignored. (Bit numbers in a long range from 0–31, and in a byte from 0–7.)

Example:

PC = 00000632 USP = 0001598C SSP = 0007BF08 ST = 0000 => IM = 0
D 00000001 00000000 00000000 00000000 00000000 00000000 00000000 00000000
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001598C
bclr #$0,DO

PC = 00000636 USP = 0001598C SSP = 0007BF08 ST = 0000 => IM = 0
D 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001598C

This instruction clears bit 0 of register D0. The Z-bit is not set after the instruction, indicating that the bit was set before the instruction.
The BSET (test a Bit and SET) instruction sets a single bit in an effective address operand. The Z-bit is set according to the state of the bit before the instruction.

The bit number is either contained in a register or in an immediate field inside the instruction itself. The operation is restricted to long data for a data register destination, and to byte data for memory locations. Bits are numbered from 0, with bit 0 being the least significant bit in a byte (or long).

Addressing Modes Allowed:

<table>
<thead>
<tr>
<th>Dn</th>
<th>An</th>
<th>(An)</th>
<th>(An) +</th>
<th>– (An)</th>
<th>x(An)</th>
<th>x(An,xr.s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>x.w</td>
<td>x.l</td>
<td>x(PC)</td>
<td>x(PC,xr.s)</td>
<td>#x</td>
<td>SR</td>
<td>CCR</td>
</tr>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

Data Sizes: byte, long

Condition Codes Affected:

- X Not affected.
- N Not affected.
- Z Set if the bit was zero before being set. Cleared otherwise.
- C Not affected.
- V Not affected.

Assembler Syntax: BSET Dn,<ea>

BSET #<data>,<ea>
Machine Code Format:

Bit Number Dynamic:

<table>
<thead>
<tr>
<th>Bit</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
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<tbody>
<tr>
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<td>0</td>
<td>0</td>
<td>Register</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Bit Number Static:

<table>
<thead>
<tr>
<th>Bit</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
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<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>Effective Address</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The Register field indicates the data register in which the bit number resides for the Bit Number Dynamic form of the instruction. In the Bit Number Static case, bits 5–7 of the extension word are ignored for data register destinations. For memory locations, bits 4 and 3 are also ignored. (Bit numbers in a long range from 0–31, and in a byte from 0–7.)

Example:

PC = 00000644 USP = 0001598C SSP = 0007BF08 ST = 0000 = >IM = 0
D 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
bset #$0,D0
- t
PC = 00000648 USP = 0001598C SSP = 0007BF08 ST = 0004 = >IM = 0 ZER
D 00000001 00000000 00000000 00000000 00000000 00000000 00000000 00000000
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001598C

This instruction sets bit 0 of register D0. The Z-bit is set after the instruction, indicating that the bit was clear before the instruction.
The BSR (Branch to SubRoutine) instruction places the address of the next instruction to be executed on top of the stack. A displacement is then added to the PC register (Program Counter), and execution continues at that address. For the purposes of the addition, the PC points to the word that follows the first word of the BSR instruction.

Addressing Modes Allowed:

There is a special addressing mode for branch instructions. Branch instructions can either have a byte or word displacement that is sign extended to a long and added to the PC (Program Counter) to perform the branch.

Data Sizes: byte, word

Condition Codes Affected: None

Assembler Syntax: BSR.S <label> Byte displacement  
BSR.W <label> Word displacement

<label> is a label contained in the instruction area of the program (.text area on UNIX and CP/M). The .S and .W suffixes are used to denote the two possible displacement sizes (short and word). Many assemblers perform this selection automatically.

Machine Code Format:

```
<table>
<thead>
<tr>
<th>Bit</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
```

8-bit displacement

```
<table>
<thead>
<tr>
<th>Bit</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
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<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
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<tbody>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
```

16-bit displacement if 8-bit displacement = 0

The format of a BSR instruction is the same as that of the Bcc instructions, with a condition field (bits 11-8) of 0001.

As with the Bcc instructions, it is not possible to have a one-word BSR to the next instruction, since the 8-bit displacement in that case would be
zero. The next word (which would be the first word of the next instruction) would erroneously be used as the 16-bit displacement in this case. Most assemblers will not allow this error condition to take place.

Example:

```
PC = 0000064E USP = 0001598C SSP = 0007BF08 ST = 0000 = >IM = 0
D 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001598C
bsr $652
-t
PC = 00000652 USP = 00015988 SSP = 0007BF08 ST = 0000 = >IM = 0
D 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00015988
rts
-d15988,1598c
00015988 00000650
```

The BSR instruction at location 64E branches to location 652, after placing 650 (the address of the next instruction) on the stack (at location 15988).

```
-t
PC = 00000650 USP = 0001598C SSP = 0007BF08 ST = 0000 = >IM = 0
D 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001598C
```

Following the RTS instruction, execution picks up at location 650, and the return address has been popped off the stack. (Register A7 now contains 1598C—four bytes have been popped.)
The BTST (Bit TeST) instruction tests a single bit in an effective address operand. The Z-bit is set according to the state of the bit.

The bit number is either contained in a register or in an immediate field inside the instruction itself. The operation is restricted to long data for a data register destination, and to byte data for memory locations. Bits are numbered from 0, with bit 0 being the least significant bit in a byte (or long).

### Addressing Modes Allowed (Bit Number Static):

<table>
<thead>
<tr>
<th>Dn</th>
<th>An</th>
<th>(An)</th>
<th>(An) +</th>
<th>− (An)</th>
<th>x(An)</th>
<th>x(An,xr.s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>x.w</td>
<td>x.I</td>
<td>x(PC)</td>
<td>x(PC,xr.s)</td>
<td>#x</td>
<td>SR</td>
<td>CCR</td>
</tr>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

### Addressing Modes Allowed (Bit Number Dynamic):

<table>
<thead>
<tr>
<th>Dn</th>
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<th>(An)</th>
<th>(An) +</th>
<th>− (An)</th>
<th>x(An)</th>
<th>x(An,xr.s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>x.w</td>
<td>x.I</td>
<td>x(PC)</td>
<td>x(PC,xr.s)</td>
<td>#x</td>
<td>SR</td>
<td>CCR</td>
</tr>
<tr>
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<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>NO</td>
</tr>
</tbody>
</table>

Data Sizes: byte, long

Condition Codes Affected:

- X Not affected.
- N Not affected.
\[ Z \text{ Set if the tested bit is zero. Cleared otherwise.} \]
\[ C \text{ Not affected.} \]
\[ V \text{ Not affected.} \]

Assembler Syntax: \( \text{BTST Dn, } \langle \text{ea} \rangle \)
\( \text{BTST } \#\langle \text{data} \rangle, \langle \text{ea} \rangle \)

Machine Code Format:

### Bit Number Dynamic:

<table>
<thead>
<tr>
<th>Bit</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
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<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>Register</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>Effective Address</td>
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<td></td>
<td></td>
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<td></td>
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</tr>
</tbody>
</table>

- Mode ➔ Reg. ➔

### Bit Number Static:

<table>
<thead>
<tr>
<th>Bit</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
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<th>3</th>
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<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td>0</td>
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<td>1</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>Effective Address</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Mode ➔ Reg. ➔

|     | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | Bit Number |

The Register field indicates the data register in which the bit number resides for the Bit Number Dynamic form of the instruction. In the Bit Number Static case, bits 5–7 of the extension word are ignored for data register destinations. For memory locations, bits 4 and 3 are also ignored. (Bit numbers in a long range from 0–31, and in a byte from 0–7.)

Example:

\[
\begin{align*}
\text{PC} &= 00000658 \quad \text{USP} = 0001598C \quad \text{SSP} = 000FBF08 \quad \text{ST} = 0000 = >IM = 0 \\
D &= 00000001 \quad 00000000 \quad 00000000 \quad 00000000 \quad 00000000 \quad 00000000 \quad 00000000 \quad 00000000 \\
A &= 00000000 \quad 00000000 \quad 00000000 \quad 00000000 \quad 00000000 \quad 00000000 \quad 00000000 \quad 0001598C \\
\text{btst} &= \#0,D0
\end{align*}
\]
This example tests the low-order bit of register D0. The bit is set, so that
the Z-bit is not set by the instruction. A BNE instruction will branch in
this case.
The CHK (CHecK register against bounds) instruction verifies that a data register contains a number within a certain positive range of values. This instruction is normally used by high-level language systems for range checking subscripts.

The low-order word (16 bits) of the data register is compared to an operand specified by the effective address field of the instruction. If the register is less than zero (i.e., bit 15 of the register is set) or greater than the upper bound, then a CHK exception results. (See Chapter 7 on Exception Processing for details.)

Addressing Modes Allowed:

<table>
<thead>
<tr>
<th>Dn</th>
<th>An</th>
<th>An</th>
<th>(An) +</th>
<th>− (An)</th>
<th>x(An)</th>
<th>x(An, xr.s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>x.w</td>
<td>x.l</td>
<td>x(PC)</td>
<td>x(PC, xr.s)</td>
<td>#x</td>
<td>SR</td>
<td>CCR</td>
</tr>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

Data Sizes: word
Condition Codes Affected:

X  Not affected.
N  Set if the data register is less than zero. Cleared if the data register is greater than the effective address operand. Undefined otherwise.
Z  Undefined.
C  Undefined.
V  Undefined.

Assembler Syntax: CHK <ea>, Dn
Machine Code Format:

<table>
<thead>
<tr>
<th>Bit</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
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<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tr>
</tbody>
</table>

Register is the number of the data register to be tested.

Example:

PC = 00000660 USP = 0001598C SSP = 000FBF08 ST = 0000 = > IM = 0
D 00000001 00000000 00000000 00000000 00000000 00000000 00000000 00000000
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 001598C
chk #$1,D0
- t
PC = 00000664 USP = 0001598C SSP = 000FBF08 ST = 0000 = > IM = 0
D 00000001 00000000 00000000 00000000 00000000 00000000 00000000 00000000
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 001598C
chk #$0,D0
- t
Exception $06 at user address 00000668. Aborted.

The first CHK instruction in this example does nothing, as the register is equal to the limit (both are 1). In the second example, an exception is generated. The message printed here shows how CP/M-68K treats exceptions in a user program. Other operating systems behave in a similar fashion. Exception 6 is the CHK instruction. (See Chapter 7 on Exception Processing for details.)
CLR Instruction

The CLR (CLEaR) instruction sets an effective address operand to zero. An anomaly of the 68000 hardware causes memory operands to be read and then cleared. This usually makes no difference in program behavior, with two exceptions of initializing some memory units with parity (which may give an erroneous parity error), or accessing memory-mapped hardware.

Addressing Modes Allowed:

<table>
<thead>
<tr>
<th>Dn</th>
<th>An</th>
<th>(An)</th>
<th>(An) +</th>
<th>− (An)</th>
<th>x(An)</th>
<th>x(An,xr.s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

x.w x.l x(PC) x(PC,xr.s) #x SR CCR

Data Sizes: byte, word, long

Condition Codes Affected:

X  Not affected.
N  Always cleared.
Z  Always set.
C  Always cleared.
V  Always cleared.

Assembler Syntax: CLR <ea>

Machine Code Format:

<table>
<thead>
<tr>
<th>Bit</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

Size Effective Address

← Mode → ← Reg. →

Size is 00 for byte data, 01 for word, and 10 for long.
Example:

PC = 000066A USP = 000159C SSP = 000FB08 ST = 0008 = >IM = 0 NEG
D FFFFFFFF 00000000 00000000 00000000 00000000 00000000 00000000 00000000
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 000159C
clr I D0
- t
PC = 000066C USP = 000159C SSP = 000FB08 ST = 0004 = >IM = 0 ZER
D 00000000 00000000 00000000 00000000 00000000 00000000 00000000
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 000159C

This example clears data register D0.
The CMP (CoMPare) instruction compares the contents of a data register with an effective address operand. The condition codes are set as if the effective address were subtracted from the data register. Neither operand is altered.

When used with conditional branches, this instruction creates a less than desirable effect. When the combination

```
CMP D0,D1
BGT X1
```

is used, the branch takes place if register D1 is greater than register D0.

Addressing Modes Allowed:

<table>
<thead>
<tr>
<th>Dn</th>
<th>An</th>
<th>(An)</th>
<th>(An) +</th>
<th>(An)</th>
<th>x(An)</th>
<th>x(An,xr.s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>x.w</td>
<td>x.l</td>
<td>x(PC)</td>
<td>x(PC,xr.s)</td>
<td>#x</td>
<td>SR</td>
<td>CCR</td>
</tr>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

Data Sizes: byte, word, long

Byte mode is not allowed when address register direct mode is used as the effective address.

Condition Codes Affected:

- X Not affected.
- N Set if the result is negative. Cleared otherwise.
- Z Set if the result is zero. (The operands are equal.) Cleared otherwise.
- C Set if a borrow is generated. Cleared otherwise.
- V Set on overflow in the subtract operation. Cleared otherwise.
Assembler Syntax: CMP <ea>,Dn

The CMPA instruction is used when the destination is an address register. CMPI compares an immediate source to an effective address operand. CMPM compares memory to memory. Many assemblers make this distinction automatically.

Machine Code Format:

<table>
<thead>
<tr>
<th>Bit</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>Register</td>
<td>0</td>
<td>Size</td>
<td>Effective</td>
<td>Address</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The Register field is the number of the data register used as the destination. The size field is 00 for comparing bytes, 01 for words, and 10 for longs.

Example:

PC = 00000674 USP = 0001598C SSP = 000FBF08 ST = 0000 = >IM = 0
D 00000001 00000002 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001598C
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001598C
 cmp.I $932,D0
     - sl932
A 0000932 00000001.

-1674,684
00000674 cmp.I $932,D0
0000067A beq $67E
0000067C addq.I #$1,D2
0000067E cmp.I D0,D1
00000680 ble $684
00000682 addq #$2,D2
00000684 nop

This program segment compares register D0 to a memory word containing 1. The BEQ instruction will branch, and the first ADDQ instruction will not be executed. The BLE instruction will not branch. (Remember that the compare operands must be read backwards.) Register D2 will have a value of 2.

-1
PC = 0000067A USP = 0001598C SSP = 000FBF08 ST = 0004 = >IM = 0 ZER
D 00000001 00000002 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001598C
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001598C
beq $67E
- t
PC = 0000067E USP = 0001598C SSP = 000FBF08 ST = 0004 = >IM = 0 ZER
D 00000001 00000002 00000000 00000000 00000000 00000000 00000000 00000000
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001598C
cmp.l D0, D1
- t
PC = 00000680 USP = 0001598C SSP = 000FBF08 ST = 0004 = >IM = 0
D 00000001 00000002 00000000 00000000 00000000 00000000 00000000 00000000
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001598C
ble $684
- t
PC = 00000682 USP = 0001598C SSP = 000FBF08 ST = 0004 = >IM = 0
D 00000001 00000002 00000000 00000000 00000000 00000000 00000000 00000000
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001598C
addq #$2, D2
- t
PC = 00000684 USP = 0001598C SSP = 000FBF08 ST = 0004 = >IM = 0
D 00000001 00000002 00000000 00000000 00000000 00000000 00000000 00000000
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001598C
### CMPA Instruction

The CMPA (CoMPare Address) instruction compares the contents of an address register with an effective address operand. The condition codes are set as if the effective address were subtracted from the address register. Neither operand is altered.

When used with conditional branches, this instruction creates a less than desirable effect. When the combination

```assembly
CMPA A0, A1
BGT X1
```

is used, the branch takes place if the value in register A1 is greater than the value in register A0.

**Addressing Modes Allowed:**

<table>
<thead>
<tr>
<th>Dn</th>
<th>An</th>
<th>(An)</th>
<th>(An) +</th>
<th>− (An)</th>
<th>x(An)</th>
<th>x(An,xr.s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>x.w</td>
<td>x.I</td>
<td>x(PC)</td>
<td>x(PC,xr.s)</td>
<td>#x</td>
<td>SR</td>
<td>CCR</td>
</tr>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

**Data Sizes:** word, long

**Condition Codes Affected:**

- X: Not affected.
- N: Set if the result is negative. Cleared otherwise.
- Z: Set if the result is zero. (The operands are equal.) Cleared otherwise.
- C: Set if a borrow is generated. Cleared otherwise.
- V: Set on overflow in the subtract operation. Cleared otherwise.

Assembler Syntax: CMPA <ea>, An
The CMP instruction is used when the destination is a data register. CMPI compares an immediate source to an effective address operand. CMPM compares memory to memory. Many assemblers make this distinction automatically.

Machine Code Format:

```
<table>
<thead>
<tr>
<th>Bit</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td></td>
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<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td>Register</td>
<td>S</td>
<td>1</td>
<td>1</td>
<td>Effective</td>
<td>Address</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
```

The Register field is the number of the data register used as the destination. The S (Size) bit is 0 for comparing words, and 1 for longs. Comparing a word is performed by sign-extend the source and making a 32-bit compare.

Example:

```
PC = 00000694 USP = 0001598C SSP = 000FBF08 ST = 0008 = >IM = 0 NEG
D FFFFFFFF 00000000 00000000 00000000 00000000 00000000 00000000 00000000
A 00000936 0000094E 00000000 00000000 00000000 00000000 00000000 0001598C
cmpa.I A0,A1
-1694,69a
  00000694 cmpa.I A0,A1
  00000696 bhi $69A
  00000698 clr.I D0
  0000069A nop
```

This code segment compares address registers A0 to A1. The BHI instruction will succeed. (Remember that the compare operands must be read backwards.) Data register D0 will remain unchanged.

```
-t
PC = 00000696 USP = 0001598C SSP = 000FBF08 ST = 0000 = >IM = 0
D FFFFFFFF 00000000 00000000 00000000 00000000 00000000 00000000 00000000
A 00000936 0000094E 00000000 00000000 00000000 00000000 00000000 0001598C
bhi $69A
-t
PC = 0000069A USP = 0001598C SSP = 000FBF08 ST = 0000 = >IM = 0
D FFFFFFFF 00000000 00000000 00000000 00000000 00000000 00000000 00000000
A 00000936 0000094E 00000000 00000000 00000000 00000000 00000000 0001598C
```
The CMPI (CoMPare Immediate) instruction compares an immediate operand with an effective address operand. The condition codes are set as if the immediate quantity were subtracted from the effective address. Neither operand is altered.

When used with conditional branches, this instruction creates a less than desirable effect. When the combination

\[
\text{CMPI} \ #<\text{data}> , D0 \\
\text{BGT} \quad X1
\]

is used, the branch takes place if the value in data register D0 is greater than the immediate data.

Addressing Modes Allowed:

<table>
<thead>
<tr>
<th>Dn</th>
<th>An</th>
<th>(An)</th>
<th>(An) +</th>
<th>− (An)</th>
<th>x(An)</th>
<th>x(An,xr.s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>x.w</td>
<td>x.l</td>
<td>x(PC)</td>
<td>x(PC,xr.s)</td>
<td>#x</td>
<td>SR</td>
<td>CCR</td>
</tr>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

Data Sizes: byte, word, long

Condition Codes Affected:

- **X** Not affected.
- **N** Set if the result is negative. Cleared otherwise.
- **Z** Set if the result is zero. (The operands are equal.) Cleared otherwise.
- **C** Set if a borrow is generated. Cleared otherwise.
- **V** Set on overflow in the subtraction operation. Cleared otherwise.

Assembler Syntax: CMPI #<data>,<ea>
The CMP instruction compares an effective address operand to a data register. The CMPA instruction compares an effective address operand to an address register. The CMPM instruction compares memory to memory. Many assemblers make this distinction automatically.

Machine Code Format:

<table>
<thead>
<tr>
<th>Bit</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
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</tr>
</tbody>
</table>

- **Size**: Effective Address
- **Mode**: Left
- **Reg.**: Right

Word data: 16 bits
Byte data: 8 bits
Long data: 32 bits, including previous word

The size field is 00 for byte compares, 01 for words, and 10 for longs.

Example:

```
PC = 000006A2 USP = 0001598C SSP = 000FBF08 ST = 0000 = >IM = 0
D 00000001 00000000 00000000 00000000 00000000 00000000 00000000 00000000
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001598C
cmp.l #$1,D0
- t
PC = 000006A8 USP = 0001598C SSP = 000FBF08 ST = 0004 = >IM = 0 ZER
D 00000001 00000000 00000000 00000000 00000000 00000000 00000000 00000000
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001598C
beq $6AC
- t
PC = 000006AC USP = 0001598C SSP = 000FBF08 ST = 0004 = >IM = 0 ZER
D 00000001 00000000 00000000 00000000 00000000 00000000 00000000 00000000
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001598C
```

This example compares the contents of data register D0 to the constant 1. The BEQ succeeds because D0 also contains a 1.
The CMPM (CoMPare Memory) instruction compares two memory operands using the post-increment addressing mode. The condition codes are set as if the source operand were subtracted from the destination. Neither operand is altered.

When used with conditional branches, this instruction creates a less than desirable effect. When the combination

\[
\text{CMPM (A0)+,(A1)+} \\
\text{BGT X1}
\]

is used, the branch takes place if the second operand is greater than the first.

Addressing Modes Allowed: Only post-increment

Data Sizes: byte, word, long

Condition Codes Affected:

- **X**: Not affected.
- **N**: Set if the result is negative. Cleared otherwise.
- **Z**: Set if the result is zero. (The operands are equal.) Cleared otherwise.
- **C**: Set if a borrow is generated. Cleared otherwise.
- **V**: Set on overflow in the subtract operation. Cleared otherwise.

Assembler Syntax: CMPM (Ay)+,(Ax)+

The CMP instruction compares an effective address operand to a data register. The CMPA instruction compares an effective address operand to an address register. The CMPI instruction compares an immediate quantity to an effective address. Many assemblers make this distinction automatically.

<table>
<thead>
<tr>
<th>Bit</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>Reg Ax</td>
<td>1</td>
<td>Size</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>Reg Ay</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Machine Code Format:
The size field is 00 for comparing bytes, 01 for words, and 10 for longs. The Ay and Ax fields specify the source and destination address registers, respectively.

Example:

PC = 0000050C USP = 0001598C SSP = 0007BF08 ST = 0000 = >IM = 0
D 00000000 00000000 00000000 00000000 00000000 00000000
A 00000514 00000524 00000000 00000000 00000000 00000000

cmpm (A0) +, (A1) +
- l50c,510
  0000050C cmpm (A0) +, (A1) +
  0000050E beq $50C
  00000510 nop
- dw514,534
00000514 0000 0001 0002 0003 0004 0005 0006 0008
00000524 0000 0001 0002 0003 0004 0005 0006 0007
- g,510

PC = 00000510 USP = 0001598C SSP = 0007BF08 ST = 0009 = >IM = 0 NEG CRY
D 00000000 00000000 00000000 00000000 00000000 00000000
A 00000524 00000534 00000000 00000000 00000000 00000000

The example above compares two word strings in memory until it finds a pair that differ. From the dw command, we can see that the first pair of words that differ is at locations 522 and 532. The address registers are incremented past these locations by the post-decrement addressing modes.
DBcc Instruction

DBcc is an instruction designed for looping. The condition cc is similar to the conditions for conditional branches (see the Bcc instructions). DBcc will commonly be placed at the end of a loop. The condition is the termination condition, much like the REPEAT/UNTIL condition of the Pascal language. The loop may also be terminated on a maximum count.

The termination count is contained in the low word of a data register. The data register is decremented until it reaches \(-1\). At this point the loop is terminated. Note that the comparison is for equal to \(-1\). If the data register initially contains \(-1\), then the loop will be repeated 65,536 times (assuming the termination condition is not satisfied).

The permissible instructions are:

- **DBCC**: Terminate if the C-bit (carry) is Clear.
- **DBCS**: Terminate if the C-bit (carry) is Set.
- **DBEQ**: Terminate on EQual. The loop terminates if the Z (Zero) bit is set.
- **DBGE**: Terminate on Greater than or Equal. The loop terminates if the N (negative) and V (overflow) bits are either both set or both clear. GE is used for two's complement binary numbers.
- **DBGTE**: Terminate on Greater Than. The loop terminates if
  - The N and V bits are both set and the Z-bit is clear, or,
  - The N, V, and Z bits are all clear.
- **DBHI**: Terminate on Higher than. The loop terminates if the C and Z bits are both clear. DBHI is similar to DBGT, except that it works on unsigned numbers.
- **DBLE**: Terminate Less than or Equal. The loop terminates if
  - The Z-bit is set, or,
  - The N-bit is set AND the V-bit is clear, or,
  - The N-bit is clear AND the V-bit is set.
  The DBLE instruction is used for two's complement binary numbers.
- **DBLS**: Terminate on Lower or Same. The loop terminates if either the C or Z bits are set. DBLS is similar to DBLE, except that it works on unsigned numbers.
- **DBLT**: Terminate on Less Than. The loop terminates if
  - The N-bit is set and the V-bit is clear, or,
The N-bit is clear and the V-bit is set.

- **DBMI**: Terminate on Minus. The loop terminates if the N-bit is set.
- **DBNE**: Terminate on Not Equal. The loop terminates if the Z-bit is clear.
- **DBPL**: Terminate on Plus. The loop terminates if the N-bit is clear.
- **DBVC**: Terminate on V Clear. The loop terminates if the V-bit is clear, indicating no overflow.
- **DBVS**: Terminate on V Set. The loop terminates if the V-bit is set, indicating overflow.
- **DBF**: Never terminate. The loop is terminated by count only. Many assemblers accept DBRA as an alternate to DBF.
- **DBT**: Always terminate. This instruction does not loop at all.

The condition is tested before decrementing the data register.

**Addressing Modes Allowed:**

DBcc instructions use a single addressing mode, where a two's complement displacement is contained in the second word of the instruction. If the loop is executed again, this displacement is sign-extended and added to the PC (Program Counter).

The PC contains the address of the displacement at the time the addition takes place.

**Data Sizes:** word

**Condition Codes Affected:** None

**Assembler Syntax:** DBcc Dn,<label>

<label> is a label on an instruction in the program.

**Machine Code Format:**

```
<table>
<thead>
<tr>
<th>Bit</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
```

16-bit displacement to loop beginning

The Register field specifies the data register number to be used as the loop counter. The condition is a four-bit encoding of the branch condition. The conditions are shown in Table 3.3.
<table>
<thead>
<tr>
<th>Condition</th>
<th>Instruction</th>
<th>Condition</th>
<th>Instruction</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>DBT</td>
<td>1000</td>
<td>DBVC</td>
</tr>
<tr>
<td>0001</td>
<td>DBRA, DBF</td>
<td>1001</td>
<td>DBVS</td>
</tr>
<tr>
<td>0010</td>
<td>DBHI</td>
<td>1010</td>
<td>DBPL</td>
</tr>
<tr>
<td>0011</td>
<td>DBLS</td>
<td>1011</td>
<td>DBMI</td>
</tr>
<tr>
<td>0100</td>
<td>DBCC</td>
<td>1100</td>
<td>DBGE</td>
</tr>
<tr>
<td>0101</td>
<td>DBCS</td>
<td>1101</td>
<td>DBLT</td>
</tr>
<tr>
<td>0110</td>
<td>DBNE</td>
<td>1110</td>
<td>DBGT</td>
</tr>
<tr>
<td>0111</td>
<td>DBEQ</td>
<td>1111</td>
<td>DBLE</td>
</tr>
</tbody>
</table>

Table 3.3 - Conditional Corresponding Instruction

Example:

PC = 0000006CC USP = 0001598C SSP = 000FBF08 ST = 0009 > IM = 0 NEG CRY
D 00000001 00000000 00000000 00000000 00000000 00000000 00000000 00000000
A 00000952 0000095A 00000000 00000000 00000000 00000000 00000000 00000000 0001598C
moveq #$A,D0
−l6ce,6d4
  000006CE move.b (A0) +,(A1) +
  000006D0 dbeq D0,6CE
  000006D4 nop

This sample code segment moves a null-terminated string whose address is contained in register A0 to an area whose address is in register A1. Putting A in D0 (10 decimal) means that if a zero byte is not found, up to eleven bytes will be moved. The areas pointed to by registers A0 and A1 are (conveniently) adjacent. The debugger display command shows:

−d952,966
00000952 48 65 6C 6C 20 00 00 00 00 00 00 00 00 00 00 Hello ...........
00000962 00 00 00 00 00 00 00 00

The string Hello should be duplicated starting at address 95A. Notice the trailing space. Executing the program shows:

−g,6d4
PC = 000006D4 USP = 0001598C SSP = 000FBF08 ST = 0004 > IM = 0 ZER
The count register (D0) is now 4, indicating that six bytes were moved out of a possible eleven. Both address registers have been incremented by seven, and now point to the byte after the first zero byte. (The address registers were incremented once more than the count register was decremented because the move.b instruction was executed seven times, while the dbeq instruction was executed only six.) Looking at memory again shows:

```
-d952,966
00000952 48 65 6C 6C 6F 20 00 00 48 65 6C 6C 6F 20 00 00 Hello ..Hello ..
00000962 00 00 00 00
```

The source string has been duplicated in the destination, including the trailing space and the null terminator.
The DIVS (DIVide Signed) instruction divides a 32-bit quantity contained in a data register by a 16-bit quantity contained in an effective address operand. The low-order word of the data register is replaced by the quotient, and the high-order word by the remainder. The remainder and quotient will always have the same sign, except when the remainder is 0.

Two error conditions are possible with a DIVS instruction:

1. An attempt is made to divide by zero. The 68000 processor generates an exception condition when this is attempted (see Chapter 7 on Exception Conditions).

2. A large number is divided by a small number, and the quotient will not fit in 16 bits. This is an Overflow condition. The V-bit in the status register is set, and the contents of the data register remain unmodified.

Addressing Modes Allowed:

<table>
<thead>
<tr>
<th>Dn</th>
<th>An</th>
<th>(An)</th>
<th>(An) +</th>
<th>− (An)</th>
<th>x(An)</th>
<th>x(An, x.r.s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>x.w</td>
<td>x I</td>
<td>x(PC)</td>
<td>x(PC, x.r.s)</td>
<td>#x</td>
<td>SR</td>
<td>CCR</td>
</tr>
</tbody>
</table>

Data Sizes: word

Condition Codes Affected:

- X  Not affected.
- N  Set if the quotient is negative. Cleared otherwise. Undefined on overflow conditions.
- Z  Set if the quotient is zero. Cleared otherwise. Undefined on overflow conditions.
C Always cleared.
V Set if overflow detected. Cleared otherwise.

Assembler Syntax: DIVS <ea>,Dn

Machine Code Format:

```
Bit 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
1 0 0 0 Register 1 1 1 Effective Address
```

The Register field specifies the data register to be used as the destination (dividend). The Effective Address field specifies the source (divisor).

Example:

```
PC = 000006DC USP = 0001598C SSP = 000FBF08 ST = 0000 = >IM = 0
D 00008887 00000000 00000000 00000000 00000000 00000000 00000000 00000000
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001598C
divs #$2,D0
  -t
PC = 000006E0 USP = 0001598C SSP = 000FBF08 ST = 0000 = >IM = 0
D 00014443 00000000 00000000 00000000 00000000 00000000 00000000 00000000
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001598C
```

This example divides 8887 by 2 to yield a quotient of 4443 with a remainder of 1.
DIVU Instruction

The DIVU (DIVide Unsigned) instruction divides a 32-bit quantity contained in a data register by a 16-bit quantity contained in an effective address operand. The low-order word of the data register is replaced by the quotient, and the high-order word by the remainder. All quantities are considered to be unsigned positive integers.

Two error conditions are possible with a DIVU instruction:

1. An attempt is made to divide by zero. The 68000 processor generates an exception condition when this is attempted (see Chapter 7 on Exception Conditions).

2. A large number is divided by a small number and the quotient will not fit in 16 bits. This is an overflow condition. The V-bit in the status register is set and the contents of the data register remain unmodified.

Addressing Modes Allowed:

<table>
<thead>
<tr>
<th>Dn</th>
<th>An</th>
<th>(An)</th>
<th>(An) +</th>
<th>− (An)</th>
<th>x(An)</th>
<th>x(An,xr.s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>x.w</td>
<td>x.I</td>
<td>x(PC)</td>
<td>x(PC,xr.s)</td>
<td>#x</td>
<td>SR</td>
<td>CCR</td>
</tr>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

Data Sizes: word

Condition Codes Affected:

X  Not affected.
N  Set if the quotient is negative. Cleared otherwise. Undefined on overflow conditions.
Z  Set if the quotient is zero. Cleared otherwise. Undefined on overflow conditions.
C  Always cleared.
V  Set if overflow detected. Cleared Otherwise.

Assembler Syntax: DIVU <ea>,Dn

Machine Code Format:

<table>
<thead>
<tr>
<th>Bit</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>Register</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>Effective</td>
<td>Address</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The Register field specifies the data register to be used as the destination (dividend). The Effective Address field specifies the source (divisor).

Example:

PC = 000006E8 USP = 0001598C SSP = 000FBF08 ST = 0000 = >IM = 0
D 00008887 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001598C
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001598C
divu #$2,D0
−t
PC = 000006EC USP = 0001598C SSP = 000FBF08 ST = 0000 = >IM = 0
D 00014443 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001598C
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001598C
nop

This example divides 8887 by 2 to yield a quotient of 4443 with a remainder of 1.
The EOR (Exclusive OR) instruction performs an exclusive OR function between a data register and memory. The data register is restricted to be the source, and the effective address is the destination.

Addressing Modes Allowed:

<table>
<thead>
<tr>
<th>Dn</th>
<th>An</th>
<th>(An)</th>
<th>(An)+</th>
<th>− (An)</th>
<th>x(An)</th>
<th>x(An,xr.s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>x.w</td>
<td>x.I</td>
<td>x(PC)</td>
<td>x(PC,xr.s)</td>
<td>#x</td>
<td>SR</td>
<td>CCR</td>
</tr>
</tbody>
</table>

Data Sizes: byte, word, long

Condition Codes Affected:

- **X** Not affected.
- **N** Set if the most significant bit of the result is set. Cleared otherwise.
- **Z** Set if the result is zero. Cleared otherwise.
- **C** Always cleared.
- **V** Always cleared.

Assembler Syntax: EOR Dn,<ea>

The EORI instruction is used to exclusive OR immediate data with an effective address. Many assemblers allow using the EOR mnemonic for both, and produce the proper instruction based on the source operand.

Machine Code Format:

```
Bit 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
1 0 1 1 Register 1 Size Effective Address
```

← Mode →  ← Reg. →
Register is the data register number to be used as the source operand. Size is 00 for byte, 01 for word, and 10 for long data sizes.

Example:

```
PC = 000006FA USP = 0001598C SSP = 000FBF08 ST = 0000 = >IM = 0
D 11113333 22222222 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001598C
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001598C
eor.I D1,D0
-t
PC = 000006FC USP = 0001598C SSP = 000FBF08 ST = 0000 = >IM = 0
D 33331111 22222222 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001598C
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001598C
```

This example executes an exclusive OR on 11113333 with 22222222 to become 33331111. The bits with place value two in all the nibbles in the high-order word of register D0 are initially zero, so the exclusive OR operation sets these bits. The inverse is true for the bits with place value two in the nibbles of the low-order word. (If you’re still not sure about how this works, convert the numbers to binary, do the EOR by hand, and then convert them back to hex.)
The EORI (Exclusive OR Immediate) instruction performs an exclusive OR function between an immediate operand and an effective address operand. The immediate operand must be the source, and the effective address is the destination.

Addressing Modes Allowed:

<table>
<thead>
<tr>
<th>Dn</th>
<th>An</th>
<th>(An)</th>
<th>(An) +</th>
<th>− (An)</th>
<th>x(An)</th>
<th>x(An,xr.s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>x.w</td>
<td>x.l</td>
<td>x(PC)</td>
<td>x(PC,xr.s)</td>
<td>#x</td>
<td>SR</td>
<td>CCR</td>
</tr>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Data Sizes: byte, word, long

Operations specifying the status register (SR) and condition code register (CCR) are restricted to word and byte data lengths, respectively. Operations specifying the status register (SR) are privileged. A 68000 privilege-violation exception will result if this instruction is attempted with the SR addressing mode from User mode. Exceptions are covered in Chapter 7, Exception Processing.

Condition Codes Affected:

- **X**: Not affected.
- **N**: Set if the most significant bit of the result is set. Cleared otherwise.
- **Z**: Set if the result is zero. Cleared otherwise.
- **C**: Always cleared.
- **V**: Always cleared.

When the status register or the condition code register are used as the destination, the condition codes are determined by the operation itself. All bits of the register are affected. Thus, if an EORI instruction to the condition code register leaves all bits in the CCR cleared, the Z-bit is not set as it would be with other operands.
Assembler Syntax: EORI #<data>,<ea>

The EOR instruction executes an exclusive OR on a data register with an effective address. Many assemblers allow using the EOR mnemonic for both EOR and EORI, and produce the proper instruction based on the source operand.

Machine Code Format:

<table>
<thead>
<tr>
<th>Bit</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Address</td>
<td>Mode</td>
<td>Reg.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Word data: 16 bits

Byte data: 8 bits

Long data: 32 bits, including previous word

Size is 00 for byte, 01 for word, and 10 for long data sizes.

Example:

PC = 00000704  USP = 0001598C  SSP = 000FBF08  ST = 0000  >IM = 0
D 11113333  00000000  00000000  00000000  00000000  00000000  00000000  00000000
A 00000000  00000000  00000000  00000000  00000000  00000000  00000000  00000000 001598C
eori.I #$22222222,D0
-t
PC = 0000070A  USP = 0001598C  SSP = 000FBF08  ST = 0000  >IM = 0
D 33331111  00000000  00000000  00000000  00000000  00000000  00000000  00000000
A 00000000  00000000  00000000  00000000  00000000  00000000  00000000  00000000 001598C

This example executes an exclusive OR on 11113333 with 22222222 to become 33331111. The bits with place value two in all the nibbles in the high-order word of register D0 are initially zero, so the exclusive OR operation sets these bits. The inverse is true for the bits with place value two in the nibbles of the low-order word. (If you’re still not sure about how this works, convert the numbers to binary, do the EOR by hand, and then convert them back to hex.)
EXG Instruction

The EXG instruction exchanges the complete contents of any two address or data registers.

Addressing Modes Allowed:
Only registers may be specified as operands.

Data Sizes: long

Condition Codes Affected: None

Assembler Syntax: EXG Rx,Ry

Machine Code Format:

Exchanging two data registers:

<table>
<thead>
<tr>
<th>Bit</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>Reg. Dx</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>Reg. Dy</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Exchanging two address registers:

<table>
<thead>
<tr>
<th>Bit</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>Reg. Ax</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>Reg. Ay</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Exchanging an address and a data register:

<table>
<thead>
<tr>
<th>Bit</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>Reg. Dx</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>Reg. Ay</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In exchanging an address and a data register, the address register must always be specified in bits 0–3 of the instruction word.
Example:

PC = 00000718 USP = 0001598C SSP = 000FBF08 ST = 0000 = >IM = 0
D 11111111 00000000 00000000 00000000 00000000 00000000 00000000 00000000
A 22222222 00000000 00000000 00000000 00000000 00000000 00000000 0001598C
exg D0,A0
-t
PC = 0000071A USP = 0001598C SSP = 000FBF08 ST = 0000 = >IM = 0
D 22222222 00000000 00000000 00000000 00000000 00000000 00000000 00000000
A 11111111 00000000 00000000 00000000 00000000 00000000 00000000 0001598C

This instruction exchanges the contents of registers A0 and D0.
**EXT Instruction**

The EXT (sign EXTend) instruction extends the sign-bit of a byte into a word, or of a word into a long. The EXT instruction takes a single operand, which must be a data register.

When extending a byte to a long, bit 7 of the register is replicated into bits 15–8 of the register. Extension of a word into a long means extending bit 15 of the register into bits 16–31 of the register.

**Addressing Modes Allowed:** Only data registers

**Data Sizes:** word, long

**Condition Codes Affected:**

- **X** Not affected.
- **N** Set if the result is negative. Cleared otherwise.
- **Z** Set if the result is zero. Cleared otherwise.
- **C** Always cleared.
- **V** Always cleared.

**Assembler Syntax:** EXT Dn

**Machine Code Format:**

```
<table>
<thead>
<tr>
<th>Bit</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
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<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>
```

The size field is 10 to extend a byte to a word, and 11 to extend a word to a long.

**Example:**

PC = 00000722  USP = 0001598C  SSP = 000FBF08  ST = 0000 = >IM = 0
D 00000080  00000000  00000000  00000000  00000000  00000000  00000000
A 00000000  00000000  00000000  00000000  00000000  00000000  00000000  0001598C
ext D0
This example extends the byte 80 hex to a word, and then to a long. Notice that 80 (hex) is a negative number (bit 7 of the byte is set).
ILLEGAL Instruction

The ILLEGAL instruction is not really an instruction at all. It is an operation code guaranteed to cause an illegal-instruction exception on all future 68000 family machines. (Illegal instructions are often used for breakpoints by debugger software.) Exceptions are detailed in Chapter 7, Exception Processing.

Addressing Modes Allowed: None
Data Sizes: None
Condition Codes Affected: None
Assembler Syntax: None
Machine Code Format:

<table>
<thead>
<tr>
<th>Bit</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
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<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
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<td>1</td>
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<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

(4AFC)
JMP Instruction

The JMP (JuMP) instruction is used to transfer control to an effective address. The address to which transfer is made is the address generated by the effective address computation. For example, if address register A0 contains 1000 hex, a JMP 4(A0) instruction transfers control to the instruction located at 1004.

Addressing Modes Allowed:

<table>
<thead>
<tr>
<th>Dn</th>
<th>An</th>
<th>(An)</th>
<th>(An) +</th>
<th>− (An)</th>
<th>x(An)</th>
<th>x(An,xr.s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>x.w</td>
<td>x.l</td>
<td>x(PC)</td>
<td>x(PC,xr.s)</td>
<td>#x</td>
<td>SR</td>
<td>CCR</td>
</tr>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

Data Sizes: Unsize

Condition Codes Affected: None

Assembler Syntax: JMP <ea>

Machine Code Format:

<table>
<thead>
<tr>
<th>Bit</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
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<th>1</th>
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<tbody>
<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Example:

PC = 0000072E USP = 0001598C SSP = 000FBF08 ST = 0008 = > IM = 0 NEG
D 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
A 00000736 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
jmp (A0)
- t
PC = 00000736 USP = 0001598C SSP = 000FBF08 ST = 0008 = >IM = 0 NEG
D 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
A 00000736 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001598C
**JSR Instruction**

The JSR (Jump to SubRoutine) instruction calls a subroutine using an effective address operand. The address of the instruction following the JSR is pushed onto the stack (as a long word). The next instruction to be executed is determined by the effective address computation. For example, if address register A0 contains 1000 hex, a JSR 4(A0) instruction would call a subroutine located at address 1004.

Addressing Modes Allowed:

<table>
<thead>
<tr>
<th>Dn</th>
<th>An</th>
<th>(An)</th>
<th>(An)</th>
<th>- (An)</th>
<th>x(An)</th>
<th>x(An,xr.s)</th>
</tr>
</thead>
<tbody>
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<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>x.w</td>
<td>x.l</td>
<td>x(PC)</td>
<td>x(PC,xr.s)</td>
<td>#x</td>
<td>SR</td>
<td>CCR</td>
</tr>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

**Data Sizes:** Unsized

**Condition Codes Affected:** None

**Assembler Syntax:** JSR <ea>

**Machine Code Format:**

```
Bit 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
0 1 0 0 1 1 1 0 1 0 Effective Address
```

**Example:**

PC = 0000073A USP = 0001598C SSP = 000FBF08 ST = 0008 = >IM = 0 NEG
D 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001598C
jsr $652
At this point, the subroutine has been called. We can see the return address at the top of the stack (the address in register A7).

```
        0015988 0000073E
```

Executing the RTS yields:

```c
        001598C
```

The return address has been popped off the stack.
The LEA (Load Effective Address) instruction places an effective address in an address register. All 32 bits of the register are affected.

The LEA instruction is normally used to write code that must be position-independent (i.e., can contain no code or data addresses in the program itself). The PC or Address register with displacement addressing modes are normally used for this type of coding.

The LEA instruction also adds a constant to an address register without altering the condition codes. By specifying the address register with displacement or index, either a constant or another register (or both) may be added to an address register in this manner.

Addressing Modes Allowed:

<table>
<thead>
<tr>
<th>Dn</th>
<th>An</th>
<th>(An)</th>
<th>(An)+</th>
<th>− (An)</th>
<th>x(An)</th>
<th>x(An, xr.s)</th>
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</thead>
<tbody>
<tr>
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<td>Yes</td>
</tr>
<tr>
<td>x.w</td>
<td>x.l</td>
<td>x(PC)</td>
<td>x(PC, xr.s)</td>
<td>#x</td>
<td>SR</td>
<td>CCR</td>
</tr>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

Data Sizes: long

Condition Codes Affected: None

Assembler Syntax: LEA <ea>, An

Machine Code Format:

```
Bit 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
  0 1 0 0 Register 1 1 1 Effective Address
```

The Register field specifies the address register used as the destination.
The Effective Address field specifies the address to be loaded into the address register.

Example:

\[
\begin{align*}
\text{PC} &= 00000740 \quad \text{USP} = 0001598C \quad \text{SSP} = 000F8F08 \quad \text{ST} = 0008 \quad \Rightarrow \text{IM} = 0 \quad \text{NEG} \\
D \quad &00000000 \quad 00000000 \quad 00000000 \quad 00000000 \quad 00000000 \quad 00000000 \quad 00000000 \quad 00000000 \\
A \quad &00000000 \quad 00000000 \quad 00000000 \quad 00000000 \quad 00000000 \quad 00000000 \quad 00000000 \quad 0001598C \\
\text{lea $736,A0} \\
\text{PC} &= 00000746 \quad \text{USP} = 0001598C \quad \text{SSP} = 000F8F08 \quad \text{ST} = 0008 \quad \Rightarrow \text{IM} = 0 \quad \text{NEG} \\
D \quad &00000000 \quad 00000000 \quad 00000000 \quad 00000000 \quad 00000000 \quad 00000000 \quad 00000000 \quad 00000000 \\
A \quad &00000736 \quad 00000000 \quad 00000000 \quad 00000000 \quad 00000000 \quad 00000000 \quad 00000000 \quad 0001598C \\
\text{lea $2(A0),A0} \\
\text{PC} &= 0000074A \quad \text{USP} = 0001598C \quad \text{SSP} = 000F8F08 \quad \text{ST} = 0008 \quad \Rightarrow \text{IM} = 0 \quad \text{NEG} \\
D \quad &00000000 \quad 00000000 \quad 00000000 \quad 00000000 \quad 00000000 \quad 00000000 \quad 00000000 \quad 00000000 \\
A \quad &00000738 \quad 00000000 \quad 00000000 \quad 00000000 \quad 00000000 \quad 00000000 \quad 00000000 \quad 0001598C
\end{align*}
\]

This example loads a constant address into address register A0 (using absolute long addressing). The second LEA instruction adds 2 to the address register.
The LINK instruction allocates a temporary area on the stack. Such an area is normally called a stack frame. Many block structured high-level languages, such as C, Pascal, and PL/I use this instruction for allocating variables that are local to a procedure. The variables are deallocated when the procedure is deactivated, permitting efficient memory usage.

The LINK instruction takes two operands: an address register and a 16-bit signed displacement. The address register is pushed onto the stack, and the resulting stack pointer is copied into the address register. The displacement (which is usually negative) is added to the stack pointer to allocate memory for the local variables. The stack winds up looking like Figure 3.5.

The local storage area is addressed using negative displacements from the address register, sometimes known as the frame pointer. In this way, local variables may be accessed without regard for intervening pushes and pops on the stack.
The UNLK instruction deallocates the stack frame and restores the stack pointer and address register to their original contents.

Addressing Modes Allowed: None

Data Sizes: None

Condition Codes Affected: None

Assembler Syntax: LINK An, #<displacement>

Machine Code Format:

```
  Bit   15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
        0 1 0 0 1 1 1 0 0 1 0 1 0
    Register

  16-bit displacement to add to A7
```

Register is the number of the address register to be used.

Example:

```
PC = 0000074C USP = 0001598C SSP = 000FBF08 ST = 0008 = >IM = 0 NEG
D 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001598C
link A6,#$FFF4
−t
PC = 00000750 USP = 0001597C SSP = 000FBF08 ST = 0008 = >IM = 0 NEG
D 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
A 00000000 00000000 00000000 00000000 00000000 00000000 00015988 0001597C
```

This instruction pushes a total of 16 (10 hex) bytes on the stack: four for the address register and twelve due to the displacement field. ($FFF4 is −12 decimal.) The long word address contained in register A6 shows the old contents of A6:

```
−sl15988
00015988 00000000
```
The UNLK instruction reverses the action of the LINK instructions.
The LSL (Logical Shift Left) instruction performs a logical left shift on a data register or an effective address operand. There are three forms of this instruction:

1. Shift a data register to the left by a constant contained in the instruction. Shifts from one to eight bits can be accomplished using this form of the instruction.
2. Shift a data register to the left by the number of bits contained in another data register.
3. Shift a memory word (16 bits) left by a single bit.

Addressing Modes Allowed: Memory form only

<table>
<thead>
<tr>
<th>Dn</th>
<th>An</th>
<th>(An)</th>
<th>(An) +</th>
<th>− (An)</th>
<th>x(An)</th>
<th>x(An,xr.s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>x.w</td>
<td>x.l</td>
<td>x(PC)</td>
<td>x(PC,xr.s)</td>
<td>#x</td>
<td>SR</td>
<td>CCR</td>
</tr>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

Data Sizes: byte, word, long

Memory operations are restricted to word length.

Condition Codes Affected:

X Set according to the last bit shifted out of the high-order bit position of the operand. Unaffected if the shift count is zero.
N Set if the high order bit of the result is set (indicating a negative result). Cleared otherwise.
Z Set if the result is zero. Cleared otherwise.
V Always cleared.
C Set according to the last bit shifted out of the high-order bit position of the operand. Unaffected if the shift count is zero.
Assembler Syntax: LSL

LSL Dx,Dy
LSL #<data>,Dy
LSL <ea>

Machine Code Format:

Data register as destination

<table>
<thead>
<tr>
<th>Bit</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
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<tbody>
<tr>
<td></td>
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<tr>
<td>Immed.</td>
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<tr>
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<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

Memory location as destination

<table>
<thead>
<tr>
<th>Bit</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
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<th>7</th>
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<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
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<td>0</td>
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<td></td>
<td>1</td>
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<td></td>
</tr>
<tr>
<td>Effective Address</td>
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<tr>
<td>← Mode → ← Reg. →</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The Immediate field contains either the shift count or the data register number that contains the shift count. A 000 in this field represents a shift count of 8. Values 001 through 111 represent shift counts of 1–7. Size is either 00 for byte data, 01 for words, and 10 for longs. The T-bit (type) is a 0 if the shift count is contained in the instruction, and 1 if the shift count is in a data register. Register is the destination data register number.

Example:

PC = 0000075E USP = 0001598C SSP = 000FBF08 ST = 0000 = >IM = 0
D 00001111 00000002 00000000 00000000 00000000 00000000 00000000 00000000 0001598C
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001598C
Isl D1,D0
   -t
PC = 00000760 USP = 0001598C SSP = 000FBF08 ST = 0000 = >IM = 0
D 00004444 00000002 00000000 00000000 00000000 00000000 00000000 00000000 0001598C
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001598C

This example uses the data register form of the instruction. 1111 is shifted left by two places to become 4444.
**LSR Instruction**

The LSR (Logical Shift Right) instruction performs a logical right shift on a data register or an effective address operand. There are three forms of this instruction:

1. Shift a data register to the right by a constant contained in the instruction. Shifts from one to eight bits can be accomplished using this form of the instruction.

2. Shift a data register to the right by the number of bits contained in another data register.

3. Shift a memory word (16 bits) right by a single bit.

Addressing Modes Allowed: Memory form only

<table>
<thead>
<tr>
<th>Dn</th>
<th>An</th>
<th>(An)</th>
<th>(An) +</th>
<th>− (An)</th>
<th>x(An)</th>
<th>x(An,xr.s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>x.w</td>
<td>x.l</td>
<td>x(PC)</td>
<td>x(PC,xr.s)</td>
<td>#x</td>
<td>SR</td>
<td>CCR</td>
</tr>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

Data Sizes: byte, word, long

Memory operations are restricted to word length.

Condition Codes Affected:

X  Set according to the last bit shifted out of the low-order bit position of the operand. Unaffected if the shift count is zero.

N  Set if the high order bit of the result is set (indicating a negative result). Cleared otherwise.

Z  Set if the result is zero. Cleared otherwise.

V  Always cleared.

C  Set according to the last bit shifted out of the low-order bit position of the operand. Unaffected if the shift count is zero.
Assembler Syntax: LSR Dx,Dy
LSR #<data>,Dy
LSR <ea>

Machine Code Format:

Data register as destination

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<th>Bit</th>
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<th>12</th>
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<td>Register</td>
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Memory location as destination

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<td>Effective Address</td>
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</tbody>
</table>

The Immediate field contains either the shift count or the data register number that contains the shift count. A 000 in this field represents a shift count of 8. Values 001 through 111 represent shift counts of 1–7. Size is either 00 for byte data, 01 for words, and 10 for longs. The T-bit (type) is a 0 if the shift count is contained in the instruction, and 1 if the shift count is in a data register. Register is the destination data register number.

Example:

PC = 0000076A USP = 0001598C SSP = 000FBF08 ST = 0000 = > IM = 0
D 88888888 00000002 00000000 00000000 00000000 00000000 00000000 00000000
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001598C
lsr D1,D0 − t

PC = 0000076C USP = 0001598C SSP = 000FBF08 ST = 0000 = > IM = 0
D 88882222 00000002 00000000 00000000 00000000 00000000 00000000 00000000
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001598C

This example shifts data register D0.W (the low word of D0) to the right by two places. The upper half of D0 is unaffected.
**MOVE Instruction**

The MOVE instruction copies a byte, word, or longword from one effective address operand to another. The condition codes are set according to the data that is moved during the operand.

**Addressing Modes Allowed: Source operand**

<table>
<thead>
<tr>
<th>Dn</th>
<th>An</th>
<th>(An)</th>
<th>(An) +</th>
<th>– (An)</th>
<th>x(An)</th>
<th>x(An,xr.s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>x.w</td>
<td>x.l</td>
<td>x(PC)</td>
<td>x(PC,xr.s)</td>
<td>#x</td>
<td>SR</td>
<td>CCR</td>
</tr>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

**Addressing Modes Allowed: Destination operand**

<table>
<thead>
<tr>
<th>Dn</th>
<th>An</th>
<th>(An)</th>
<th>(An) +</th>
<th>– (An)</th>
<th>x(An)</th>
<th>x(An,xr.s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>x.w</td>
<td>x.l</td>
<td>x(PC)</td>
<td>x(PC,xr.s)</td>
<td>#x</td>
<td>SR</td>
<td>CCR</td>
</tr>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

Use of the An (address register direct) addressing mode is restricted to instructions with word and long data sizes.

**Data Sizes:** byte, word, long

**Condition Codes Affected:**

X  Not affected.
N  Set if the high order bit of the result is a one. Cleared otherwise.
Z  Set if the result is zero. Cleared otherwise.
V  Always cleared.
C  Always cleared.

Assembler Syntax: MOVE  <ea>,<ea>

MOVEA moves to an address register. Most assemblers automatically use the right instruction with an address register destination.

Machine Code Format:

<table>
<thead>
<tr>
<th>Bit</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Size</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Destination &lt;ea&gt;</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Source &lt;ea&gt;</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Size is the size of the data to be transferred: 01 for bytes, 11 for words, and 10 for longs.

Example:

PC = 00000774 USP = 0001598C SSP = 000FBF08 ST = 0000 = >IM = 0
D 11111111 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001598C
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001598C

move.b $92D,D0
- s92d
0000092D 99.
- t
PC = 0000077A USP = 0001598C SSP = 000FBF08 ST = 0008 = >IM = 0 NEG
D 11111199 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001598C
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001598C

This instruction moves a memory location into a data register. Byte moves into a data register leave the upper three bytes of the register unmodified.
**MOVE to CCR Instruction**

The MOVE to CCR instruction moves the low-order byte of a word operand to the condition code register (CCR), the User byte of the status register. The high-order byte of the source is ignored.

Addressing Modes Allowed:

<table>
<thead>
<tr>
<th>Dn</th>
<th>An</th>
<th>(An)</th>
<th>(An) +</th>
<th>− (An)</th>
<th>x(An)</th>
<th>x(An,xr.s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>x.w</td>
<td>x.l</td>
<td>x(PC)</td>
<td>x(PC,xr.s)</td>
<td>#x</td>
<td>SR</td>
<td>CCR</td>
</tr>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

Data Size: word

Condition Codes Affected:

- **X** Set from bit 4 of the source operand.
- **N** Set from bit 3 of the source operand.
- **Z** Set from bit 2 of the source operand.
- **V** Set from bit 1 of the source operand.
- **C** Set from bit 0 of the source operand.

Assembler Syntax: MOVE <ea>,CCR

Machine Code Format:

<table>
<thead>
<tr>
<th>Bit</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Effective Address

Example:

PC = 00x0077C USP = 0001598C SSP = 000FBF08 ST = 0000 = >IM = 0
D 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
This instruction sets all condition code bits in the status register.
**MOVE to SR Instruction**

The MOVE to SR (Status Register) instruction transfers a word operand to the CPU status register. All bits of the status register are affected. This instruction requires that the S-bit of the status register (bit 13) be set at the beginning of the instruction (i.e., the CPU must be in Supervisor state).

This instruction may be used to alter the Status register Trace bit, Supervisor bit, interrupt mask, and condition codes. Typical uses include:

- Clearing the Supervisor bit to transfer to User mode.
- Clearing the Interrupt mask to enable CPU interrupts.
- Setting bits in the Interrupt mask to partially or completely disable CPU interrupts.

Changing the condition codes is normally done with the MOVE to CCR instruction, which is not privileged, and can be executed from either supervisor or user mode.

**Addressing Modes Allowed:**

<table>
<thead>
<tr>
<th>Dn</th>
<th>An</th>
<th>(An)</th>
<th>(An) +</th>
<th>− (An)</th>
<th>x(An)</th>
<th>x(An,xr.s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>x.w</td>
<td>x.l</td>
<td>x(PC)</td>
<td>x(PC,xr.s)</td>
<td>#x</td>
<td>SR</td>
<td>CCR</td>
</tr>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

Data Size: word

Condition Codes Affected:

- X  Set from bit 4 of the source operand.
- N  Set from bit 3 of the source operand.
- Z  Set from bit 2 of the source operand.
- V  Set from bit 1 of the source operand.
- C  Set from bit 0 of the source operand.
Assembler Syntax: MOVE <ea>,SR

Machine Code Format:

<table>
<thead>
<tr>
<th>Bit</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Effective Address

Example:

- g.786
PC = 00000786 USP = 0001598C SSP = 0007BF08 ST = 2010 = >SUP IM = 0

EXT
D 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
move #$200F,SR
- g.78a
PC = 00078A USP = 01598C SSP = 07BF08 ST = 200F = >SUP IM = 0 NEG ZER OFL CRY
D 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000

This instruction sets the N, Z, O, C, condition codes, as well as the S-bit. The S (Supervisor) bit is set before execution. A Privilege-violation exception results if this instruction is attempted from User mode. Notice that address register A7 reflects the supervisor stack pointer (SSP) rather than the user stack pointer (USP).
**MOVE from SR Instruction**

The MOVE from SR (Status Register) instruction transfers the entire status register to a word operand. Memory operands are read before writing. This instruction is privileged on the 68010 processor. (A privileged instruction requires that the S-bit [bit 13] in the status register be set prior to execution.)

Addressing Modes Allowed:

<table>
<thead>
<tr>
<th>Dn</th>
<th>An</th>
<th>(An)</th>
<th>(An) +</th>
<th>− (An)</th>
<th>x(An)</th>
<th>x(An,xr.s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>x.w</td>
<td>x.I</td>
<td>x(PC)</td>
<td>x(PC,xr.s)</td>
<td>#x</td>
<td>SR</td>
<td>CCR</td>
</tr>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

Data Size: word

Condition Codes Affected: None

Assembler Syntax: MOVE SR,<ea>

Machine Code Format:

```
0 1 0 0 0 0 0 0 0 1 1 0
```

Example:

PC = 0000078C   USP = 0001598C   SSP = 0007BF08   ST = 200F = >SUP   IM = 0
NEG ZER OFL CRY
D 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0007BF08
move SR,D0
- t
PC = 0000078E USP = 0001598C SSP = 0007BF08 ST = 200F = >SUP IM = 0
NEG ZER OFL CRY
D 0000200F 00000000 00000000 00000000 00000000 00000000 00000000 00000000
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0007BF08

This instruction transfers the status register to the low-order word of data register D0. Notice that address register A7 reflects the supervisor stack pointer (SSP) rather than the user stack pointer (USP).
**MOVE USP Instruction**

The MOVE USP instruction transfers the user stack pointer to or from an address register. This instruction is a privileged instruction. (The S-bit [bit 13] in the status register must be set.)

A MOVE USP instruction is normally used by a supervisor program to set up a stack area in a user program. The 68000 has separate user and supervisor stack pointer registers, so this special instruction is required to enable the supervisor program to access the user mode stack pointer.

Addressing Modes Allowed: Only An

Data Size: long

Condition Codes Affected: None

Assembler Syntax:

```
MOVE USP,An
MOVE An,USP
```

Machine Code Format:

<table>
<thead>
<tr>
<th>Bit</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

To transfer the address register to the USP, the T field is 0, and 1 to transfer the USP to the address register. The Register field specifies the number of the address register to be used.

Example:

```
PC=000790 USP=01558C SSP=07BF08 ST=200F = >SUP IM=0 NEG ZER OFL CRY
D 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
move.I USP,A0
-t
PC=000792 USP=01558C SSP=07BF08 ST=200F = >SUP IM=0 NEG ZER OFL CRY
D 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
A 0001558C 00000000 00000000 00000000 00000000 00000000 00000000 00000000
```

This example transfers the user stack pointer (USP) to address register A0. The status register S bit must be set for this privileged instruction.
**MOVEA Instruction**

The MOVEA (Move Address) instruction moves an effective address operand to an address register. Only word and long data sizes are allowed. All 32 bits of the address register are always affected. Word operations are sign extended to 32 bits before loading the address register.

Addressing Modes Allowed:

<table>
<thead>
<tr>
<th>Dn</th>
<th>An</th>
<th>(An)</th>
<th>(An) +</th>
<th>− (An)</th>
<th>x(An)</th>
<th>x(An,xr.s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>x.w</td>
<td>x.l</td>
<td>x(PC)</td>
<td>x(PC,xr.s)</td>
<td>#x</td>
<td>SR</td>
<td>CCR</td>
</tr>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

Data Sizes: word, long

Condition Codes Affected: None

Assembler Syntax: MOVEA <ea>,An

Many assemblers will generate the MOVEA instruction when a MOVE instruction specifies an address register as the destination.

Machine Code Format:

<table>
<thead>
<tr>
<th>Bit</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The Size field is 11 for word transfers, and 10 for long transfers. The Register field gives the destination address register. Notice that this instruction is really a MOVE instruction with a destination addressing mode of 001.
Example:

\[
\begin{array}{c}
\text{PC = 00000796 USP = 0001558C SSP = 0007BF08 ST = 0000 = }>IM = 0 \\
D 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 \\
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 \\
\text{move.I #$1234567,A0} \\
-t \\
\text{PC = 0000079C USP = 0001558C SSP = 0007BF08 ST = 0000 = }>IM = 0 \\
D 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 \\
A \text{01234567} 00000000 00000000 00000000 00000000 00000000 00000000 0001558C
\end{array}
\]

This example loads address register A0 with the constant 01234567.
**MOVEM Instruction**

The MOVEM (MOVE Multiple) instruction provides a means for rapidly transferring a group of registers to or from memory. The size of the operation is restricted to word or long data. For word operations that transfer data to the registers, each word is sign-extended to 32 bits before loading the register. All 32 bits of the register are always affected, regardless of whether the register is an address or data register.

The order in which the registers are stored in memory is as follows:

<table>
<thead>
<tr>
<th>Address (effective address)</th>
<th>Register</th>
</tr>
</thead>
<tbody>
<tr>
<td>+0</td>
<td>DO</td>
</tr>
<tr>
<td>+4</td>
<td>D1</td>
</tr>
<tr>
<td>.</td>
<td></td>
</tr>
<tr>
<td>.</td>
<td></td>
</tr>
<tr>
<td>+28</td>
<td>D7</td>
</tr>
<tr>
<td>+32</td>
<td>A0</td>
</tr>
<tr>
<td>+36</td>
<td>A1</td>
</tr>
<tr>
<td>.</td>
<td></td>
</tr>
<tr>
<td>.</td>
<td></td>
</tr>
<tr>
<td>+60</td>
<td>A7</td>
</tr>
<tr>
<td>+64</td>
<td>(Unused)</td>
</tr>
</tbody>
</table>

Any combination of the registers may be loaded or stored using this instruction. The illustration above assumes that all registers are present and long data size.

This instruction is used primarily for pushing a group of registers on the stack so that they may be used temporarily and later reset to their original
values, also using a MOVEM instruction. This technique is especially valuable for subroutines and exception-processing routines, where it is often not known which registers can be modified.

An anomaly of 68000 architecture causes an extra memory reference when transferring memory to registers using a MOVEM. In the diagram above, offsets 64 and 65 from the base of the register area in memory would be read (again assuming all registers were present). This is usually not significant, but it can cause problems in certain specialized cases. For example, trying to transfer registers from the very last locations in memory will cause an erroneous BUSERR to occur due to the access of the next word (which is not a valid memory address in this case). The BUSERR exception is explained in Chapter 7, Exception Processing.

Addressing Modes Allowed: Registers to memory

<table>
<thead>
<tr>
<th>Dn</th>
<th>An</th>
<th>(An)</th>
<th>(An) +</th>
<th>– (An)</th>
<th>x(An)</th>
<th>x(An, Xr, s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>x.w</td>
<td>x.l</td>
<td>x(PC)</td>
<td>x(PC, Xr, s)</td>
<td>#x</td>
<td>SR</td>
<td>CCR</td>
</tr>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

Memory to Registers:

<table>
<thead>
<tr>
<th>Dn</th>
<th>An</th>
<th>(An)</th>
<th>(An) +</th>
<th>– (An)</th>
<th>x(An)</th>
<th>x(An, Xr, s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>x.w</td>
<td>x.l</td>
<td>x(PC)</td>
<td>x(PC, Xr, s)</td>
<td>#x</td>
<td>SR</td>
<td>CCR</td>
</tr>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

Data Sizes: word, long

Condition Codes Affected: None
Assembler Syntax: MOVEM <register list>,<ea>
MOVEM <ea>,<register list>

The register list is composed of a series of register specifications separated by a slash (the / character). For example, D0/D2/A5 specifies registers D0, D2, and A5 as operands. It is also possible to use one or more ranges in the register list. A range consists of two register specifications separated by the – character. For instance, D0–D5/A0–A2 specifies registers D0, D1, D2, D3, D4, D5, A0, A1, and A2.

Machine Code Format:

Registers to Memory:

<table>
<thead>
<tr>
<th>Bit</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
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<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>Sz</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Effective Address

Mode → Reg. →

Register List Bit Mask

Memory to Registers:

<table>
<thead>
<tr>
<th>Bit</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>Sz</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Effective Address

Mode → Reg. →

Register List Bit Mask

The Sz (size) bit is a 0 for word transfers and a 1 for long transfers. The register list mask contains a single bit for each register that can be transferred by a MOVEM instruction (16 registers). If the bit is a 1, then the register is transferred. If the bit is 0, then the register is not transferred.

The register-list word has two possible orientations, one for pre-decrement mode addressing and one for all other addressing modes. In all cases, the low-order bit of the mask corresponds to the register that is
to be transferred first. The two sets of correspondence between registers and bits are as follows:

**Pre-decrement (−(An)) addressing mode:**

<table>
<thead>
<tr>
<th>Bit</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>D0</td>
<td>D1</td>
<td>D2</td>
<td>D3</td>
<td>D4</td>
<td>D5</td>
<td>D6</td>
<td>D7</td>
<td>A0</td>
<td>A1</td>
<td>A2</td>
<td>A3</td>
<td>A4</td>
<td>A5</td>
<td>A6</td>
<td>A7</td>
</tr>
</tbody>
</table>

**All other addressing modes:**

<table>
<thead>
<tr>
<th>Bit</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A7</td>
<td>A6</td>
<td>A5</td>
<td>A4</td>
<td>A3</td>
<td>A2</td>
<td>A1</td>
<td>A0</td>
<td>D7</td>
<td>D6</td>
<td>D5</td>
<td>D4</td>
<td>D3</td>
<td>D2</td>
<td>D1</td>
<td>D0</td>
</tr>
</tbody>
</table>

**Example:**

PC = 0000079E  USP = 0001558C  SSP = 0007BF08  ST = 0000 = >IM = 0  
D  000000D0  000000D1  00000000  00000000  00000000  00000000  00000000  00000000  00000000  00000000  00000000  00000000  00000000  001558C
A  000000A0  000000A1  00000000  00000000  00000000  00000000  00000000  00000000  00000000  00000000  00000000  00000000  00000000  0001558C
movem.I D0 − D1/A0 − A0, −(A7)  
−t  
PC = 000007A2  USP = 00015580  SSP = 0007BF08  ST = 0000 = >IM = 0  
D  000000D0  000000D1  00000000  00000000  00000000  00000000  00000000  00000000  00000000  00000000  00000000  00000000  00000000  0001558C  
A  000000A0  000000A1  00000000  00000000  00000000  00000000  00000000  00000000  00000000  00000000  00000000  00000000  00000000  0001558C

This instruction pushes the contents of registers D0, D1, and A0 on the stack. Using the S command, we can look at the stack and see the saved registers.

−s15580  
0015580 000000D0  
0015584 000000D1  
0015588 000000A0  
−t  
PC = 000007A4  USP = 00015580  SSP = 0007BF08  ST = 0000 = >IM = 0  
D  00000000  00000000  00000000  00000000  00000000  00000000  00000000  00000000  00000000  00000000  00000000  00000000  00000000  00015580  
A  00000000  000000A1  00000000  00000000  00000000  00000000  00000000  00000000  00000000  00000000  00000000  00000000  00000000  00015580
movem.I (A7) +,D0 − D1/A0 − A0
The second half of the example above restores the registers from the stack. Notice that D0, D1, and A0 are valid hexadecimal numbers as well as names for registers.
MOVEP Instruction

The MOVEP (MOVE Peripheral) instruction provides a convenient method for accessing 8-bit peripheral devices connected to a 68000. The 68000 is a 16-bit microprocessor. This means that there are sixteen data lines connecting the processor to memory, as illustrated in Figure 3.6.

Many I/O devices were designed for 8-bit microprocessors, and thus have only eight data lines. These devices can be connected to the 68000 using either the Upper byte data lines or the Lower byte data lines. Addressing a device connected in such a fashion is done by using alternate memory addresses (for example, 1,3,5 for devices connected to the Lower byte lines, or 0,2,4 for devices connected to the Upper byte lines). The MOVEP instruction is facilitates this process.

The MOVEP instruction transfers a word or a longword contained in a data register to or from these alternate memory addresses. The destination memory address is specified using the address register with displacement addressing mode— x(An).

Figure 3.6 – Sixteen data lines connecting the processor to memory
The high-order byte of the data register is transferred to or from address x(An), the next byte to or from x+2(An), and so forth. If the original address was odd, then all transfers from the MOVEP will use the Lower byte of the 68000 data bus. Even addresses use the High byte.

Addressing Modes Allowed: x(An) only

Data Sizes: word, long

Condition Codes Affected: None

Assembler Syntax: MOVEP Dn,x(An)
               MOVEP x(An),Dn

Machine Code Format:

```
<table>
<thead>
<tr>
<th>Bit</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
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<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>Dr</td>
<td>Sz</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>An</td>
<td>Reg.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
```

The Dn Register and An Register give the numbers of the data and address registers to be used, respectively. The Dr (direction) bit is 0 for memory to register transfers and 1 for register to memory transfers. The Sz (size) bit is 1 for long data and 0 for words. The displacement field is a 16-bit offset that is added to the address register to form the base memory address at which the transfer begins.

Example:

```
PC = 0000B6 USP = 00158C SSP = 007F08 ST = 0000 = >IM = 0
D 01234567 00000000 00000000 00000000 00000000 00000000 00000000 00000000
A 0000964 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001558C
movep.l D0,0(A0)
-t
PC = 0000BA USP = 00158C SSP = 007F08 ST = 0000 = >IM = 0
D 01234567 00000000 00000000 00000000 00000000 00000000 00000000 00000000
A 0000964 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001558C
-d964,96c
00000964 01 00 23 00 45 00 67 00 00
```

In this example, register D0 is stored starting at address 964. Since the starting address is even, the bytes in D0 will go into the high-order bytes of successive words, as illustrated by the d command. The high-order byte of D0 is stored first.
The MOVEQ instruction provides a method for loading a small immediate quantity into a data register. The instruction is two bytes in length, and can load any constant in the range –128 to +127 (decimal). All 32 bits of the register are affected. (The corresponding MOVE immediate long instruction takes six bytes.)

Data Size: long

Condition Codes Affected:

- X: Not affected.
- N: Set if the result is negative. Cleared otherwise.
- Z: Set if the result is zero. Cleared otherwise.
- V: Always cleared.
- C: Always cleared.

Assembler Syntax: MOVEQ  #<data>,Dn

Many assemblers automatically convert a move with the appropriate operands into a MOVEQ.

Machine Code Format:

<table>
<thead>
<tr>
<th>Bit</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
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<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Register</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The Register field identifies the destination data register. The Immediate Data is an 8-bit immediate operand that is sign-extended before loading into the data register.

Example:

PC = 000007BC  USP = 0001558C  SSP = 0007BF08  ST = 0000 = >IM = 0
D 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001558C
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001558C
moveq #$80,D0
This example loads register D0 with the constant 80 hex (−128 decimal). The data is sign-extended into a long by the operation.
MULS Instruction

The MULS (MULtiply Signed) instruction multiplies a 16-bit data register operand by a 16-bit effective address operand, leaving the 32-bit result in the data register. The operation assumes two's complement arithmetic.

Addressing Modes Allowed:

<table>
<thead>
<tr>
<th>Dn</th>
<th>An</th>
<th>(An)</th>
<th>(An) +</th>
<th>(An)</th>
<th>x(An)</th>
<th>x(An,xr.s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>x.w</td>
<td>x.l</td>
<td>x(PC)</td>
<td>x(PC,xr.s)</td>
<td>#x</td>
<td>SR</td>
<td>CCR</td>
</tr>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

Data Size: word

Condition Codes Affected:

X  Not affected.
N  Set if the result is negative. Cleared otherwise.
Z  Set if the result is zero. Cleared otherwise.
V  Always cleared.
C  Always cleared.

Assembler Syntax: MULS <ea>,Dn

Machine Code Format:

<table>
<thead>
<tr>
<th>Bit</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Register</td>
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<td>1</td>
<td>1</td>
<td></td>
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<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mode →</td>
<td></td>
<td>Reg. →</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The Register field identifies the data register to be used as the destination.
Example:

```
PC = 000007C6 USP = 0001598C SSP = 0007BF08 ST = 0000 = >IM = 0
D 00001234 00000000 00000000 00000000 00000000 00000000 00000000 00000000
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001598C
muls #$10,D0
  - t
PC = 000007CA USP = 0001598C SSP = 0007BF08 ST = 0000 = >IM = 0
D 00012340 00000000 00000000 00000000 00000000 00000000 00000000 00000000
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001598C
```

This example multiplies the contents of register D0 by the constant 10 hex (16 decimal).
MULU Instruction

The MULU (MULtiply Unsigned) instruction multiplies a 16-bit data register operand by a 16-bit effective address operand, leaving the 32-bit result in the data register. The operation assumes unsigned arithmetic.

Addressing Modes Allowed:

<table>
<thead>
<tr>
<th>Dn</th>
<th>An</th>
<th>(An)</th>
<th>(An) +</th>
<th>− (An)</th>
<th>x(An)</th>
<th>x(An,xr.s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>x.w</td>
<td>x.I</td>
<td>x(PC)</td>
<td>x(PC,xr.s)</td>
<td>#x</td>
<td>SR</td>
<td>CCR</td>
</tr>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

Data Size: word

Condition Codes Affected:

- X  Not affected.
- N  Set if the most significant bit of the result is set. Cleared otherwise.
- Z  Set if the result is zero. Cleared otherwise.
- V  Always cleared.
- C  Always cleared.

Assembler Syntax: MULU <ea>,Dn

Machine Code Format:

<table>
<thead>
<tr>
<th>Bit</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
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<th>6</th>
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<td>1</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

The Register field identifies the data register to be used as the destination.
Example:

```
PC = 000007D2 USP = 0001598C SSP = 0007BF08 ST = 0000 = >IM = 0
D 00008000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001598C
mulu #$5, D0
 - t
PC = 000007D6 USP = 0001598C SSP = 0007BF08 ST = 0000 = >IM = 0
D 00280000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001598C
```

This example multiplies hex 8000 (normally a negative number) by 5. Notice that the result is positive. This is because unsigned arithmetic was used in the MULU instruction.
The NBCD (Negate BCD) instruction forms the negative of a BCD (binary coded decimal) number. The technique used is ten's complement, analogous to the two's complement used with binary numbers. The ten's complement of a number is formed by subtracting the number from all 9s and then adding one. As with binary numbers, the complementing process works only if you have a fixed number of digits.

For example, assume you have a 4-digit BCD system. The ten's complement of 0001 is (9999 − 0001) + 1, or 9999. Adding this number to a positive decimal number is equivalent to subtracting 1.

As with the other 68000 BCD instructions, NBCD is intended for multiprecision BCD arithmetic. The X (eXtend) bit is added to the ten's complement process. This bit provides the borrow necessary for multiprecision arithmetic. The Z-bit is only cleared by this instruction. This allows the Z-bit to accurately reflect a multiprecision result. Normally, a series of NBCD instructions begins with the X-bit clear and the Z-bit set. The size of the operation is restricted to byte size.

Addressing Modes Allowed:

<table>
<thead>
<tr>
<th>Dn</th>
<th>An</th>
<th>(An)</th>
<th>(An) +</th>
<th>− (An)</th>
<th>x(An)</th>
<th>x(An,xr.s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>x.w</td>
<td>x.l</td>
<td>x(PC)</td>
<td>x(PC,xr.s)</td>
<td>#x</td>
<td>SR</td>
<td>CCR</td>
</tr>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

Data Size: byte

Condition Codes Affected:

X Set if a borrow was generated in the subtraction operation. Cleared otherwise.
N Undefined.
Z Cleared if the result was not a zero. Unchanged otherwise.
V Undefined.
C Set if a borrow was generated in the subtraction operation.
Cleared otherwise.

Assembler Syntax: NBCD <ea>

Machine Code Format:

<table>
<thead>
<tr>
<th>Bit</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
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<th>6</th>
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<tbody>
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<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Effective Address

Example:

PC = 000007DA USP = 0001598C SSP = 0007BF08 ST = 0000 = >IM = 0
D 00000001 00000000 00000000 00000000 00000000 00000000 00000000 00000000
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001598C
nbcd D0
- t
PC = 000007DC USP = 0001598C SSP = 0007BF08 ST = 0019 = >IM = 0 EXT NEG CRY
D 00000099 00000000 00000000 00000000 00000000 00000000 00000000 00000000
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001598C

This example takes the ten's complement of 01 to produce 99. (Remember, BCD is the same as hex.)
**NEG Instruction**

The NEG (NEGate) instruction forms the two’s complement of an effective address operand.

**Addressing Modes Allowed:**

<table>
<thead>
<tr>
<th>Dn</th>
<th>An</th>
<th>(An)</th>
<th>(An) +</th>
<th>− (An)</th>
<th>x(An)</th>
<th>x(An,xr.s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>x.w</td>
<td>x.l</td>
<td>x(PC)</td>
<td>x(PC,xr.s)</td>
<td>#x</td>
<td>SR</td>
<td>CCR</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Dn</th>
<th>An</th>
<th>(An)</th>
<th>(An) +</th>
<th>− (An)</th>
<th>x(An)</th>
<th>x(An,xr.s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

**Data Sizes:** byte, word, long

**Condition Codes Affected:**

- X  Cleared if the result is zero. Set otherwise.
- N  Set if the result is negative. Cleared otherwise.
- Z  Set if the result is zero. Cleared otherwise.
- V  Set if an overflow is generated. Cleared otherwise.
- C  Cleared if the result is zero. Set otherwise.

**Assembler Syntax:** NEG <ea>

**Machine Code Format:**

```
Bit  15  14  13  12  11  10  9  8  7  6  5  4  3  2  1  0
  0  1  0  0  0  1  0  0  Size  Effective  Address
```

The Size field is 00 for byte data, 01 for words, and 10 for longs.
Example:

PC = 000007E2 USP = 0001598C SSP = 0007BF08 ST = 0010 = >IM = 0 EXT
D 00000001 00000000 00000000 00000000 00000000 00000000 00000000 00000000
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 001598C
neg D0
-t
PC = 000007E4 USP = 0001598C SSP = 0007BF08 ST = 0019 = >IM = 0 EXT NEG CRY
D 0000FFFF 00000000 00000000 00000000 00000000 00000000 00000000 00000000
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 001598C

This example takes the two's complement in the low-order word of register D0. (1 is complemented to become –1.)
NEGX Instruction

The NEGX (Negate with eXtend) instruction provides a method for taking the two's complement of a multiprecision binary number. The X (extended) condition code serves as the carry between multiprecision instructions.

Addressing Modes Allowed:

<table>
<thead>
<tr>
<th>Dn</th>
<th>An</th>
<th>(An)</th>
<th>(An) +</th>
<th>– (An)</th>
<th>x(An)</th>
<th>x(An,xr.s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>x.w</td>
<td>x.l</td>
<td>x(PC)</td>
<td>x(PC,xr.s)</td>
<td>#x</td>
<td>SR</td>
<td>CCR</td>
</tr>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

Data Sizes: byte, word, long

Condition Codes Affected:

- **X**: Set if a borrow is generated. Cleared otherwise.
- **N**: Set if the result is negative. Cleared otherwise.
- **Z**: Cleared if the result is not zero. Unchanged otherwise.
- **V**: Set if an overflow is generated. Cleared otherwise.
- **C**: Set if a borrow is generated. Cleared otherwise.

As with other 68000 multiprecision instructions, a group of NEGX instructions should begin with the Z-bit set and the X-bit clear. At the completion of the multiprecision operation, the Z-bit will then correctly indicate whether the entire operand is zero. The usual storage order for multiprecision integers on the 68000 is to place the high-order portion at the lowest address, and the low-order portion at the highest address. ADDs, SUBtracts, and NEGates begin with the low-order word and normally use the pre-decrement addressing mode.
Assembler Syntax: NEGX <ea>

Machine Code Format:

<table>
<thead>
<tr>
<th>Bit</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Address</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mode</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reg.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The Size field is 00 for byte operands, 01 for words, and 10 for longs.

Example:

PC = 000007EA USP = 0001598C SSP = 0007BF08 ST = 0014 = >IM = 0 EXT ZER
D 00000001 00000000 00000000 00000000 00000000 00000000 00000000 00000000
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
neg.I D0

PC = 000007EC USP = 0001598C SSP = 0007BF08 ST = 0019 = >IM = 0 EXT NEG CRY
D FFFFFFFF 00000000 00000000 00000000 00000000 00000000 00000000 00000000
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
negx.I D1

This example uses data registers D0 and D1 as an 8-byte (64 bit) binary integer. Register D1 is the high-order part of the integer. The example complements 1 to become −1 across 64 bits.
The NOP (No OPeration) instruction provides a way for idling the 68000 for one instruction. Nothing is changed, except that the Program Counter is advanced to the next instruction. NOP instructions are often used for inserting small delays, or for providing space in a program for patching purposes.

Addressing Modes Allowed: None
Data Sizes: None
Condition Codes Affected: None
Assembler Syntax: NOP
Machine Code Format:

<table>
<thead>
<tr>
<th>Bit</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

(4E71 hex)

Example:

```
PC = 000007F2 USP = 0001598C SSP = 0007BF08 ST = 0019 = >IM = 0 EXT NEG CRY
D 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
nop

PC = 000007F4 USP = 0001598C SSP = 0007BF08 ST = 0019 = >IM = 0 EXT NEG CRY
D 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
```
The NOT instruction forms the one's complement of an effective address operand.

Addressing Modes Allowed:

<table>
<thead>
<tr>
<th>Dn</th>
<th>An</th>
<th>(An)</th>
<th>(An) +</th>
<th>− (An)</th>
<th>x(An)</th>
<th>x(An,xr.s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>x.w</td>
<td>x.I</td>
<td>x(PC)</td>
<td>x(PC,xr.s)</td>
<td>#x</td>
<td>SR</td>
<td>CCR</td>
</tr>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

Data Sizes: byte, word, long

Condition Codes Affected:

- X: Not affected.
- N: Set if the result is negative. Cleared otherwise.
- Z: Set if the result is zero. Cleared otherwise.
- V: Always cleared.
- C: Always cleared.

Assembler Syntax: NOT <ea>

Machine Code Format:

```
<table>
<thead>
<tr>
<th>Bit</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>14</td>
<td>13</td>
<td>12</td>
<td>11</td>
<td>10</td>
<td>9</td>
</tr>
<tr>
<td>8</td>
<td>7</td>
<td>6</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
```

The Size field is 00 for byte operations, 01 for words, and 10 for longs.
Example:

PC = 000007F6 USP = 0001598C SSP = 0007BF08 ST = 0010 = >IM = 0 EXT
D 00000001 00000000 00000000 00000000 00000000 00000000 00000000 0001598C
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001598C
not D0
-t
PC = 000007F8 USP = 0001598C SSP = 0007BF08 ST = 0018 = >IM = 0 EXT NEG
D 0000FFFFE 00000000 00000000 00000000 00000000 00000000 00000000 0001598C
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001598C

This example takes the one's complement of the 16-bit quantity 0001 hex to form FFFE hex.
OR Instruction

The OR instruction performs a bit-wise inclusive binary OR operation between a data register and an effective address operand. There are two forms of this instruction:

1. OR the contents of the effective address operand with a data register, leaving the result in the data register.
2. OR the contents of the effective address operand with a data register, leaving the result in the effective address operand.

Addressing Modes Allowed:

Effective address as source:

<table>
<thead>
<tr>
<th>Dn</th>
<th>An</th>
<th>(An)</th>
<th>(An) +</th>
<th>− (An)</th>
<th>x(An)</th>
<th>x(An,xr.s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>x.w</td>
<td>x.l</td>
<td>x(PC)</td>
<td>x(PC,xr.s)</td>
<td>#x</td>
<td>SR</td>
<td>CCR</td>
</tr>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

Effective address as destination:

<table>
<thead>
<tr>
<th>Dn</th>
<th>An</th>
<th>(An)</th>
<th>(An) +</th>
<th>− (An)</th>
<th>x(An)</th>
<th>x(An,xr.s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>x.w</td>
<td>x.l</td>
<td>x(PC)</td>
<td>x(PC,xr.s)</td>
<td>#x</td>
<td>SR</td>
<td>CCR</td>
</tr>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

Data Sizes: byte, word, long
Condition Codes Affected:

- **X**: Not affected.
- **N**: Set if the most significant bit of the result is set. Cleared otherwise.
- **Z**: Set if the result is zero. Cleared otherwise.
- **V**: Always cleared.
- **C**: Always cleared.

Assembler Syntax: OR <ea>,Dn  
OR Dn,<ea>

The ORI instruction is usually used when the source is immediate data and the destination is not a data register. Many assemblers use the ORI instruction when OR is specified with this combination of operands.

Machine Code Format:

<table>
<thead>
<tr>
<th>Bit</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>Register</td>
<td>Dr</td>
<td>Size</td>
<td>Effective</td>
<td>Address</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The Register field indicates which data register is to be used. The Dr bit is 0 if the data register is the destination, and 1 if the effective address is the destination. Size is 00 for byte operations, 01 for words, and 10 for longs.

Example:

```plaintext
PC = 00000806 USP = 0001598C SSP = 0007BF08 ST = 0010 = >IM = 0 EXT
D 11111111 22222222 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001598C
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001598C
or. D0,D1
-t
PC = 00000808 USP = 0001598C SSP = 0007BF08 ST = 0010 = >IM = 0 EXT
D 11111111 33333333 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001598C
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001598C
```

This example ORs the contents of registers D0 and D1, leaving the result in D1. Notice that this is the data register destination form of the instruction.


**ORI Instruction**

The ORI (OR Immediate) performs a bit-wise OR between an immediate operand (always the source) and an effective address operand (always the destination).

Addressing Modes Allowed:

<table>
<thead>
<tr>
<th>Dn</th>
<th>An</th>
<th>(An)</th>
<th>(An) +</th>
<th>− (An)</th>
<th>x(An)</th>
<th>x(An,xr.s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>x.w</td>
<td>x.l</td>
<td>x(PC)</td>
<td>x(PC,xr.s)</td>
<td>#x</td>
<td>SR</td>
<td>CCR</td>
</tr>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

When the status register is specified as the destination, the S-bit in the status register must be set (i.e., the 68000 must be executing in Supervisor state).

Data Sizes: byte, word, long

Condition Codes Affected:

- X Not affected.
- N Set if the high-order bit of the result is set. Cleared otherwise.
- Z Set if the result is zero. Cleared otherwise.
- V Always cleared.
- C Always cleared.

If the status register (SR) or condition code register (CCR) is specified as the destination, the condition code bits are set according to bits 5–0 of the immediate source.

Assembler Syntax: ORI #<data>,<ea>
Machine Code Format:

<table>
<thead>
<tr>
<th>Bit</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Size | Effective | Address

← Mode → ← Reg. →

Word data: 16 bits

Byte data: 8 bits

Long data: 32 bits, including previous word

The Size field is 00 for byte data, 01 for word data, and 10 for long data.

Example:

PC = 00000810 USP = 0001598C SSP = 0007BF08 ST = 0010 = >IM = 0 EXT
D 11111111 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001598C
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001598C
ori.1 #$22222222,DO
−t
PC = 00000816 USP = 0001598C SSP = 0007BF08 ST = 0010 = >IM = 0 EXT
D 33333333 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001598C
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001598C

This example performs an OR operation on the contents of register D0 with a long constant.
The PEA (Push Effective Address) instruction places a computed address on top of the stack. The size of the instruction is restricted to long data.

**Addressing Modes Allowed:**

<table>
<thead>
<tr>
<th>Dn</th>
<th>An</th>
<th>(An)</th>
<th>(An) +</th>
<th>− (An)</th>
<th>x(An)</th>
<th>x(An,xr.s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>x.w</td>
<td>x.l</td>
<td>x(PC)</td>
<td>x(PC,xr.s)</td>
<td>#x</td>
<td>SR</td>
<td>CCR</td>
</tr>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

Data Size: long
Condition Codes Affected: None
Assembler Syntax: PEA <ea>
Machine Code Format:

```
Bit 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
0 1 0 0 1 0 0 0 0 1 Effective Address
```

**Example:**

PC = 00000816 USP = 001598C SSP = 0007BF08 ST = 0010 = >IM = 0 EXT
D 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001598C
pea $81E
−t
PC = 0000081C USP = 0015988 SSP = 0007BF08 ST = 0010 = >IM = 0 EXT
D 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00015988
−s15988
00015988 0000081E .
This example pushes the absolute long address 81E. The PUSH is verified by examining memory at the address contained in address register A7 after the instruction executes.
The RESET instruction is a privileged operation that causes all external devices to be reset.

Addressing Modes Allowed: None

Data Sizes: unsized

Condition Codes Affected: None

Assembler Syntax: RESET

Machine Code Format:

<table>
<thead>
<tr>
<th>Bit</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>(4E70 hex)</td>
</tr>
</tbody>
</table>
The ROL (ROtate Left) instruction performs a left rotate on a data register or memory operand. There are three forms of this instruction:

1. Rotate a data register to the left by a constant contained in the instruction. Shifts from one to eight bits can be accomplished using this form of the instruction.
2. Rotate a data register to the left by the number of bits contained in another data register.
3. Rotate a memory word left by one bit only.

The Rotate operation is performed without an auxiliary bit. Bits shifted out of the high-order bit position go to both the carry bit and the low-order bit position.

Addressing Modes Allowed: Memory form only

<table>
<thead>
<tr>
<th>Dn</th>
<th>An</th>
<th>(An)</th>
<th>(An) +</th>
<th>− (An)</th>
<th>x(An)</th>
<th>x(An,xr,s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>x.w</td>
<td>x.l</td>
<td>x(PC)</td>
<td>x(PC,xr,s)</td>
<td>#x</td>
<td>SR</td>
<td>CCR</td>
</tr>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

Data Sizes: byte, word, long

Data size is restricted to word for the in-memory form of the instruction.
Condition Codes Affected:

- **X** Not affected.
- **N** Set if the most significant bit of the result is set. Cleared otherwise.
- **Z** Set if the result is zero. Cleared otherwise.
- **C** Set according to the last bit shifted out of the operand. Cleared if the shift count is zero.
- **V** Always cleared.

Assembler Syntax:

```
ROL  #<count>,Dy
ROL  Dx,Dy
ROL  <ea>
```

Machine Code Format:

Data Register as destination:

```
Bit  15 14 13 12 11 10  9  8  7  6  5  4  3  2  1  0
    1 1 1 0   Immed.   1   Size   T  1  1   Register
```

Memory location as destination:

```
Bit  15 14 13 12 11 10  9  8  7  6  5  4  3  2  1  0
    1 1 1 0   0   1 1 1 1 1   Effective Address

← Mode → ← Reg. →
```

The T-field determines the type of the register-destination form of the instruction. If T is 0, then the Immediate field contains the shift count, with 000 binary representing a count of 8. If T is 1, then the register number that contains the shift count is contained in the Immediate field.

Example:

```
PC = 00000830 USP = 0001598C SSP = 0007BF08 ST = 0000 = >IM = 0
D 11111111 00000000 00000000 00000000 00000000 00000000 00000000 00000000
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001598C
rol #3,D0
```
This instruction rotates the lower word of register D0 left by three bits. Notice that the high word of D0 is unaffected.
**ROR Instruction**

The ROR (ROtate Right) instruction performs a right rotate on a data register or memory operand. There are three forms of this instruction:

1. Rotate a data register to the right by a constant contained in the instruction. Shifts from one to eight bits can be accomplished using this form of the instruction.

2. Rotate a data register to the right by the number of bits contained in another data register.

3. Rotate a memory word right by one bit only.

The Rotate operation is performed without an auxiliary bit. Bits shifted out of the low-order bit position go to both the carry bit and the high-order bit position.

Addressing Modes Allowed: Memory form only

<table>
<thead>
<tr>
<th>Dn</th>
<th>An</th>
<th>(An)</th>
<th>(An) +</th>
<th>− (An)</th>
<th>x(An)</th>
<th>x(An,xr.s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>x.w</td>
<td>x.l</td>
<td>x(PC)</td>
<td>x(PC,xr.s)</td>
<td>#x</td>
<td>SR</td>
<td>CCR</td>
</tr>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

Data Sizes: byte, word, long

Data size is restricted to word for the in-memory form of the instruction.
Condition Codes Affected:

X Not affected.
N Set if the most significant bit of the result is set. Cleared otherwise.
Z Set if the result is zero. Cleared otherwise.
C Set according to the last bit shifted out of the operand. Cleared if the shift count is zero.
V Always cleared.

Assembler Syntax: ROR #<count>,Dy
ROR Dx,Dy
ROR <ea>

Machine Code Format:

Data Register as destination:

```
Bit 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
1 1 1 0 Immed. 0 Size T 1 1 Register
```

Memory location as destination:

```
Bit 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
1 1 1 0 0 1 1 0 1 1 Effective Address

Mode → Reg. ←
```

The T-field determines the type of the register-destination form of the instruction. If T is 0, then the Immediate field contains the shift count, with 000 binary representing a count of 8. If T is 1, the register number that contains the shift count is contained in the Immediate field.

Example:

PC = 0000083E USP = 001598C SSP = 0007BF08 ST = 0000 = >IM = 0
D 11111111 00000000 00000000 00000000 00000000 00000000 00000000
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001598C
ror #3,D0
This instruction rotates the low-order word of register D0 right by three bits. The upper word of register D0 is unaffected.
**ROXL Instruction**

The ROXL (ROtate Left with eXtend) instruction performs a left rotate on a data register or memory operand. There are three forms of this instruction:

1. Rotate a data register to the left by a constant contained in the instruction. Shifts from one to eight bits can be accomplished using this form of the instruction.
2. Rotate a data register to the left by the number of bits contained in another data register.
3. Rotate a memory word left by one bit only.

The Rotate operation is performed using the X-bit as an auxiliary bit. Bits shifted out of the high-order bit position go to both the carry bit and the X-bit. The X-bit is rotated into the low-order bit position.

![Diagram of ROXL Instruction]

**Addressing Modes Allowed: Memory form only**

<table>
<thead>
<tr>
<th>Dn</th>
<th>An</th>
<th>(An)</th>
<th>(An) +</th>
<th>− (An)</th>
<th>x(An)</th>
<th>x(An,xr.s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>x.w</td>
<td>x.l</td>
<td>x(PC)</td>
<td>x(PC,xr.s)</td>
<td>#x</td>
<td>SR</td>
<td>CCR</td>
</tr>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

Data Sizes: byte, word, long
Data size is restricted to word for the in-memory form of the instruction.

Condition Codes Affected:

X  Set according to the last bit shifted out of the operand. Unaffected if the shift count is zero.
N  Set if the most significant bit of the result is set. Cleared otherwise.
Z  Set if the result is zero. Cleared otherwise.
C  Set according to the last bit shifted out of the operand. Set to the value of the X-bit if the shift count is zero.
V  Always cleared.

Assembler Syntax: ROXL #<count>,Dy
    ROXL Dx,Dy
    ROXL <ea>

Machine Code Format:

Data Register as destination:

<table>
<thead>
<tr>
<th>Bit</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>Immed.</td>
<td>1</td>
<td>Size</td>
<td>T</td>
<td>1</td>
<td>0</td>
<td>Register</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Memory location as destination:

<table>
<thead>
<tr>
<th>Bit</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
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<td></td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>Effective Address</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The T-field determines the type of the register-destination form of the instruction. If T is 0, then the Immediate field contains the shift count, with 000 binary representing a count of 8. If T is 1, then the register number that contains the shift count is contained in the Immediate field.

Example:

PC = 0000084C  USP = 0001598C  SSP = 0007BF08  ST = 0000 = >IM = 0
D 11111111  00000000  00000000  00000000  00000000  00000000  00000000  00000000
A 00000000  00000000  00000000  00000000  00000000  00000000  00000000  001598C
roxl #4,D0
This example rotates the low-order word of register D0 to the left by four bits. The high-order word of register D0 is unaffected. The X-bit is set following the instruction.
The ROXR (ROtate Right with eXtend) instruction performs a right rotate on a data register or memory operand. There are three forms of this instruction:

1. Rotate a data register to the right by a constant contained in the instruction. Shifts from one to eight bits can be accomplished using this form of the instruction.

2. Rotate a data register to the right by the number of bits contained in another data register.

3. Rotate a memory word right by one bit only.

The Rotate operation is performed using the X bit as an auxiliary bit. Bits shifted out of the low-order bit position go to both the carry-bit and the X bit. The X bit is rotated into the high-order bit position.

Addressing Modes Allowed: Memory form only

<table>
<thead>
<tr>
<th>Dn</th>
<th>An</th>
<th>(An)</th>
<th>(An) +</th>
<th>− (An)</th>
<th>x(An)</th>
<th>x(An, xr.s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>x.w</td>
<td>x.1</td>
<td>x(PC)</td>
<td>x(PC, xr.s)</td>
<td>#x</td>
<td>SR</td>
<td>CCR</td>
</tr>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

Data Sizes: byte, word long

Data size is restricted to word for the in-memory form of the instruction.
Condition Codes Affected:

X  Set according to the last bit shifted out of the operand. Unaffected if the shift count is zero.
N  Set if the most significant bit of the result is set. Cleared otherwise.
Z  Set if the result is zero. Cleared otherwise.
C  Set according to the last bit shifted out of the operand. Set to the value of the X-bit if the shift count is zero.
V  Always cleared.

Assembler Syntax: ROXR  #<count>,Dy
                   ROXR  Dx,Dy
                   ROXR  <ea>

Machine Code Format:

Data Register as destination:

<table>
<thead>
<tr>
<th>Bit</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
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<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>Immed.</td>
<td>0</td>
<td>Size</td>
<td>T</td>
<td>1</td>
<td>0</td>
<td>Register</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Memory location as destination:

<table>
<thead>
<tr>
<th>Bit</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
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<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Mode →</td>
<td>Reg. →</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The T-field determines the type of the register-destination form of the instruction. If T is 0, then the Immediate field contains the shift count, with 000 binary representing a count of 8. If T is 1, then the register number that contains the shift count is contained in the Immediate field.

Example:

PC = 0000085A  USP = 0001598C  SSP = 0007BF08  ST = 0000 = >IM = 0
D 11111111  00000000  00000000  00000000  00000000  00000000  00000000  00000000
A 00000000  00000000  00000000  00000000  00000000  00000000  00000000  0001598C
roxr #4,D0
This example rotates the low-order word of register D0 to the right by four places. The upper word of register D0 is not affected.
The RTE (ReTurn from Exception) is used to load the status register and the program counter (PC) with a single instruction. This type of operation is required when an operating system in supervisor mode passes control to a user program in user mode. The new contents of the status register and PC are popped off the stack. The status register is taken from the first 16-bit word on the stack, and the PC from the next 32-bit long word. The stack pointer is incremented by six bytes.

This is a privileged instruction. The processor must be in supervisor state (i.e., bit 13 of the status register must be set) at the beginning of the RTE instruction. The RTE instruction changes all the bits of the status register, so the processor might be in user mode at the completion of the instruction.

Condition Codes Affected:
The condition codes are all loaded from the word at the top of the stack.

Assembler Syntax: RTE
Machine Code Format:

<table>
<thead>
<tr>
<th>Bit</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(4E73 hex)

Example:

PC = 00000868 USP = 0001598C SSP = 0007BF08 ST = 2004 = >SUP IM = 0 ZER
D 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
pea $876

The following code pushes a new status register contents (with all the condition code bits set), and a new PC. Since the PC is lower on the stack than the status register, it must be pushed first.

Here is a disassembly of the program:

- 1868,876
  00000868 pea $876
0000086E move #$1F, -(A7)
00000872 rte
00000874 moveq #$FF,D0
00000876 nop

Executing this program yields the following results:

- g,876
PC = 00000876 USP = 0001598C SSP = 0007BF08 ST = 001F = >IM = 0 EXT NEG ZER OFL CRY
D 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 001598C

Notice that the breakpoint was set on the address that the RTE instruction loads into the PC. (The debugger will not trace RTE instructions.)

This example shows how a supervisor mode program can transfer control to a user mode program. Note how register A7 reflects the supervisor stack pointer (SSP) before the RTE and the user stack pointer (USP) afterward.
RTR Instruction

The RTR (ReTurn and Restore) instruction loads the condition codes and the program counter (PC) from the stack. The condition codes are loaded from the low byte from the word at the top of the stack. The high byte of this word is discarded. The PC is loaded from the long word immediately after the word containing the condition codes. The stack pointer is incremented by six by an RTR instruction.

Condition Codes Affected:

The condition codes are loaded from the first word popped from the stack.

Assembler Syntax: RTR

Machine Code Format:

```
Bit 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
0 1 0 0 1 1 1 0 0 1 1 1 0 1 1 1
(4E77 hex)
```

Example:

PC = 00000888 USP = 00015986 SSP = 0007BF08 ST = 0000 = >IM = 0
D 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00015986
rtr

At this point, we are about to execute an RTR instruction. Using the s command, we will examine the information on the stack.

```
- sw15986  (Contents of A7)
00015986 001F  (New condition codes)
00015988 0000  (High word of PC)
0001598A 088C . (Low word of PC)
- t
PC = 0000088C USP = 0001598C SSP = 0007BF08 ST = 001F = >IM = 0 EXT NEG ZER OFL CRY
D 00000000 00000000 00000000 00000000 00000000 00000000 00000000 001598C
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001598C
```

The stack pointer was incremented by six bytes and the PC and status register now have different contents.
The RTS (ReTurn from Subroutine) instruction reverses the action of a BSR (Branch to SubRoutine) or JSR (Jump to SubRoutine) instruction. The PC is loaded from the long word at the top of the stack. This causes execution to resume at the instruction that follows the JSR or BSR instruction.

Condition Codes Affected: None

Assembler Syntax: RTS

Machine Code Format:

```
Bit 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
0 1 0 0 1 1 1 0 0 1 1 1 0 1 0 1 (4E75 hex)
```

Example:

```
PC = 0000089A USP = 00015988 SSP = 0007BF08 ST = 0000 >IM = 0
D 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00015988
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00015988
rts
- si15988
00015988 0000089E.
-t
PC = 0000089E USP = 0001598C SSP = 0007BF08 ST = 0000 >IM = 0
D 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00015988 00000000
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001598C
```

This RTS instruction causes a transfer to address 89E. The stack pointer is incremented by four bytes (which is the size of the address that was popped off the stack).
**SBCD Instruction**

The SBCD (Subtract BCD with extend) instruction subtracts two bytes in BCD format. The destination operand is replaced with the difference (Destination – Source – Extend bit).

Addressing Modes Allowed:

<table>
<thead>
<tr>
<th>Dn</th>
<th>An</th>
<th>(An)</th>
<th>(An) +</th>
<th>– (An)</th>
<th>x(An)</th>
<th>x(An,xr.s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>NO</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>x.w</td>
<td>x.l</td>
<td>x(PC)</td>
<td>x(PC,xr.s)</td>
<td>#x</td>
<td>SR</td>
<td>CCR</td>
</tr>
<tr>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

There are two forms of this instruction:

1. Subtract data register from a data register (Dn addressing modes). The low-order bytes of two data registers are subtracted and the result stored in the destination register.

2. Subtract memory to memory. This form of the instruction allows multiple bytes to be subtracted. The only valid addressing mode is – (An). Since the 68000 stores BCD data with the highest byte first, to subtract multibyte quantities, one must start at the highest address and work down. (Hence the use of pre-decrement addressing.) If there is a carry out of the most significant BCD digit in the byte, each instruction sets the X bit. The X bit is then subtracted from the next pair of bytes.

Data Sizes: byte only

Condition Codes Affected:

- **X** Set by a borrow-out of the most significant BCD digit.
- **N** Undefined.
- **Z** Cleared if result is not zero. Unchanged otherwise.
V Undefined.
C Set by a borrow-out of the most significant BCD digit.

The Z bit is cleared if the result is not zero. Not setting the bit when the result of the present byte is zero allows the Z bit to be accurate after a series of SBCD instructions is executed. The Z bit must be set before beginning such a series. (Comparing a register to itself is an easy way to set the Z bit.) The N and V bits are undefined as a result of this instruction.

Assembler Syntax: SBCD Dx,Dy

SBCD - (Ax), - (Ay)

Machine Code Format:

<table>
<thead>
<tr>
<th>Bit</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>D. Reg</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>F</td>
<td>S. Reg.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The D. Reg and S. Reg fields specify the destination and source register numbers, respectively. If the F (format) bit is 0, then the registers are data registers. If the F bit is a 1, then the registers are address registers, and the pre-decrement addressing mode is used.

Example:

```
PC = 00000510 USP = 0001598C SSP = 0007BF08 ST = 0000 = >IM = 0
D 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
A 00000518 0000051A 00000000 00000000 00000000 00000000 00000000 00000000
sbc d - (A0), - (A1)
- d516,519
00000516 00 01 01 00
- t
PC = 00000512 USP = 0001598C SSP = 0007BF08 ST = 0019 = >IM = 0 EXT NEG CRY
D 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
A 00000517 00000519 00000000 00000000 00000000 00000000 00000000 00000000
sbc d - (A0), - (A1)
- d516,519
00000516 00 01 01 99
- t
PC = 00000514 USP = 0001598C SSP = 0007BF08 ST = 0000 = >IM = 0
D 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
A 00000516 00000518 00000000 00000000 00000000 00000000 00000000 00000000
- d516,519
00000516 00 01 00 99
```

...
This example illustrates how to do a multiprecision BCD subtraction operation. A two-byte subtraction operation is executed, subtracting 1 from 100 to obtain 99. The operands are displayed using the d command after each step of the process. Notice the action of the borrow.
The Scc instruction sets a byte specified by an effective address operand to all ones if a specified condition is true. The byte is cleared if the condition is false. The permissible instructions are:

**SCC**  Set <ea> if the C-bit (carry) is clear.

**SCS**  Set <ea> if the C-bit is set.

**SEQ**  Set <ea> on EQual. The byte is set if the Z-bit is set.

**SGE**  Set <ea> on Greater than or Equal. The byte is set if the N (negative) and V (overflow) bits are either both set or both clear. SGE is used for two's complement binary numbers.

**SGT**  Set <ea> on Greater Than. The byte is set if:
- The N and V bits are both set and the Z-bit is clear, or,
- The N, V, and Z-bits are all clear.

**SHI**  Set <ea> on Higher than. The byte is set if the C and Z bits are both clear. SHI is similar to SGT, except it works on unsigned numbers.

**SLE**  Set <ea> on Less than or Equal. The byte is set if:
- The Z-bit is set, or,
- The N-bit is set and the V-bit is clear, or,
- The N-bit is clear and the V-bit is set.

The SLE instruction is used for two's complement binary numbers.

**SLS**  Set <ea> on Lower or Same.
The byte is set if either the C or Z bits are set. SLS is similar to the SLE instruction, except it works on unsigned numbers.
SLT  Set <ea> on Less Than. The byte is set if:
   • The N-bit is set and the V-bit is clear, or,
   • The N-bit is clear and the V-bit is set.

SMI  Set <ea> on Minus. The byte is set if the N-bit is set.

SNE  Set <ea> on Not Equal. The byte is set if the Z-bit is clear.

SPL  Set <ea> on Plus. The byte is set if the N-bit is clear.

SVC  Set <ea> on V Clear. The byte is set if the V-bit is clear, indicating no overflow.

SVS  Set <ea> on V Set. The byte is set if the V-bit is set, indicating overflow.

SF   Never set <ea>.

ST   Always set <ea>.

Addressing Modes Allowed:

<table>
<thead>
<tr>
<th>Dn</th>
<th>An</th>
<th>(An)</th>
<th>(An)+</th>
<th>− (An)</th>
<th>x(An)</th>
<th>x(An,xr.s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>x.w</td>
<td>x.1</td>
<td>x(PC)</td>
<td>x(PC,xr.s)</td>
<td>#x</td>
<td>SR</td>
<td>CCR</td>
</tr>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

Data Size: byte
Condition Codes Affected: None
Assembler Syntax: Scc   <ea>
Machine Code Format:
The Condition is a four-bit encoding of the condition code combination. The conditions are as follows:

<table>
<thead>
<tr>
<th>Condition</th>
<th>Instruction</th>
<th>Condition</th>
<th>Instruction</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>ST</td>
<td>1000</td>
<td>SVC</td>
</tr>
<tr>
<td>0001</td>
<td>SF</td>
<td>1001</td>
<td>SVS</td>
</tr>
<tr>
<td>0010</td>
<td>SHI</td>
<td>1010</td>
<td>SPL</td>
</tr>
<tr>
<td>0011</td>
<td>SLS</td>
<td>1011</td>
<td>SMI</td>
</tr>
<tr>
<td>0100</td>
<td>SCC</td>
<td>1100</td>
<td>SGE</td>
</tr>
<tr>
<td>0101</td>
<td>SCS</td>
<td>1101</td>
<td>SLT</td>
</tr>
<tr>
<td>0110</td>
<td>SNE</td>
<td>1110</td>
<td>SGT</td>
</tr>
<tr>
<td>0111</td>
<td>SEQ</td>
<td>1111</td>
<td>SLE</td>
</tr>
</tbody>
</table>

Example:

PC = 000008BC USP = 0001598C SSP = 0007BF08 ST = 0000 = >IM = 0
D 00000001 00000002 00000000 00000000 00000000 00000000 00000000 00000000
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001598C
cmp.l D0,D1
-t
PC = 000008BE USP = 0001598C SSP = 0007BF08 ST = 0000 = >IM = 0
D 00000001 00000002 00000000 00000000 00000000 00000000 00000000 00000000
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001598C
slt D2
-t
PC = 000008C0 USP = 0001598C SSP = 0007BF08 ST = 0000 = >IM = 0
D 00000001 00000002 00000000 00000000 00000000 00000000 00000000 00000000
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001598C
sgt D2
-t
PC = 000008C2 USP = 0001598C SSP = 0007BF08 ST = 0000 = >IM = 0
D 00000001 00000002 000000FF 00000000 00000000 00000000 00000000 00000000
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001598C

This example illustrates the use of the ScC instruction with a compare instruction. Since the value in register D1 is greater than the value in register D0, the SLT instruction did not set D2, and the SGT instruction did set D2. With the ScC instruction, as with the Bcc and DBcc instructions, the operands of a compare instruction must be read in reverse order.
STOP Instruction

The STOP instruction provides a way to simultaneously enable interrupts and to wait for an interrupt to occur. Other processors, notably the PDP-11, had separate instructions for enabling interrupts and for waiting for interrupts. An interrupt between the enabling instruction and the waiting instruction could result in waiting for an interrupt that has already occurred.

The STOP instruction is a privileged instruction and is used only by code that must service interrupts. The Supervisor bit in the status register must be set at the beginning of the instruction. The contents of a 16-bit immediate data field are loaded into the Status Register. Bit 13 (which corresponds to the S-bit in the status register) of the immediate data must be set or a privilege violation exception will occur. See Chapter 7 on Exception Processing for additional information.

Addressing Modes Allowed: None

Data Size: unsized

Condition Codes Affected:
The condition codes are set from bits 5-0 of the immediate operand.

Assembler Syntax: STOP \#<data>

Machine Code Format:

```
<table>
<thead>
<tr>
<th>Bit</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>
```

(4E72 hex)

Immediate Data (16 bits)
The SUB (SUBtract binary) instruction subtracts a source operand from a destination operand and stores the result in the destination operand. There are two forms of this instruction:

1. Subtract an effective address operand from a data register.
2. Subtract a data register from an effective address operand.

Addressing Modes Allowed:
All Addressing modes (except SR and CCR) are allowed when the effective address specifies a source operand. When the effective address field is the destination, then the following addressing modes are allowed:

<table>
<thead>
<tr>
<th>Dn</th>
<th>An</th>
<th>(An)</th>
<th>(An) +</th>
<th>– (An)</th>
<th>x(An)</th>
<th>x(An,xr.s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>x.w</td>
<td>x.I</td>
<td>x(PC)</td>
<td>x(PC,xr.s)</td>
<td>#x</td>
<td>SR</td>
<td>CCR</td>
</tr>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

Using a data register as a destination must be accomplished using the register destination form of the instruction.

Data Sizes: byte, word, long
Using an address register as the source is valid only for word and long data lengths.

Condition Codes Affected:

X  Set by borrow out of most significant bit. Cleared otherwise.
N  Set if high-order bit of result was 1. Cleared otherwise.
Z  Set if result is zero. Cleared otherwise.
C  Set by borrow-out of most significant bit. Cleared otherwise.
V  Set if operation resulted in overflow condition. Cleared otherwise.
Assembler Syntax:  
\[
\text{SUB Dn,<ea>}
\]
\[
\text{SUB <ea>,Dn}
\]

The SUBA instruction is used when the destination is an address register. The SUBI and SUBQ instructions are used when the source is immediate data. Many assemblers will accept the SUB mnemonic for these instructions, and choose the correct instruction based on the operands.

Machine Code Format:

```
Bit  15 14 13 12 11 10  9  8  7  6  5  4  3  2  1  0

  1 0 0 1 | Register D | Size | Effective Address

  ← Mode →  ← Reg. →
```

The Register field gives the data register that must be one of the operands. The D bit is 0 if the Register field is the destination operand, and 1 if the effective address is the destination.

The Size field is 00 for byte, 01 for word, and 10 for long operands.

Example:

PC = 000008CE  USP = 0001598C  SSP = 0007BF08  ST = 0000  >IM = 0
D 00000002  00000001  00000000  00000000  00000000  00000000  00000000  00000000
A 00000000  00000000  00000000  00000000  00000000  00000000  00000000  00000000
sub.I D1,D0

PC = 000009D0  USP = 0001598C  SSP = 0007BF08  ST = 0000  >IM = 0
D 00000001  00000000  00000000  00000000  00000000  00000000  00000000  00000000
A 00000000  00000000  00000000  00000000  00000000  00000000  00000000  00000000

This instruction subtracts 1 from 2 to form 1. When both operands are data registers, the data register destination form of the instruction is used.
The SUBA instruction does a binary subtraction operation with an address register destination. In order to allow address computations to be freely intermixed with data operations, this instruction does not affect the condition codes.

The source operand is subtracted from the address register. The result is placed in the address register.

Addressing Modes Allowed:

<table>
<thead>
<tr>
<th>Mode</th>
<th>(An)</th>
<th>(An)+</th>
<th>− (An)</th>
<th>x(An)</th>
<th>x(An,xr.s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dn</td>
<td>An</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>x.w</td>
<td>x.l</td>
<td>x(PC)</td>
<td>x(PC,xr.s)</td>
<td>#x</td>
<td>SR</td>
</tr>
<tr>
<td>x.w</td>
<td>x.l</td>
<td>x(PC)</td>
<td>x(PC,xr.s)</td>
<td>#x</td>
<td>CCR</td>
</tr>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>

All addressing modes are allowed, except SR and CCR. The effective address must be the source operand.

Data Sizes: word, long

The SUBA operation always affects all 32 bits of the destination address register.

Condition Codes Affected: None

Assembler Syntax: SUBA <ea>,An

Many assemblers will generate a SUBA instruction if a SUB instruction is specified with an address register as the destination operand.

Machine Code Format:
The Register field gives the address register to be used as the destination operand. The S-bit is 1 for long operands and 0 for word operands.

Example:

```
PC = 000008D8  USP = 0001598C  SSP = 0007BF08  ST = 0000  >IM = 0
D 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
A 000008DC 00000000 00000000 00000000 00000000 00000000 00000000 0001598C
suba #$22,A0
-t
PC = 000008DC  USP = 0001598C  SSP = 0007BF08  ST = 0000  >IM = 0
D 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
A 000008BA 00000000 00000000 00000000 00000000 00000000 00000000 0001598C
```

This example subtracts a constant 22 hex from the address contained in address register A0.
**SUBI Instruction**

The SUBI instruction subtracts an immediate quantity from an effective address operand. The result is left in the effective address operand.

Addressing Modes Allowed:

<table>
<thead>
<tr>
<th>Dn</th>
<th>An</th>
<th>(An)</th>
<th>(An) +</th>
<th>– (An)</th>
<th>x(An)</th>
<th>x(An,xr.s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>x.w</td>
<td>x.l</td>
<td>x(PC)</td>
<td>x(PC,xr.s)</td>
<td>#x</td>
<td>SR</td>
<td>CCR</td>
</tr>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

Data Sizes: byte, word, long

Condition Codes Affected:

- X  Set on borrow out of high-order bit. Cleared otherwise.
- N  Set if high-order bit of result is set. Cleared otherwise.
- Z  Set if result is zero. Cleared otherwise.
- C  Set on borrow out of high-order bit. Cleared otherwise.
- V  Set on overflow condition. Cleared otherwise.

Assembler Syntax: SUBI  #x, <ea>

Most assemblers automatically choose the SUBI instruction if the source operand of a SUB instruction is immediate.
Machine Code Format:

```
<table>
<thead>
<tr>
<th>Bit</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>Size</td>
<td>Effective</td>
<td>Address</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
```

- Mode →
- Reg. →

Word data: 16 bits

Byte data: 8 bits

Long data: 32 bits, including previous word

The Size field is 00 for byte operands, 01 for words, and 10 for longs.

Example:

```
PC = 000008E4 USP = 0001598C SSP = 0007BF08 ST = 0000 = IM = 0
D 00000100 00000000 00000000 00000000 00000000 00000000 00000000 00000000
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001598C
subi.l #$10, D0
- t
```

```
PC = 000008EA USP = 0001598C SSP = 0007BF08 ST = 0000 = IM = 0
D 000000F0 00000000 00000000 00000000 00000000 00000000 00000000 00000000
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001598C
```

This instruction subtracts the constant 10 hex (16 decimal) from data register D0.
The SUBQ instruction subtracts a three-bit immediate value from an effective address operand. This allows you to subtract a small number from a register or memory address using a small, fast instruction.

Addressing Modes Allowed:

<table>
<thead>
<tr>
<th>Dn</th>
<th>An</th>
<th>(An)</th>
<th>(An) +</th>
<th>– (An)</th>
<th>x(An)</th>
<th>x(An,xr.s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>x.w</td>
<td>x.l</td>
<td>x(PC)</td>
<td>x(PC,xr.s)</td>
<td>#x</td>
<td>SR</td>
<td>CCR</td>
</tr>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

Data Sizes: byte, word, long
When an address register is used as the destination, only word and long sizes are allowed.

Condition Codes Affected:

- X  Set on borrow out of high-order bit position. Cleared otherwise.
- N  Set if high-order bit of result is set. Cleared otherwise.
- V  Set on overflow. Cleared otherwise.
- Z  Set if result is zero. Cleared otherwise.
- C  Set on borrow out of high-order bit position. Cleared otherwise.

No condition codes are affected if an address register is used as the destination operand.

Assembler Syntax: SUBQ #<data>,<ea>
#<data> is a constant number in the range 1 to 8.
Machine Code Format:

<table>
<thead>
<tr>
<th>Bit</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td></td>
<td></td>
<td>Data</td>
<td>1</td>
<td>Size</td>
<td>Effective</td>
<td>Address</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Data is a three-bit immediate field, with 000 representing 8, 001-111 representing 1-7. Size is 00 for byte operations, 01 for word, and 10 for long operations.

Example:

PC = 000008EE USP = 0001598C SSP = 0007BF08 ST = 0000 = >IM = 0
D 00000001 00000000 00000000 00000000 00000000 00000000 00000000 00000000
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
subq.I #$2,D0
- t
PC = 000008F0 USP = 0001598C SSP = 0007BF08 ST = 0019 = >IM = 0 EXT NEG CRY
D FFFFFFFF 00000000 00000000 00000000 00000000 00000000 00000000 00000000
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000

This example subtracts 2 from 1 (in data register D0) to form \(-1\).
The SUBX (SUBtract eXtended) instruction executes multiple precision subtraction operations. Integers of any length can be subtracted using the SUB and SUBX instructions. This makes it possible to represent numbers much larger than the 32-bit longword allows.

There are two forms of this instruction:

1. Subtract a data register from a data register.
2. Subtract a memory location from a memory location. The \(-(An)\) addressing mode is used for both the source and destination in this form.

In both cases, the difference (Destination \(-\) Source \(-\) X-bit) is placed in the destination operand.

**Addressing Modes Allowed:**

<table>
<thead>
<tr>
<th>Dn</th>
<th>An</th>
<th>(An)</th>
<th>(An)+</th>
<th>(-(An))</th>
<th>x(An)</th>
<th>x(An,xr,s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>x.w</th>
<th>x.I</th>
<th>x(PC)</th>
<th>x(PC,xr.s)</th>
<th>#x</th>
<th>SR</th>
<th>CCR</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

**Data Sizes:** byte, word, long

**Condition Codes Affected:**

- X Set on borrow out of high-order bit. Cleared otherwise.
- N Set if result is negative. Cleared otherwise.
- Z Cleared if result is not zero. Unchanged otherwise.
- C Set on carry out of high-order bit. Cleared otherwise.
- V Set on overflow condition. Cleared otherwise.
The Z bit is not set if the result is zero, but it is cleared if the result is not zero. This property of the instruction allows the Z bit to correctly indicate the result of a multiprecision subtraction operation. The Z bit must be set before subtraction begins, however. (This can be done with a MOVE to CCR, or by comparing a register to itself. The latter instruction is two bytes shorter.)

Assembler Syntax: 

```
SUBX  Dy,Dx
```

```
SUBX  -(Ay), -(Ax)
```

Machine Code Format:

```
<table>
<thead>
<tr>
<th>Bit</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>Reg. Rx</td>
<td>1</td>
<td>Size</td>
<td>0</td>
<td>0</td>
<td>T</td>
<td>Reg. Ry</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
```

The Reg. Rx and Reg. Ry fields contain the destination and source register numbers, respectively. The size field is 00 for byte operations, 01 for word, and 10 for long operations. The T (type) bit is 0 for the data register to data register form of the instruction. The Reg. Rx and Reg. Ry fields identify data registers in this case. The T-bit is 1 for the memory to memory form of the instruction. The Rx and Ry fields identify the address registers used by the pre-decrement addressing mode for this form.

Example:

```
PC = 000008FE  USP = 0001558C  SSP = 0007BF08  ST = 0004 = >IM = 0 ZER
D 00000000 1 00000000 00000001 00000000 00000000 00000000 00000000 00000000
A 00000000 1 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001558C
```

```
subx.l D3,D1
```

```
PC = 00000900  USP = 0001558C  SSP = 0007BF08  ST = 0019 = >IM = 0 EXT NEG CRY
D 00000000 1 FFFFFFFF 00000000 00000001 00000000 00000000 00000000 00000000
A 00000000 1 00000000 00000000 00000000 00000000 00000000 00000000 0001558C
```

```
subx.l D2,D0
```

```
PC = 00000902  USP = 0001558C  SSP = 0007BF08  ST = 0000 = >IM = 0
D 00000000 1 FFFFFFFF 00000000 00000001 00000000 00000000 00000000 00000000
A 00000000 1 00000000 00000000 00000000 00000000 00000000 00000000 0001558C
```

This operation subtracts the register pair (D2,D3) from the register pair (D0,D1). The high-order longword of each pair is contained in the even numbered register. The example shows that (1,0) - (0,1) is (0,FFFFFFF).
The SWAP instruction exchanges the 16-bit words in a data register. Bits 31-16 are exchanged with bits 15-0.

Addressing Modes Allowed: Dn only

Data Size: word

Condition Codes Affected:

- X  Not affected.
- N  Set if bit 31 of the result is set. Cleared otherwise.
- Z  Set if all 32 bits of the register are zero. Cleared otherwise.
- V  Always cleared.
- C  Always cleared.

Assembler Syntax: SWAP  Dn

Machine Code Format:

```
Bit 15 14 13 12 11 10  9  8  7  6  5  4  3  2  1  0
0 1 0 0 1 0 0 0 0 1 0 0 0  
```

The Register field specifies which data register is to be swapped.

Example:

```
-x
PC  = 0000090A USP  = 0001558C SSP  = 0007BF08 ST  = 0000  = >IM  = 0
D  11112222  00000000  00000000  00000000  00000000  00000000  00000000  00000000
A  00000000  00000000  00000000  00000000  00000000  00000000  00000000  0001558C
  swap D0
-t
PC  = 0000090C USP  = 0001558C SSP  = 0007BF08 ST  = 0000  = >IM  = 0
D  22221111  00000000  00000000  00000000  00000000  00000000  00000000  00000000
A  00000000  00000000  00000000  00000000  00000000  00000000  00000000  0001558C
```

This example swaps the words in data register D0.
TAS Instruction

The TAS (Test And Set) instruction tests a byte specified by an effective address operand. The high-order bit of the byte is set to 1. The N- and Z-bits are set according to the value of the byte before the operation. The operation is indivisible, using a read-modify-write memory operation.

The TAS operation provides synchronization when two or more CPU chips have access to the same area of memory. Since TAS is indivisible, a processor can claim a resource and mark it as claimed before another processor can test the memory location. If the operation were not indivisible, two processors could test the flag and set it in such a way that they both assess the resource as free and claim it erroneously. The TAS instruction guarantees that one processor will win and all others lose.

Addressing Modes Allowed:

<table>
<thead>
<tr>
<th>Dn</th>
<th>An</th>
<th>(An)</th>
<th>(An) +</th>
<th>− (An)</th>
<th>x(An)</th>
<th>x(An,xr.s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>x.w</td>
<td>x.l</td>
<td>x(PC)</td>
<td>x(PC,xr.s) #x</td>
<td>SR</td>
<td>CCR</td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

A TAS operation on a data register (which is allowed) is of no value for synchronization purposes.

Data Size: byte

Condition Codes Affected:

X   Not affected.
N   Set if the high-order bit of the operand is set prior to the operation. Cleared otherwise.
Z   Set if all bits of the operand are zero prior to the operation. Cleared otherwise.
V   Always cleared.
C   Always cleared.
Assembler Syntax: TAS  \(<ea>\)

Machine Code Format:

```
<table>
<thead>
<tr>
<th>Bit</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
```

Example:

PC = 0000090C USP = 0001558C SSP = 0007BF08  ST = 0000 = >IM = 0
D 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001558C
tas $97C
−s97c
0000097C 00.
−t
PC = 00000912 USP = 0001558C SSP = 0007BF08  ST = 0004 = >IM = 0  ZER
D 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001558C
−s97c
0000097C 80.

This example executes a TAS operation on memory location 97C. The memory location contained zero before the operation and 80 hex afterward. The Z-bit is set, indicating that the operand was zero initially.
TRAP Instruction

The TRAP instruction stacks the PC and the status register on the supervisor mode stack. The Processor is switched to supervisor state, and the PC is taken from one of sixteen trap vectors specified by a four-bit quantity in the TRAP instruction.

This instruction is normally used by user mode programs to call supervisor mode programs (such as operating systems). The TRAP instruction provides a method for the user mode program to request an operating system function, such as I/O, without having to know where the operating system is located in memory.

Condition Codes Affected: None

Assembler Syntax: TRAP #<vector>

Machine Code Format:

```
<table>
<thead>
<tr>
<th>Bit 15</th>
<th>Bit 14</th>
<th>Bit 13</th>
<th>Bit 12</th>
<th>Bit 11</th>
<th>Bit 10</th>
<th>Bit 9</th>
<th>Bit 8</th>
<th>Bit 7</th>
<th>Bit 6</th>
<th>Bit 5</th>
<th>Bit 4</th>
<th>Bit 3</th>
<th>Bit 2</th>
<th>Bit 1</th>
<th>Bit 0</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td>Vector</td>
</tr>
</tbody>
</table>
```

Vectors used by the trap instruction are located at the following absolute memory locations:

<table>
<thead>
<tr>
<th>Vector</th>
<th>Address</th>
<th>Vector</th>
<th>Address</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>80</td>
<td>8</td>
<td>A0</td>
</tr>
<tr>
<td>1</td>
<td>84</td>
<td>9</td>
<td>A4</td>
</tr>
<tr>
<td>2</td>
<td>88</td>
<td>10</td>
<td>A8</td>
</tr>
<tr>
<td>3</td>
<td>8C</td>
<td>11</td>
<td>AC</td>
</tr>
<tr>
<td>4</td>
<td>90</td>
<td>12</td>
<td>B0</td>
</tr>
<tr>
<td>5</td>
<td>94</td>
<td>13</td>
<td>B4</td>
</tr>
<tr>
<td>6</td>
<td>98</td>
<td>14</td>
<td>B8</td>
</tr>
<tr>
<td>7</td>
<td>9C</td>
<td>15</td>
<td>BC</td>
</tr>
</tbody>
</table>
The TRAPV instruction tests for overflow. The TRAPV instruction does nothing if the V-bit is clear. If the V-bit is set, the PC and the status register are pushed onto the stack, and a new PC is loaded from absolute location 1C hex. The CPU is switched into Supervisor state. This action is called a TRAPV exception.

The TRAPV instruction is used after computations in which an overflow condition would result in meaningless data. Many high-level languages use this instruction to detect overflow.

Data Size: unsized
Condition Codes Affected: None
Assembler Syntax: TRAPV
Machine Code Format:

<table>
<thead>
<tr>
<th>Bit</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

(4E76)
The TST instruction tests an effective address operand for negative or zero. The results are not saved, except that the condition codes are set appropriately.

Addressing Modes Allowed:

<table>
<thead>
<tr>
<th>Dn</th>
<th>An</th>
<th>(An)</th>
<th>(An) +</th>
<th>− (An)</th>
<th>x(An)</th>
<th>x(An,xr.s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>x.w</td>
<td>x.l</td>
<td>x(PC)</td>
<td>x(PC,xr.s)</td>
<td>#x</td>
<td>SR</td>
<td>CCR</td>
</tr>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

Data Sizes: byte, word, long

Condition Codes Affected:

- X  Not affected.
- N  Set if the high-order bit of the operand is set. Cleared otherwise.
- Z  Set if the operand is zero. Cleared otherwise.
- V  Always cleared.
- C  Always cleared.

Assembler Syntax: TST  <ea>

Machine Code Format:

<table>
<thead>
<tr>
<th>Bit</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Size is 00 to test a byte, 01 for a word, and 10 for a long.
Example:

PC = 00000918 USP = 0001558C SSP = 0007BF08 ST = 0004 = >IM = 0 ZER
D 00000001 00000000 00000000 00000000 00000000 00000000 00000000 0001558C
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001558C
tst.I D0
- t
PC = 0000091A USP = 0001558C SSP = 0007BF08 ST = 0000 = >IM = 0
D 00000001 00000000 00000000 00000000 00000000 00000000 00000000 0001558C
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001558C
tst.I D1
- t
PC = 0000091C USP = 0001558C SSP = 0007BF08 ST = 0004 = >IM = 0 ZER
D 00000001 00000000 00000000 00000000 00000000 00000000 00000000 0001558C
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001558C

This example shows two TST instructions: one on a register that is non-zero and one on a register that is zero.
UNLK Instruction

The UNLK (UNLinK) instruction frees a stack frame that was allocated previously by a LINK instruction. (See the description of the LINK instruction.) The instruction works like this:

The specified address register (normally the frame pointer) is placed in the stack pointer. A long word is then popped off the stack into the address register. This is exactly the opposite of the action of the LINK operation. The UNLK instruction functions properly regardless of stack PUSHes and POPs between the LINK and UNLK instructions.

Data Size: unsized

Condition Codes Affected: None

Assembler Syntax: UNLK An

Machine Code Format:

<table>
<thead>
<tr>
<th>Bit</th>
<th>15</th>
<th>14</th>
<th>13</th>
<th>12</th>
<th>11</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The Register field is the address register specified as the frame pointer.

Example:

PC = 0000091E USP = 0001558C SSP = 0007BF08 ST = 0004 = >IM = 0 ZER
D 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
A 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001558C
link A0,#$FFF4
- t
PC = 00000922 USP = 0001557C SSP = 0007BF08 ST = 0004 = >IM = 0 ZER
D 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001557C
A 00015588 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001558C
- si15588
00015588 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 0001557C
unlk A0
This example shows a typical pair of LINK and UNLK instructions. The LINK instruction pushes sixteen bytes (four for the address register and twelve specified by the link instruction), which are in turn popped by the UNLK instruction.

**SUMMARY**

In this chapter we have covered:

1. The 68000 instruction classes
2. Program development mechanics using the Macintosh MDS software
3. The 68000 instruction set

This material is primarily for reference in later chapters. It is important that you at least know how to generate a program on your system before continuing, however.

**EXERCISES**

1. Use your own computer to run the program shown in Listing 3.1.
2. Learn how to make backup copies of your files on your system.
3. Why do the ADDX and SUBX instructions use the pre-decrement \((- (A_n))\) addressing mode while CMPM uses the post-increment \(((A_n)+)\) addressing mode?
4. Why won't the debugger trace RTE instructions? What other instructions will the debugger fail to trace?
INTRODUCTION

Now that we’ve been over the necessary background material, we can start to write Macintosh programs in earnest. Computer programming is the art of combining a small number of simple concepts to produce something both innovative and functional, much as the artist combines oils and canvas to produce a painting. The materials of computer programming are relatively commonplace and simple. What you can create with them is limited only by your own ability and imagination.

To make the process of learning to program a little easier, we have provided standardized software in the form of a macro library, listed in Appendix E. This software makes it possible to learn part of the system without having to learn immediately how Macintosh applications manage windows, files, and other parts of the system. Once you learn how these macros work and how they are used in the programs in this chapter, you can modify them, rewrite them, or create more.
THE HELLO WORLD PROGRAM

Perhaps the simplest computer program is one that displays a short message on the screen. This program was christened the "Hello World" program by Kernighan and Ritchie in The C Programming Language (Prentice Hall, 1978). A BASIC version of the program looks like this:

```
10 PRINT "Hello, World"
20 END
```

To write the same program in assembly language on the Macintosh, you need the Macintosh Development System (or an alternative) and three separate files: a source file (Hello.asm), a link file (Hello.link), and an EXEC job file (Hello.job) to assemble and link the program. These files are shown in Figure 4.1.

The Hello.asm File

The file in the window labeled Hello.asm is the assembly language source file. The lines beginning with semicolons are comments and have no effect on the program's execution. All of the lines in this program, with the exception of the INCLUDE directive, are macro calls. The INCLUDE
directive references a file containing macro definitions, which in turn contain macros for each of the other program statements.

The PROGRAM macro is normally the first line of code in the programs we will be writing for the rest of this book. The PROGRAM macro contains the first instructions that the program must execute. The first operand for this macro appears as the title for the window created when the program is run. The second operand, if present, is either DEBUGON or DEBUGOFF. This operand determines whether an illegal instruction exists in the program just before the first instruction following the PROGRAM macro. (In Hello.asm, this would be just before the PRINT statement.

The PRINT macro functions like a PRINT statement in BASIC, except that the macro version prints only a single string. The string can be specified as an operand (contained in single quotes) or as a label on a DC.B statement that specifies a string to be printed. The PRINT macro expects the address specified as the operand to contain a byte indicating the number of characters to be printed. The string immediately follows this count byte. The assembler generates this byte automatically for strings in single-quote characters.

The QUIT macro causes the program to wait for a Quit selection from the File menu. After Quit has been selected, the program returns to the Finder.

The program must end with an ENDPogram macro call. An END statement may follow ENDPogram if desired.

The Hello.link File

The linker command file for the Hello World program is called Hello.link. This file links two .REL files together: Hello.rel and RTL.REL. Hello.rel is the result of assembling Hello.asm, and RTL.REL is a file which contains code that is the same from one application to the next. The source code for this file is explained in detail in Chapter 8.

The Hello.job File

The Hello.job file contains the commands that assemble and link the Hello World program. A quirk in some early versions of EXEC required that the fields on each line be separated by a single tab character.

Running the Hello World Program

In order to run this program, create a disk containing the files MACLIB-ASM, RTL.REL, and RTL.RSRC. See Appendix E for instructions on creating
these files. Boot from the disk supplied with the Macintosh Development System that contains the assembler, linker, and EXEC programs. Put the disk you just made into the other drive. Start the editor and create the files shown in Figure 4.1 on the new disk.

To build the executable file, start by choosing EXEC from the editor's Transfer menu. Then choose Open Job File from EXEC's File menu. Choose Hello.job from the file window that appears. When the assembler and linker finish execution, you will be in the EXEC program. Choose Open Application from the File menu, and then choose Hello from the file window that appears.

When Hello executes, the screen will look like Figure 4.2. Choose Quit from the File menu to return to the Finder.

All of the programs in this book require a similar build procedure. You can use the files just created and edit them as necessary to make files for subsequent programs.

**OUTPUT CONVERSION ROUTINES**

Most programs must output numeric quantities to provide the user with computational results. To output numeric quantities, you have to translate the binary numbers into character format. This is normally accomplished
using subroutines called conversion routines. We will develop two such routines next: one for hexadecimal conversion and one for decimal conversion.

**Converting Binary to Hexadecimal**

Perhaps the simplest conversion to write is binary to hexadecimal. Our routine is called BinHex and is shown in Listing 4.1.

This routine converts a binary longword to eight ASCII characters, which are a printable hexadecimal number. The technique employed is to take four bits at a time and index them into a string of printable hex characters, placing the resulting character into the output area.

Lines 10–13 are initialization code. Register D0 contains the number to be converted when the routine is called. Register A0 contains the address of an eight-byte memory area that will receive the converted number. This area is filled from right to left, to minimize shifting. Register D1 contains a loop count. This value is 7 to obtain eight hex digits. (Remember, the DBRA instruction terminates the loop when the count value becomes –1.)

Lines 14–18 form the conversion loop. In lines 14–15, the low-order four

```assembly
0001 ; BinHex routine. Converts a longword to ASCII hex.
0002 ; Enter with:
0003 ;
0004 ; DO.L = Binary value
0005 ; A0.L -> 8-byte output area
0006 ;
0007 ; XDEF BinHex
0008 ;
0009 BinHex: MOVE.L D0-D2/A1,-(SP) ; Save caller's registers
0010 LEA HexTab,A1 ; A1 -> Table of hex digits
0011 ADDA.L $8,A0 ; A0 -> 1 past last digit position
0012 MOVE.L $7,D1 ; DBRA-Adjusted loop counter
0013 Loop: MOVE.L D0,D2 ; Copy present number
0014 ANDI.L $15,D2 ; Isolate low-order 4 bits
0015 MOVE.B 0(A1,D2),-(A0) ; Place a byte in output area
0016 LSR.L $4,D0 ; Shift away bits just used
0017 DBRA D1,Loop ; Loop until done
0018 MOVE.L (SP)+,D0-D2/A1 ; Restore registers
0019 RTS ; Return to caller
0020 STRING FORMAT 0 ; Non-Pascal string format
0021 HexTab: DC.B '0123456789ABCDEF'
```

Listing 4.1 – The BinHex routine
bits of register D0 are copied to register D2. The ANDI instruction guarantees that D2 will contain a value from 0–15. The MOVE.B instruction at line 16 places the proper ASCII value into the buffer. Lines 17–18 position the next hex digit in the low-order four bits of D0 and repeat the loop.

Note the STRING_FORMAT directive at line 21. The Macintosh assembler normally treats characters between single quotes as Pascal language strings. When it comes across single quotes, the assembler inserts a one-byte character count at the beginning of the string. The STRING_FORMAT directive instructs the assembler not to insert this byte for subsequent strings.

**Converting Binary to Decimal**

Since decimal numbers are used more frequently than hex numbers, the ability to convert decimal numbers is more important than the ability to convert hex numbers. However, it is harder to convert from binary to decimal numbers because you must divide the binary numbers by 10 to determine each new digit. The process is further complicated by the fact that the 68000 has no 32-bit division instruction. Our binary to decimal converter therefore works only on 16-bit numbers. Fortunately, this is usually adequate. The routine is called BinDec and is shown in Listing 4.2.

You call BinDec with the number to be converted in the low-order word of D0, and the address of a six-byte area that will receive the converted number in A0. Lines 11–15 handle negative numbers. If D0 is negative, a minus sign is placed in the buffer and D0 is negated, producing a positive number. Lines 17–18 form the initialization code for the conversion loop. A0 is advanced to point one byte beyond the conversion area, and D1 contains the loop count (adjusted for the DBRA instruction).

The main body of the routine (lines 19–24) works as follows:

1. Extend D0.W to a longword to clear the high word of the register. Divide this by 10.

2. Place the remainder (in the high word of D0) in the buffer. Add the ASCII code for “0” (hex 30) to this byte, yielding a character between 0 and 9.

3. Use the quotient from step 1 as the new number, and repeat until five digits have been processed.

The output of this routine is a little crude. Possible improvements include adding a floating minus sign and suppressing leading zeros. Despite the lack of sophistication, this routine is adequate for the programs in the rest of this chapter.
**SUMMING THE FIRST FIVE INTegers**

We can use the routines just developed to rewrite the program that sums the first five integers, used as the debugger example in Chapter 3. The first improvement we will make is to display the answer on the Macintosh screen with the PRINT macro. We can also use the DBRA instruction to make the program considerably shorter, as shown in Listing 4.3.

Lines 10–15 form the sum of the first five integers in register D0. Lines 19–22 convert this number to hex and decimal at the data areas labeled Hex and Dec respectively. Finally, line 22 prints the answer on the screen, as shown in Figure 4.3.

Note how the count byte for the PRINT macro is calculated in line 26. Remember that the STRING_FORMAT directive instructs the assembler not to insert the count byte in front of quoted strings.

It is important to notice how much easier it is to write this program given the conversion routines developed earlier in this chapter. We were

```
0001 ; BinDec routine. Converts binary to decimal ASCII.
0002 ; Enter with:
0003 ; D0.W = Number to convert
0004 ; A0.L -> 6-byte output area
0005 ;
0006 ;
0007 ; 0009
0010 BinDec: MOVEM.L D0-D1/A0,-(SP) ; Preserve registers
0011 MOVE.B #',,D1 ; Assume positive number
0012 TST.W D0 ; Is number negative?
0013 BPL NotNeg ; No, use ' ' sign
0014 MOVE.B #'-',D1 ; Number is negative, use '-'
0015 NEG.W D0 ; Force positive
0016 NotNeg: MOVE.B D1,(A0)+ ; Put sign in buffer
0017 ADDA.L $5,A0 ; A0 -> I beyond last digit
0018 MOVE.W #4,D1 ; DBRA_Adjusted loop count
0019 Loop: EXT.L D0 ; Extend to long for DIV instruction
0020 DIVS $10,D0 ; Divide by 10
0021 SWAP D0 ; Remainder to low-order word
0022 MOVE.B D0,-(A0) ; Put in buffer (0-9 binary)
0023 ADD.B #'0',,(A0) ; Add ASCII offset (0-9 ASCII)
0024 SWAP D0 ; Put quotient in low word now
0025 DBRA D1,Loop ; Do 5 digits
0026 MOVEM.L (SP)+,D0-D1/A0 ; Restore registers
0027 RTS ; Return to caller
```

Listing 4.2 – The BinDec routine
able to treat each conversion process as two instructions, rather than the 20-30 instructions that the routines actually require. Indeed, we don’t even have to know how the routines work, only how to call them.

**READING KEYBOARD INPUT**

Many programs require user interaction or input to function properly. Examples of this type of software include editor programs, calculator programs, game programs, spreadsheets, and database managers.

Keyboard input on the Macintosh can be accomplished using the INPUT macro, contained in the macro library file mentioned earlier. This macro reads a line of characters from the keyboard and stops reading when the Return key is pressed. The characters are stored at an address

```
Listing 4.3 – The Sum5 program
```

<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0001</td>
<td>;</td>
</tr>
<tr>
<td>0002</td>
<td>;</td>
</tr>
<tr>
<td>0003</td>
<td>;</td>
</tr>
<tr>
<td>0005</td>
<td>XREF BinHex ; Hex conversion routine</td>
</tr>
<tr>
<td>0006</td>
<td>XREF BinDec ; Decimal conversion routine</td>
</tr>
<tr>
<td>0007</td>
<td>Include MACLIB.ASM ; Include RTL macros</td>
</tr>
<tr>
<td>0009</td>
<td>PROGRAM Sum5</td>
</tr>
<tr>
<td>0010</td>
<td>CLR.L D0 ; Clear accumulator</td>
</tr>
<tr>
<td>0011</td>
<td>MOVE.L #1,D1 ; Initialize counter</td>
</tr>
<tr>
<td>0012</td>
<td>MOVE.L #4,D2 ; DBRA-Adjusted loop counter</td>
</tr>
<tr>
<td>0013</td>
<td>ADD.L D1,D0 ; Add to sum</td>
</tr>
<tr>
<td>0014</td>
<td>ADD.L #1,D1 ; Increment integer</td>
</tr>
<tr>
<td>0015</td>
<td>DBRA D2,Loop ; Loop till done</td>
</tr>
<tr>
<td>0016</td>
<td>;</td>
</tr>
<tr>
<td>0017</td>
<td>;</td>
</tr>
<tr>
<td>0018</td>
<td>;</td>
</tr>
<tr>
<td>0019</td>
<td>LEA Hex,A0 ; A0 -&gt; Hex area</td>
</tr>
<tr>
<td>0020</td>
<td>JSR BinHex ; Do the conversion</td>
</tr>
<tr>
<td>0021</td>
<td>LEA Dec,A0 ; A0 -&gt; Decimal area</td>
</tr>
<tr>
<td>0022</td>
<td>JSR BinDec ; Do the conversion</td>
</tr>
<tr>
<td>0023</td>
<td>PRINT Answer ; Print answer on screen</td>
</tr>
<tr>
<td>0024</td>
<td>QUIT ; and quit</td>
</tr>
<tr>
<td>0025</td>
<td>STRING_FORMAT 0 ; No count bytes</td>
</tr>
<tr>
<td>0026</td>
<td>Answer: DC.B EndAnswer-1 ; Compute count byte</td>
</tr>
<tr>
<td>0027</td>
<td>DC.B 'Sum is: ' ; First part of string</td>
</tr>
<tr>
<td>0028</td>
<td>Hex: DC.B 'xxxxxxxx (Hex) or ' ; Hex part of string</td>
</tr>
<tr>
<td>0029</td>
<td>Dec: DC.B 'xxxxxx (Decimal)' ; Decimal part of string</td>
</tr>
<tr>
<td>0030</td>
<td>EndAnswer ; Label for string end</td>
</tr>
<tr>
<td>0031</td>
<td>ENDPogram</td>
</tr>
</tbody>
</table>
specified as the first parameter in the macro call. The second parameter, if present, is the number of characters in the buffer. If this parameter is not present, a default buffer length of 80 characters is assumed. The INPUT macro sets the first byte in the buffer to the number of characters actually read. This count does not include the Return character, nor is the Return character stored in the buffer. An empty line (that is, one consisting only of a Return) causes a count byte of zero to be stored. The count byte is not included in the character count, so the buffer in memory must be one byte larger than the size specified in the macro call, or 81 bytes if the size parameter is omitted.

Use of the INPUT macro is demonstrated in Listing 4.4. This program echoes a line typed by the user back to the screen.

This program introduces two new macro features. The second parameter to the PRINT macro, if not blank, specifies that the cursor not be advanced to the next line after printing. This is useful for prompting the user for input and for building a line from several PRINT calls. The second feature is the EXIT macro. This macro returns to the Finder directly, without waiting for the user to select Quit from a menu.

This program also uses a new assembler directive. The buffer is defined using a DS (Define Storage) directive. This directive causes the assembler to reserve an area of memory. The memory thus reserved has no particular initial value. The Macintosh assembler requires that memory reserved

Figure 4.3 – Sum5 execution
in this way be addressed using register A5, as in lines 11, 12, and 15. Using the DS directive is advantageous because memory reserved in this way is not stored in the application file on disk. The program thus takes up less disk space and also loads faster. A sample execution of the INPUT program is shown in Figure 4.4.

```
0001    ; Input.Asm. This program illustrates the use of the INPUT macro.
0002    ; The user is prompted for a line of input, and the input is then
0003    ; echoed to the screen with a PRINT macro.
0004    ; The program terminates when the user types an empty line.
0005    ;
0006    ; INCLUDE MACLIB.ASM        ; Include macro definitions
0007    ; PROGRAM INPUT
0008    ; Loop: PRINT 'Type a line: ',$ ; Prompt the user
0009    ; INPUT Buffer(A5) ; Take the input
0010    ; TST.B Buffer(A5) ; Any characters?
0011    ; BEQ NoChars ; No, quit
0012    ; PRINT 'You Typed: ',$ ; Print the input
0013    ; PRINT Buffer(A5)
0014    ; BRA Loop ; Repeat till empty line
0015    ; NoChars:
0016    ; EXIT ; Here to exit
0017    ; Buffer: DS.B 81 ; Back to Finder
0018    ; ENDPROGRAM ; Storage for input
```

**Listing 4.4** - The Input program

![Figure 4.4 - Input program execution](image-url)
Input Conversion

In order to use numeric keyboard input, one must first convert it from ASCII characters to binary. This is the reverse of output conversion.

A routine that converts a decimal ASCII number to binary is shown in Listing 4.5. This routine is named DecBin, and it takes the address of the ASCII string in A0.L. The converted number is returned in D0.L.

DecBin works using a technique called an accumulator variable (which is register D0 in this case). The input is processed from left to right (starting with the most significant digit). For each digit processed, the accumulator is multiplied by 10 and the digit added. (This obviates the need to assign a place value to the first digit encountered.) Processing stops when

```
0001 ; DecBin routine. Converts decimal ASCII to longword binary.
0002 ; Enter with:
0003 ;      A0.L -> Input string
0004 ; Exit with:
0005 ;      D0.L = Converted number
0006 ; Conversion stops at the first nondecimal digit. No
0007 ; overflow or error detection.
0008 ;
0009 XDEF DecBin
0010 DecBin:
0011  MOVE.L D1/A0,-(SP) ; Preserve registers
0012  CLR.L D0 ; Clear accumulator
0013  Loop: CMP.B #'9',(A0) ; Check upper bound
0014  BHI NotDec ; Not a decimal digit
0015  CMP.L #'0',(A0) ; Check lower bound
0016  BLO NotDec ; Not a decimal digit
0017  LSL.L #1,D0 ; Multiply current value x 2
0018  MVIJE.L D1,D0 ; Save this value
0019  MOVE.L D0,D1 ; Multiply again x 4
0020  LSL.L #2,D0 ; 32-bit multiply x 10
0021  ADD.L D1,D0 ; Fetch digit from memory
0022  MOVE.B (A0)+,D1 ; Isolate low-order 4 bits
0023  ANDI.L #15,D1 ; Add to accumulator
0024  BRA Loop ; Back for next digit
0025 NotDec: MOVE.L (SP)+,D1/A0 ; Restore registers
0026  RTS ; Return to caller
```

Listing 4.5 – The DecBin routine
a nondecimal digit is encountered. There is no provision for overflow
detection or for the calling program to learn how many digits were pro-
cessed. This routine also does not handle negative numbers.

Lines 18–21 perform a range check to ensure that the next byte in the
buffer does, in fact, contain a decimal digit. Lines 22–25 multiply register
D0 by 10. This technique is a holdover from machines that had no hard-
ware multiplication feature. You use left shift operations to calculate \(2n\)
and \(8n\). Adding these two quantities yields \(10n\). We use this trick because
the 68000 hardware multiply instruction does not work on 32-bit quantities. Lines 26–28 convert the digit to binary and add it to the accumulator.

**DECIMAL TO HEX CONVERSION PROGRAM**

Now that we have both input and output conversion routines, let’s use
them to write a program that receives a decimal number as input and
produces the hexadecimal equivalent. The program should prompt for
input, read the number from the keyboard, and print both the original
number and its hex equivalent. Listing 4.6 shows the finished conversion
program.

Lines 11–14 of this program prompt the user for input and accept a line
from the keyboard. Lines 15–20 perform the conversions from decimal
ASCII to binary and then back to decimal and hex ASCII. Line 21 prints
the answer on the screen.

This program would have to be much longer if all the subroutines that
we developed earlier had destroyed register contents, or had taken their
inputs in different registers. The program is very short because the sub-
routines all expect parameters in the same registers. This allows you to
place many parameters in registers at one time.

Figure 4.5 shows a sample execution of the conversion program. Note
that an input value of 99999 caused an incorrect decimal value. Because of
the limitation of the 68000 DIVS instruction, the BinDec routine (see Listing
4.2) works only for 16-bit numbers. The exercises at the end of the chapter
suggest a remedy for this bug.

**FILE I/O**

Understanding how Macintosh disks work is an important part of learn-
ing to write Macintosh programs. Information on a disk is kept in collec-
tions of bytes known as *files*. Each file consists of three collections of data:

1. Data concerning the file itself: file type, size, creation date, modifica-
tion date, and file attributes. This data is called the *file information*. 
2. A set of bytes that form the file contents. This information is called the file's *data fork*.

3. A secondary set of bytes that normally contain auxiliary information. This area is known as the file's *resource fork*.

Each file on the disk contains all three of these areas, as shown in Figure 4.6. The file information is always present and always occupies a fixed amount of available storage space. Either or both of the resource and data forks can be empty (contain no bytes).

**Operations on Files**

The most straightforward way to interact with files is to first select a file in an OPEN or CREATE macro. These macros attach the program to an

---

```
0001 ; DecHex program. This program converts decimal numbers
0002 ; to hex. Numbers are input from the keyboard and output
0003 ; to the screen.
0004 ;
0005 ;
0006 include MACLIB.ASM
0007 XREF BinHex ; Hex output conversion
0008 XREF BinDec ; Decimal output conversion
0009 XREF DecBin ; Decimal input conversion
0010 PROGRAM DecHex
0011 Loop: PRINT 'Enter Decimal Number: ',$ ; Prompt for input
0012 INPUT InBuff(A5) ; Get a line of input
0013 TST.B InBuff(A5) ; Check for null line
0014 BBQ done ; if null, then quit
0015 LEA InBuff+1(A5),A0 ; A0 -> Digits input
0016 JSR DecBin ; Convert to binary
0017 LEA DecBuf,A0 ; A0 -> Decimal output area
0018 JSR DecDec ; Convert to decimal ASCII
0019 LEA HexBuf,A0 ; A0 -> Hex output area
0020 JSR BinHex ; Convert to hex ASCII
0021 PRINT OutLine ; Type the answer
0022 BRA Loop ; Do it again
0023 done: EXIT ; Back to Finder
0024 STRING_FORMAT 0 ; No count bytes
0025 OutLine DC.B - EndLine-DecBuf ; Count byte
0026 DecBuf: DC.B 'XXXXXX Decimal is'
0027 HexBuf: DC.B 'XXXXXX Hex'
0028 EndLine: ; Tag for end of line
0029 Inbuff: DS.B 81 ; Input area
0030 ENDPROGRAM
```

**Listing 4.6 - The DecHex program**
Figure 4.5 – DecHex execution

Figure 4.6 – Macintosh files
existing or new file, respectively. You can then transfer information from
the file into memory with a READ macro, or from memory into the file
with a WRITE macro. When you are through with a file, the CLOSE
macro disconnects it from your program. The resource and data forks of
the file are treated independently. There are separate OPEN macros for
each file fork. To access both forks of a file, you must open and process
the forks separately.

Normally, files are processed from beginning to end. This is known as
sequential access. The SEEK macro provides a method for specifying the
byte offset within the file at which the next transfer will begin, allowing
you to access the information in the file in any order. This capability is
known as random access.

The GETFINFO and SETFINFO macros allow you to obtain and change
a file's information area.

File Information

Associated with each Macintosh file is a data area that contains the file
information. Figure 4.7 shows the layout of this data area.

The first seven longwords of this area (offsets 0–27) constitute a Macin­tosh input/output parameter block. An I/O parameter block is used for
each file operation on the Macintosh. This parameter block is explained in
detail in Chapter 8.

Offset 28 contains the file directory index, which gives the order in
which the file appears in the disk's directory. This field is normally used in
advanced applications to reference a file by position rather than by name.

Offset 30 contains the file attributes, a set of eight single-bit flags that
give the following information on the file's current state:

- If bit 0 is a 1, the file is locked. Locked files cannot be altered or
deleted.
- Bits 1–6 are unused.
- If bit 7 is a 1, the file is currently open.

Offset 31 is the file version number. Different files with the same name
must have different version numbers.

The Finder file type (offset 32) is a four-byte identifier that the Finder
uses to determine the type of file. For example, the Finder file type is
APPL for applications and TEXT for textfiles. Files generated by the CRE­
ATE macro are textfiles. The Finder file creator (offset 36) is a four-byte
identifier that indicates the application that will start when the user clicks
<table>
<thead>
<tr>
<th>Offset</th>
<th>Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>I/O Link Word</td>
</tr>
<tr>
<td>4</td>
<td>I/O Type</td>
</tr>
<tr>
<td>8</td>
<td>I/O Command Address</td>
</tr>
<tr>
<td>12</td>
<td>Completion Routine Address</td>
</tr>
<tr>
<td>16</td>
<td>I/O Result Code</td>
</tr>
<tr>
<td>20</td>
<td>File Name Address (Low)</td>
</tr>
<tr>
<td>24</td>
<td>I/O Reference Number</td>
</tr>
<tr>
<td>28</td>
<td>File Directory Index</td>
</tr>
<tr>
<td>32</td>
<td>Finder File Type</td>
</tr>
<tr>
<td>36</td>
<td>Finder File Creator (Application Signature)</td>
</tr>
<tr>
<td>40</td>
<td>Finder Flags</td>
</tr>
<tr>
<td>44</td>
<td>Finder Icon Location (Low)</td>
</tr>
<tr>
<td>48</td>
<td>File Number</td>
</tr>
<tr>
<td>52</td>
<td>Data Fork Start Block</td>
</tr>
<tr>
<td>56</td>
<td>Data Fork Logical EOF (Low)</td>
</tr>
<tr>
<td>60</td>
<td>Data Fork Physical EOF (Low)</td>
</tr>
<tr>
<td>64</td>
<td>Resource Fork Logical EOF</td>
</tr>
<tr>
<td>68</td>
<td>Resource Fork Physical EOF</td>
</tr>
<tr>
<td>72</td>
<td>Creation Date and Time</td>
</tr>
<tr>
<td>76</td>
<td>Last Modification Date and Time</td>
</tr>
</tbody>
</table>

**Macintosh File Information**

*Figure 4.7 – File information layout*
on the file icon. This is normally EDIT (the Macintosh editor) for textfiles.

The Finder flags field (offset 40) is a series of 16 one-bit flags that the
Finder uses when displaying the file. If bit 14 is a 1, the file is an "invisible"
file. Invisible files do not show up in the Finder file display. If bit 13 is a 1,
the file has "bundled" resources (explained in Chapter 6). This bit is used
by applications that have custom icons. The rest of the word is unused.

The two Finder icon location words give the location of the file icon
within its folder. The first word gives the vertical distance from the top of
the folder, and the second word gives the horizontal distance from the left
edge of the folder.

The Finder folder number associates the file with a given folder dis­
played by the Finder. An application has no access to the folder informa­
tion, except through the folder number. The folder number can take on
certain special values:

- 3  A value of −3 indicates that the file is in the trash icon. The
  file will be deleted when an application is launched or Empty
  Trash is selected from the Finder's Special menu.

- 2  A value of −2 indicates that the file is located on the desktop
  and is not in any folder.

0    A value of zero indicates that the file is in the folder that will
  be opened if the user clicks on the disk icon.

Other folders have values of 1 or greater.

The file number (offset 48) is a unique 32-bit number assigned to each
file by the operating system. This number is used by the operating system
to distinguish the file from other files on the same disk.

File space is assigned in terms of allocation blocks. An allocation block is
the minimum quantity of space that can be added to a file. For the original
Macintosh without a hard disk, an allocation block is 1024 (1K) bytes.
Thus, a file containing only a single byte still occupies 1K on the disk. A
file containing 1025 bytes occupies 2048 (2K) bytes on the disk. The data
fork start block (offset 52) and the resource fork start block (offset 62) con­
tain the numbers of the first allocation block in each fork. If a file fork is
empty, the start block field will be zero. The data fork logical EOF and
resource fork logical EOF each contain a 32-bit number that is one greater
than the number of the last byte in the file fork. Bytes in the file are num­
bered from zero, so this quantity is also equal to the number of bytes in
the fork. The data fork physical EOF and resource fork physical EOF give
the number of bytes actually allocated to each fork of the file.
The creation date and time (offset 72) and the last modification date and time (offset 76) indicate when the file was created and last modified. These times are recorded in units of seconds starting from 12:00 A.M. on January 1, 1904.

File I/O Macros

The macros contained in MACLIB.ASM provide a convenient way to perform standard file I/O. These macros are designed to work with Macintosh textfiles, although they will work with other file types with a little extra effort. Macros exist for all of the file operations mentioned previously.

Open File Macros

The macro library provides three methods of opening a file:

- The OPEN macro, which opens the data fork of a file when given the file name
- The OPENR macro, which opens the resource fork of a file
- The POPEN macro, which opens a file selected by the user from a menu generated by the Macintosh standard file package

The OPEN and OPENR macros have a common syntax:

```
OPEN[R] filename, filebuff, volref
```

The filename parameter is the address of a Pascal string that gives the name of the file to be opened. This parameter can be a label or a string contained in single quotes. A disk or volume name can be specified as part of the string. The string

```
vol1:file.type
```

specifies a file name of "file.type" on the disk "vol1". File names cannot contain the colon (:) character.

The filebuff parameter, if specified, is the address of a 522-byte buffer for the file system. If no buffer is specified, the file system uses a buffer that is shared by the entire disk. Using a buffer that is not shared results in slightly better file I/O speed.

The volref parameter is a volume reference number. A volume reference number is either a drive number or a negative number, which references an ejected disk. The Macintosh internal drive is drive 1, and the add-on
drive is drive 2. If this parameter is omitted and the file name does not contain a volume name, all drives are scanned for the named file.

The POPEN macro has the following syntax:

```
POpen types,extent,namebuf,filebuff
```

This macro generates a display like the one shown in Figure 4.8. Files are displayed in the file window, and the user selects one by clicking on the file name and then on the Open button. Double-clicking on the file name also opens that file. The user can also change drives or eject a disk and insert a new one.

The POPEN types parameter is the address of a type array of the form shown in Figure 4.9. The first item in the array is a 16-bit count of the number of types that follow. Each type is a four-byte quantity. If this parameter is specified, only those files whose types appear in the array are shown in the selection window. If the types parameter is the string DEFAULT, files of all types are displayed.

The extent parameter is the address of a Pascal string that must match the file name extension if the file is to appear in the selection window. Use the string DEFAULT if you do not wish to select files in this manner. This feature is normally used by software tools that have standard file types. For instance, the linker requires that the link file name end in .LINK. When specifying the extent parameter, use all capital letters. The software invoked by the macro relies on the comparison string being uppercase. Only in the file name are lowercase characters converted to uppercase for comparison. This means that an extent parameter of .LINK will match both File.link and File.LINK. However, an extent parameter of .link will match neither File.link nor File.LINK.

The namebuf parameter is the address of a buffer or memory area that receives the name of the file selected by the user. This area need be only 65

![Figure 4.8 - The POPEN dialog box](image)
bytes in length to store the names of files that can be displayed by the Finder. The first byte of the buffer is set to the number of characters in the file name string. You can therefore display the buffer with the PRINT macro.

The filebuff parameter is the address of a 522-byte buffer discussed in the description of the OPEN and OPENR macros.

All three open macros return a 16-bit identifier in D0 called the I/O reference number. This quantity is used by subsequent READ, WRITE, and CLOSE requests to reference the file. If the file cannot be opened for some reason (for example, the named file doesn't exist), D0 will contain an error code. Error codes are all less than zero, so a

```
TST.W D0
BMI
```

instruction sequence can be used to detect an unsuccessful open attempt.

The POPEN macro opens only the data fork of the file selected by the user. To open the resource fork, use the name returned in the namebuf area as the file name for an OPENR macro.

<table>
<thead>
<tr>
<th>Offset</th>
<th>Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Number of entries that follow (N)</td>
</tr>
<tr>
<td>2</td>
<td>Type 0 (4 bytes)</td>
</tr>
<tr>
<td>6</td>
<td>Type 1 (4 bytes)</td>
</tr>
<tr>
<td>(4 \times (N - 1) + 2)</td>
<td>Type (N - 1) (4 bytes)</td>
</tr>
</tbody>
</table>

*Figure 4.9 - The POPEN type array*
Create File Macros

There are two macros used to create new files:

- The CREATE macro, used when the name of the file is not to be selected by the user
- The PCREATE macro, used when the name of the file is to be entered by the user

The CREATE macro installs a new file on the disk and leaves the data fork open for subsequent I/O operations. Any previously existing file with the same name is destroyed. The CREATE macro is used as follows:

```
CREATE filename,filebuff,volref
```

The `filename` parameter is the address of a Pascal string containing the name of the file to be created. This name can be prefixed by a volume name, like the OPEN and OPENR macros. `Filebuff` is the address of a 522-byte buffer to be used for the file. Use the string DEFAULT to specify no buffering. `Volref` is an optional volume reference number, which is an alternate way to specify the volume on which to create the file.

The PCREATE macro installs a new file whose name is supplied by the user. To call this macro, use this form:

```
PCREATE prompt,defname,namebuf,filebuff
```

`Prompt` is the address of a prompt string that appears above the area where the user types the file name. `Defname` is a default name, which the user can select by clicking on the Save choice in the dialog box. `Namebuf` is the optional address of an area of memory that will receive the selected file name. `Filebuff` is the address of a 522-byte area to be used as a buffer for the open file.

The layout of the dialog box for the PCREATE macro is shown in Figure 4.10. The user is given the options of accepting the file name, typing in a new file name, canceling the request, or specifying the disk drive on which the file is to be created.

The I/O reference number for the new file is returned in D0.W for both the CREATE and PCREATE macros. If the file cannot be created, D0.W will be less than zero. This can happen for a variety of reasons, such as using a write-protected disk, having a locked file of the same name already on the disk, or, in the case of the PCREATE macro, a selection of Cancel by the user.
Any file created with the CREATE or PCREATE macros is initially a text-file, and the default application for the file is EDIT. This can be changed using the GETINFO and SETINFO macros described below.

**Read File Macros**

There are two macros that transfer data from a file into memory. The READ macro transfers a fixed number of bytes, and the READLN macro transfers bytes until it encounters a carriage return. The READ macro is normally used on files that do not contain ASCII text, while the READLN macro is very useful in reading a single line at a time from a file. These macros are used as follows:

```
READ refnum,buffer,count
READLN refnum,buffer,count
```

The *refnum* parameter is a file reference number returned by an OPEN, OPENR, POPEN, CREATE, or PCREATE macro. *Buffer* is the memory address where the first byte read from the file is to be placed. *Count* is the number of bytes available in the buffer. Both macros return the number of bytes actually transferred in DO.L.

The READ macro tries to place exactly the requested number of bytes in the buffer. If there are insufficient bytes remaining in the file to do this, READ returns less than the number of bytes requested.

The READLN macro reads bytes until it encounters a carriage-return character (a byte containing hex 0D, or decimal 13). Macintosh textfiles use this character to signal the end of a line. READLN returns the number of characters read in DO.L. Normally, the last character placed in the buffer is the carriage return. If the buffer is too short to accommodate the whole line, however, READLN will put only as much as will fit in the buffer. A subsequent READ or READLN will begin reading the next part of the line.
The WRITE Macro

To transfer data from memory to a file, use the WRITE macro. This macro is used as follows:

```
WRITE refnum,buffer,count
```

The parameters are analogous to the READ macro parameters. Refnum is an I/O reference number, buffer is the address of the first byte to be written to the file, and count is the number of bytes to be written.

The WRITE macro returns the number of bytes actually written in D0.L. The actual number will always be the same as the count parameter, unless an error occurs during the transfer. Errors can occur if you use WRITE on a full disk, a write-protected disk, or a locked file.

The SEEK Macro

Normally, you read or write a file in order from beginning to end. This is called sequential access to the file. In some applications, however, it is necessary to access information in a different order. The SEEK macro allows you to specify the byte number within the file (relative to zero) at which the next READ or WRITE macro will begin. The SEEK macro is used as follows:

```
SEEK refnum,offset,sense
```

Refnum is the reference number for an open file. Offset is the 32-bit offset that gives the position in the file. This number can be interpreted in any of three ways, as indicated by the sense parameter:

<table>
<thead>
<tr>
<th>Sense Value</th>
<th>Meaning of Offset</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>From beginning of file</td>
</tr>
<tr>
<td>1</td>
<td>From current file position</td>
</tr>
<tr>
<td>2</td>
<td>From end of file</td>
</tr>
</tbody>
</table>

If the offset is a negative value, you can seek backwards from the current file position or from the end of the file. If you attempt to seek beyond the end of the file, the file pointer will be set to one byte beyond the end of the file.

The SEEK macro returns the resulting offset from the beginning of the file in D0.L. You can thus obtain the value of the file pointer by using SEEK and specifying zero bytes from the current file position. You can find the file size by using SEEK and specifying zero bytes from the end of the file.
Macros for Accessing File Information

You can obtain and change the file information (described previously) using the GETINFO and SETINFO macros. These macros are used as follows:

GETINFO   filename,buffer,volref
SETINFO   filename,buffer,volref

Filename is the address of a string that specifies the name of the file. This string can contain a volume name, as with the OPEN, OPENR, and CREATE macros. Buffer is the address of an 80-byte buffer that receives the information shown in Figure 4.7. Volref is an optional volume reference (drive) number. Omit this parameter if you want to search all drives for the named file.

FILE I/O EXAMPLE

Having covered the necessary background material, we can now write a sophisticated program. The final section of this chapter presents and discusses a dump utility for the Macintosh—a sample program that performs file I/O. This program produces a textfile containing a hexadecimal listing of the contents of the resource and data forks of a user-selected file. The file information is also formatted and sent to the file.

This sample program is typical of noninteractive programs that deal with files. Such programs normally take an input file and perform some transformation on it to produce an output file. The Macintosh assembler and linker programs are also examples of such programs.

This program is large enough that it must be explained in several different parts. Splitting a program into smaller components is known as modular programming. Well-written programs are composed of small and for the most part independent pieces of code called modules. The subroutine call mechanism (BSR/JSR and RTS instructions) is normally used as the interface between modules.

A module diagram showing the structure of the Dump program is shown in Figure 4.11. This program is implemented in a typical hierarchical fashion. The subroutine relationships are shown by lines between the boxes. Calling is done in a downward direction only.

The main routine (at the beginning of the program) calls three other routines: OpenFiles, DoFInfo, and DoFork. OpenFiles is a routine that opens the data fork of the input file and creates the output file. DoFInfo formats and writes the file information, and DoFork formats and writes the contents of a file fork. The main routine calls DoFInfo and then calls DoFork once for each fork of the input file.
The DoFInfo routine calls a set of routines that convert binary to ASCII. The Date routine converts a binary date in Macintosh format to ASCII. A routine called TwoDig converts a small binary number to a two-digit decimal ASCII number as part of this process. DumpAsc formats the binary data into printable ASCII, substituting a period character for bytes that have no meaningful ASCII representation. Routines HexL, HexW, and HexB convert a binary longword, word, or byte, respectively, to hex ASCII. The hex routines and the TwoDig routine are left as exercises.

The DoFork routine reads, converts, and writes the contents of a file fork. This routine also calls the hex conversion routines and the DumpAsc routine described above.

**The Dump Program Main Routine**

Listing 4.7 contains the main routine of the Dump program. Line 20 is the call to the OpenFiles routine. Lines 21–24 echo on the screen the file names selected by the user. OpenFiles leaves the file reference numbers
Listing 4.7 – The main routine for the Dump program

0001 ; Dump.asm This program dumps an arbitrary file to an ASCII textfile.
0002 ;
0003 ; Version 01.00 18-Feb-85
0004 ;
0005 ; This program prompts for a file to be dumped, changes the extension to
0006 ; ".dmp", and prints the contents of the file in hex and ASCII in the
0007 ; output file.
0008 ; The dump may be repeated as desired.
0009 ;
0010 ; include MACLIB.ASM
0011 ;
0012 BufSize EQU 16 ; 16 bytes per dump line
0013 Space EQU $20 ; ASCII value for a blank
0014 ;
0015 PROGRAM DUMP ; Set up program entry
0016 Start: BSR OpenFiles ; Start with opening input/output
0017 PRINT 'Dumping ',* ; Echo file names
0018 PRINT INamemBuf(A5),* ; to main window
0019 PRINT 'To ',* ;
0020 PRINT ONamemBuf(A5) ;
0021 WRITE ORefNum(A5),InfoStr,Inflen; Write "File Information" on file
0022 BSR DoFInfo ; Dump file information first
0023 TST.L D0 ; Successful?
0024 BNE DQuit ; No, quit
0025 WRITE ORefNum(A5),DataStr,DatLen; Write "Data Fork" on file
0026 BSR DoFork ; Do the data fork
0027 TST.L D0 ; Successful?
0028 BNE DQuit ; No, quit
0029 CLOSE IRefNum(A5) ; Close the file
0030 OPENR INamemBuf(A5),IFBuff(A5) ; Open resource fork now
0031 MOVE.W D0,IRefNum(A5) ; Save file number
0032 BGT ROpenOK ; If GT, then OK
0033 PRINT 'Unable to Open Resource Fork: ',* ;
0034 PRINT INamemBuf(A5) ; Identify file name
0035 CLOSE ORefNum(A5) ; Close output file
0036 BRA Start ; To next file
0037 ROpenOK: ; Here if resource open OK
0038 WRITE ORefNum(A5),ResStr,ResLen; Write resource ID
0039 DQuit: CLOSE IRefNum(A5) ; Close the file
0040 BRA Start ; and output file
0041 BRA Start ; Go get next file name
for the input and output files in global variables IRefNum and ORefNum. The names of the files are Pascal strings in INameBuf and ONameBuf.

Lines 25–28 initiate the file information output part of the program. The WRITE macro in line 25 places the heading “File Information:” in the output file. The DoFInfo routine called in line 26 formats and writes the file information. If an output error occurs, register D0.L returns a nonzero value. Lines 27–28 handle this case.

Lines 29–46 complete the dump process. Line 29 writes a heading for the data fork. The call to DoFork in line 30 writes the converted data fork contents. Lines 31–32 check for an error from DoFork. Lines 33–35 close the data fork of the file and open the resource fork. Lines 36–40 handle the unlikely case of a problem with opening the resource fork. Lines 37–38 print a message on the screen identifying the error and the file name. Lines 39–40 close the output file and restart the program. Lines 42–46 dump the resource fork. Lines 44–46 close the input and output files and restart the program.

The OpenFiles Routine

The Dump program OpenFiles routine is shown in Listing 4.8. This routine uses the POPEN and PCREATE macros to open the input and output files, respectively.

Lines 62–64 perform the POPEN for the input file. If the user selects the Cancel option, the reference number returned in D0 will be negative. In this case the program exits to the Finder at line 94.

Lines 65–86 construct the output file name from the input file name. Lines 70–74 find a period (.) character in the input file name. Line 75 appends a period if none is found. Lines 77–81 change whatever appears after the period to the characters DMP. Thus if the input file name is Test.asm, the program produces the file name Test.DMP as output. Lines 82–86 calculate the count byte for the output file name string.

Lines 87–93 complete the OpenFiles routine. The PCREATE macro opens the output file. If this fails, the input file is closed and the OpenFiles procedure begins all over again. If PCREATE is successful, OpenFiles returns to the main routine.

The DoFInfo Routine

Listing 4.9 contains the DoFInfo routine, which formats and writes the file information to the output file. Lines 107–123 of this routine are equates defining the offsets in the buffer shown in Figure 4.7. The DoFInfo routine
OpenFiles routine. Here to open input file and output file using
POPEN and PCREATE macros.

Entry conditions:

Exit conditions:

IREfNum = Input file number
ORefNum = Output file number

OpenFiles:

FindDot:

MoveExt:

MoveExt:

FindDot:

Loop label:

Move in

Corrected count byte

Create dump file

Save output file number

If OK, continue

Close input file

Go try next file

Restore registers

Back to main routine

Quit routine

Listing 4.8 – The OpenFiles routine
DoFinfo routine. Dumps the file information block.

**Entry Conditions:**

- (none)

**Exit Conditions:**

- (none)

**Equates for file info:**

```assembly
0107 DirIndex EQU 28 ; Directory index
0108 Attrib EQU 30 ; File attributes
0109 Version EQU 31 ; File version number
0110 Type EQU 32 ; Finder file type
0111 File EQU 36 ; Finder file creator
0112 Flags EQU 40 ; Finder flags word
0113 Icon EQU 42 ; Finder icon location
0114 Folder EQU 46 ; Finder folder number
0115 FileNum EQU 48 ; File number
0116 DataStart EQU 52 ; Data fork start block
0117 DataLEOF EQU 54 ; Data fork logical EOF
0118 DataPEOF EQU 58 ; Data fork physical EOF
0119 RsrcStart EQU 62 ; Resource fork start block
0120 RsrcLEOF EQU 64 ; Resource fork logical EOF
0121 RsrcPEOF EQU 68 ; Resource fork physical EOF
0122 CreateDate EQU 72 ; Creation date
0123 ModifyDate EQU 76 ; Modification date
```

**Listing 4.9 – The DoFinfo routine**

```assembly
0095 ;
0096 ;
0097 ;
0098 ;
0099 ;
0100 ;
0101 ;
0102 ;
0103 ;
0104 ;
0105 ;
0106 ; DoFinfo routine. Dumps the file information block.
0107 ;
0108 ; Entry conditions:
0109 ; (none)
0110 ;
0111 ; Exit conditions:
0112 ; (none)
0113 ;
0114 ; Equates for file info:
0115 ;
0116 ;
0117 ;
0118 ;
0119 ;
0120 ;
0121 ;
0122 ;
0123 ;
0124 ;
0125 ; Get file info for input file
0126 ;
0127 ;
0128 ;
0129 ;
0130 ;
0131 ;
0132 ;
0133 ;
0134 ;
0135 ;
0136 ;
0137 ;
0138 ;
0139 ;
0140 ;
0141 ;
0142 ;
0143 ;
0144 ;
0145 ;
```

The DoFinfo routine listings include:
- **DirIndex**: EQU 28 (Directory index)
- **Attrib**: EQU 30 (File attributes)
- **Version**: EQU 31 (File version number)
- **Type**: EQU 32 (Finder file type)
- **File**: EQU 36 (Finder file creator)
- **Flags**: EQU 40 (Finder flags word)
- **Icon**: EQU 42 (Finder icon location)
- **Folder**: EQU 46 (Finder folder number)
- **FileNum**: EQU 48 (File number)
- **DataStart**: EQU 52 (Data fork start block)
- **DataLEOF**: EQU 54 (Data fork logical EOF)
- **DataPEOF**: EQU 58 (Data fork physical EOF)
- **RsrcStart**: EQU 62 (Resource fork start block)
- **RsrcLEOF**: EQU 64 (Resource fork logical EOF)
- **RsrcPEOF**: EQU 68 (Resource fork physical EOF)
- **CreateDate**: EQU 72 (Creation date)
- **ModifyDate**: EQU 76 (Modification date)

The routine processes file information block entries and converts various file attributes and versions for output.
LEA FiCreate(A3),A1; A1 -> Binary creator
LEA FFCAsc,A0; A0 -> Output area
MOVEQ.L #4,D0; D0 = Byte count
BSR DumpAsc; Convert
MOVE.W FiFlags(A3),D0; D0 = Finder flags word
LEA FFflags,A0; A0 -> Output area
BSR HexW; Convert
MOVE.L FIcon(A3),D0; D0 = Finder icon location
LEA FFIcon,A0; A0 -> Output area
BSR HexL; Convert
MOVE.W FiFolder(A3),D0; D0 = Finder folder number
LEA FFNum,A0; A0 -> Output area
BSR HexW; Convert
MOVE.L FileName(A3),D0; D0 = File number
LEA OFileNum,A0; A0 -> Output area
BSR HexL; Convert
MOVE.W DataStart(A3),D0; D0 = Data fork start block
LEA DFStart,A0; A0 -> Output area
BSR HexW; Convert
MOVE.L DataEOF(A3),D0; D0 = Data fork logical EOF
LEA DFEOF,A0; A0 -> Output area
BSR HexL; Convert
MOVE.L DataPEOF(A3),D0; D0 = Data fork physical EOF
LEA DFPEOF,A0; A0 -> Output area
BSR HexL; Convert
MOVE.W RsrcStart(A3),D0; D0 = Resource fork start block
LEA RFStart,A0; A0 -> Output area
BSR HexW; Convert
MOVE.L RsrcEOF(A3),D0; D0 = Resource fork logical EOF
LEA RFEof,A0; A0 -> Output area
BSR HexL; Convert
MOVE.L RsrcPEOF(A3),D0; D0 = Resource fork physical EOF
LEA RFP EOF,A0; A0 -> Output area
BSR HexL; Convert
MOVE.L CreateDate(A3),D0; D0 = Creation date
LEA Creation,A0; A0 -> Output area
BSR Date; Convert
MOVE.L ModifyDate(A3),D0; D0 = Modification date
LEA Modify,A0; A0 -> Output area
BSR Date; Convert
WRITE ORefNum(A5),FInfoStr,FInfoLen; Write converted data to file
CMP.L FInfoLen,D0; Check for write error
BNE WError; Had an error, indicate it
CLR.L D0; Clear return register
FIREt: MOVEM.L (SP)+,D1-D7/A0-A4; Unstack registers
BRA FIREt; Back to caller
WError: PRINT 'Write Error on File:',*; Print error message
PRINT ONameBuf(A5); Identify file by name
MOVEQ.L #1,D0; Return error code
BRA FIREt; Do return

Listing 4.9 - The DoFInfo routine (continued)
first converts each of the binary values in the buffer to ASCII and then performs a single WRITE operation to place the converted data in the output file. There is a multiline output buffer in the data area that defines the output format. This buffer is contained in lines 453–474 of Listing 4.13.

Line 125 contains the GETFINFO macro invocation, which returns the file information. Note that the third parameter (the volume reference number) has been omitted. This causes the program to search all drives for the input file.

Lines 126–185 are a series of calls to the ASCII conversion routines to format the various fields of the file information buffer. Depending on the field size and contents, either the HexL, HexW, HexB, DumpAsc, or Date routine does the conversion. All of these routines take a binary value, usually in D0, and convert it to an ASCII string whose address is passed in A0.

Line 182 writes the entire file information display to the output file. The buffer is defined (in Listing 4.13) with carriage-return characters at the end of each line, to produce multiline output. Following the WRITE macro, lines 187–191 check for a WRITE error and return zero in D0 if the operation is successful. If it fails, lines 192–195 print an error message. Register D0.L is set to –1 to indicate the error.

The DoFork Routine

Listing 4.10 contains the DoFork routine, which formats and outputs one fork of a file. This routine refers to the input file by reference number only, and it works equally well on the data or resource fork of a file. Register D7 contains the file address throughout this routine. Dumping starts at address 0, and the initialization is performed in line 211.

Lines 213–216 initialize the binary input area to all zeros. When the end of the file is reached, the final READ operation may not completely fill the buffer. Since the output routine always converts 16 bytes, we must initialize the buffer before reading so that there will not be any garbage left from the previous READ at the end of the buffer.

Lines 217–219 give the user a chance to terminate the dumping process. The CHKABORT macro tests to see whether the user has typed Command-Period (indicating a desire to terminate). Register D0 contains a nonzero number if Command-Period was typed at the keyboard. A user abort is treated like an output error: D0.L is set to –1, and DoFork returns to the main routine immediately.

Lines 220–222 read the input file. If the READ macro returns an error in D0, this is treated as the end of the input file fork. In this case DoFork returns zero in D0.L, indicating successful completion.

Lines 223–226 convert the file address to hex in the output buffer. Lines
Listing 4.10 – The DoFork routine
227–233 convert the 16 bytes read from the file to four hexadecimal longwords in the buffer. Lines 234–236 convert these same 16 bytes to printable ASCII code using the DumpAsc routine.

Line 237 sends the converted output string to the output file. Lines 238–239 check to see that the WRITE macro was successful. A WRITE failure is handled by the code in the DoFInfo routine (lines 192–195).

Lines 240–242 form the end of the loop. The file address is incremented by 16, and the loop repeats if 16 bytes were transferred on the last READ. If less than 16 bytes were transferred, the end of the file was reached on the previous READ. Lines 243–245 return a success indicator to the calling routine.

**The DumpAsc Routine**

Listing 4.11 contains the DumpAsc routine. This routine moves a specified number of bytes from one location to another, replacing all nonprintable characters with periods. This makes it easy to spot ASCII strings in a dump output.

```
0289 ;
0290 ; Dump ASCII conversion routine. Converts binary to printable ASCII.
0291 ; Unprintable binary characters are converted to periods.
0292 ;
0293 ; Enter with:
0294 ;
0295 ; A0 -> Output area
0296 ; Al -> Input data
0297 ; DO = Byte count
0298 ;
0299 ; Exit with:
0300 ;
0301 ; (No change to registers)
0302 ;
0303 DumpAsc MOVEM,L D0/A0-Al, -(SP) ; Save registers
0304 SUBQ,W $1,DO ; Adjust for DBRA
0305 DALoop: CPI.B #$Space,(Al)+ ; Printable?
0306 BGE NoDot ; Yes, use character
0307 MOVE.B '#',(Al)+ ; No, use '.'
0308 BRA DADBRA ; Do loop end stuff
0309 NoDot: MOVE.B -1(A1),(A0)+ ; Move in actual character
0310 DADBRA: DBRA D0,DALoop ; Repeat until done
0311 MOVEM,L (SP)+,D0/A0-Al ; Restore registers
0312 RTS ; and return
```

Listing 4.11 – The DumpAsc routine
Lines 304–310 copy the source to the destination. If a byte’s value is less than the value for a space (20 hex), it is replaced by a period (2E hex). Registers are preserved and restored in lines 303 and 311.

**The Date Routine**

The Date routine is shown in Listing 4.12. This routine converts a Macintosh-format date in D0.L to an ASCII string at the address contained in A0. Macintosh dates consist of the number of seconds since 12:00 A.M. (midnight) on January 1, 1904. The format of the output string is

```
mm/dd/yy hh:mm:ss
```

which is the usual representation for date and time in the United States. The algorithm used for the conversion is to divide the date by the number of seconds in a year (allowing for leap years) to obtain the year, subtract the number of seconds in each month to find the month, and so on. Lines 328–336 contain equates for the number of seconds in all of the needed units (minutes, hours, months, years). Note that because the number of seconds in a day is greater than 64K, the 68000 hardware divide cannot be used for many of these calculations.

Lines 338–352 calculate the year minus 1900. This is done by repeatedly subtracting the number of seconds in a year until the remaining number is less than a year. Note that the number of seconds in a year changes depending on whether the year is a leap year. This is handled by a loop that first subtracts the number of seconds in a leap year (lines 340–342) and then subtracts the number of seconds in a regular year three times (lines 343–350). Register D1, initially 4, is incremented by 1 after each subtraction. At line 352, D1 contains the correct year number. Note that the branches at lines 341 and 347 are unsigned. This is due to the fact that the number of seconds since 1904 is larger than 31 bits can represent. This means that unsigned arithmetic must be used in calculating the year.

The month is calculated by subtracting entries in a table of months from the remainder in D0.L. There are two tables, one for nonleap years and one for leap years. Lines 353–357 load the correct table address into register A1. Lines 358–365 calculate the month number (1–12) in D2.

The day of the month is calculated by repeatedly subtracting the number of seconds in a day from the remainder in D0.L. When D0 becomes negative, the last number subtracted is added back. Lines 366–373 perform this calculation.

Once the correct day of the month is found, the DIVS instruction can
Simple Macintosh Programs

Macintosh Date conversion routine. Converts binary date to date/time: mm/dd/yy hh:mm:ss

Enter with:

DO.L = Binary date
AO -> Output area

Exit with:

(No change to registers)

0313 ; Doesn't work for year 2100 (wrongly considers 2100 a leap year).
0314 ;
0315 ;
0316 ;
0317 ;
0318 ;
0319 ;
0320 ;
0321 ;
0322 ;
0323 ;
0324 ;
0325 ;
0326 ;
0327 ;
0328 SecsMin EQU 60 ; Seconds/minute
0329 SecsHr EQU 3600 ; Seconds/hour
0330 SecsDay EQU 86400 ; Seconds/day
0331 SecsM28 EQU 2419200 ; Seconds/28-day month
0332 SecsM29 EQU 2505600 ; Seconds/29-day month
0333 SecsM30 EQU 2592000 ; Seconds/30-day month
0334 SecsM31 EQU 2678400 ; Seconds/31-day month
0335 SecsYr EQU 31536000 ; Seconds/(nonleap) year
0336 SecsLYr EQU 31622400 ; Seconds/leap year
0337 Dte: MOVEM.L D0-D6/A0-Al,-(SP) ; Save registers
0338 MOVE.L #4,D1 ; D1 to be year
0339 LYearLoop: ; Here to do years
0340 CMP.L #SecsLYr,D0 ; (Starts with 1904, a leap year)
0341 BLO YearFound ; Year is now correct
0342 SUB.L #SecsLYr,D0 ; Subtract a year
0343 ADDQ.L #1,D1 ; Bump year counter
0344 MOVE.W #2,D3 ; Count 3 more nonleap years
0345 YearLoop: ; Loop of nonleap years
0346 CMP.L #SecsYr,D0 ; Another year left?
0347 BLO YearFound ; No, do the rest
0348 SUB.L #SecsYr,D0 ; Subtract a year
0349 ADDQ.L #1,D1 ; Bump year counter
0350 DBRA D3,YearLoop ; Repeat for nonleap years
0351 BRA LYearLoop ; Repeat till expired
0352 YearFound: ; Here when year found
0353 LEA MonthTab,Al ; A1 -> Table of secs/month
0354 MOVE.W D1,D3 ; Copy year to D3
0355 ANDI.W #3,D3 ; Check for divisible by 4
0356 BNE NotLeap ; Not a leap year
0357 LEA IMonthTab,Al ; A1 -> Secs/month for leap year
0358 NotLeap MOVEQ.L #1,D2 ; D2 to be month
0359 MonthLoop: ; Now calculate month number
0360 CMP.L (Al),D0 ; Enough seconds left?
0361 BLT MonthFound ; No, month correct
0362 SUB.L (Al)+,D0 ; Subtract off month
0363 ADDQ.L #1,D2 ; Bump counter
0364 BRA MonthLoop

Listing 4.12 – The Date routine
Listing 4.12 – The Date routine (continued)
be used to calculate the time of day. Lines 373–381 calculate the correct time of day in D4 through D6.

Lines 385–401 convert the binary quantities calculated above to ASCII. The TwoDig routine is used for numeric conversion. This routine converts a byte to two decimal digits.

Lines 404–412 contain the data used by this routine, the two tables of the number of seconds in each month of the year.

**The Dump Program Data Area**

Listing 4.13 contains the data locations used by the Dump program. Lines 442–447 define ASCII strings used as headers in the output file. Lines 448–449 define the line output by routine DoFork, with fields for the file address, contents in hex, and contents in ASCII. Lines 453–474 contain the file information buffer, with labels added for ease of conversion. Line 479 contains the output file prompt used by the PCREATE macro in OpenFiles. Lines 484–488 define the lengths of the buffers used by WRITE macros. Note that the lengths must be 32 bits for use in a WRITE call.

Lines 492–501 define data that have no initial value. This is normally done for buffers or variables that need not be initialized, such as the file names returned by POPEN and PCREATE.

```
0435 ;
0436 ;
0437 ;       Dump program data area.
0438 ;
0439 ;       Strings that are written to the .DMP file:
0440 ;
0441 ;       STRING_FORMAT 0
0442 InfoStr: DC.B 13,'File Information:',13
0443 InfoEnd:
0444 ResStr: DC.B 13,'Resource Fork:',13
0445 ResEnd:
0446 DataStr: DC.B 13,'Data Fork: ',13
0447 DataEnd:
0448 DumpLine: DC.B 'xxxxxxxx: XXXXXXXX XXXXXXXX XXXXXXXX XXXXXXXX ..........',13
0449 EndDum:
0450 ;
0451 ;       ASCII output area for file information
0452 ;
0453 FInfoStr:
0454 Diridx: DC.B 'Directory Index: '
0455 Diridx: DC.B 'hhhh',13,'Attributes: '
```

**Listing 4.13 — The Dump program data area (continued)***
Listing 4.13 - The Dump program data area (continued)
Sample Output

Listing 4.14 shows the output of the Dump program for an input file that contains the single line

Hello, World

The line of text is contained in the file's data fork. Note that the editor uses the resource fork to store information about the file.

File Information:
Directory Index: 0000
Attributes: 80
Version: 00
Finder File Type: 54455854 TEXT
Finder File Creator: 45444954 EDIT
Finder Flags: 0100
Finder Icon Location: 000300EB
Finder Folder Number: 0000
File Number: 00000025
Data Fork Start: 00000000
Resource Fork Start: 00000000
Creation Date: 02/23/85 08:22:02
Modification Date: 02/23/85 08:22:03

Data Fork:
00000000: 48656C6C 6F2C2057 6F726C64 0D000000 Hello, World....

Resource Fork:
00000000: 00000100 00000116 00000016 000000D4
00000010: 61726444 69736B3A 69736B3A 3AFFFFFF 
00000020: FFFFFFFF FFFFFFFF FFFFFFFF FFFFFFFF
00000030: FFFFFFFF FFFFFFFF FFFFFFFF FFFFFFFF
00000040: FFFFFFFF FFFFFFFF FFFFFFFF FFFFFFFF
00000050: FFFFFFFF FFFFFFFF FFFFFFFF FFFFFFFF
00000060: FFFFFFFF FFFFFFFF FFFFFFFF FFFFFFFF
00000070: FFFFFFFF FFFFFFFF FFFFFFFF FFFFFFFF
00000080: FFFFFFFF FFFFFFFF FFFFFFFF FFFFFFFF
00000090: FFFFFFFF FFFFFFFF FFFFFFFF FFFFFFFF
000000A0: FFFFFFFF FFFFFFFF FFFFFFFF FFFFFFFF
000000B0: FFFFFFFF FFFFFFFF FFFFFFFF FFFFFFFF
000000C0: FFFFFFFF FFFFFFFF FFFFFFFF FFFFFFFF
000000D0: FFFFFFFF FFFFFFFF FFFFFFFF FFFFFFFF
000000E0: FFFFFFFF FFFFFFFF FFFFFFFF FFFFFFFF
000000F0: FFFFFFFF FFFFFFFF FFFFFFFF FFFFFFFF
00000100: 0000000A 0009064D 6F6E6163
00000110: 00040006 00080000 01000000 01160000
00000120: 00160000 00D40000 009C007A 0000001C
00000130: 00460001 45464E54 00000012 45544142 
00000140: 0000001E 03EB0000 00000000 001622A

Listing 4.14 – The Hello.DMP file
SUMMARY

In this chapter, we have developed the background input/output material for writing sophisticated programs: keyboard input, terminal-style output, file operations, and numeric conversion. This basic tool kit provides us with the building blocks necessary to construct larger programs on the Macintosh.

EXERCISES

1. A division instruction can be simulated as a loop that subtracts until the dividend is reduced to a number less than the divisor. Write a subroutine called "ldiv" that divides a 32-bit number by another 32-bit number. Use the following calling convention:

   Enter with:
   D0.L = dividend
   D1.L = divisor

   Exit with:
   D0.L = quotient
   D1.L = remainder

   What is the major disadvantage of this scheme?

2. Use the "ldiv" subroutine developed in Exercise 1 to create a new routine that successfully converts 32-bit binary numbers to decimal ASCII. Use a 10-byte output area. Can you think of a better way to do this function?
3. Modify the DecHex program (Listing 4.6) to use the “Idiv” conversion routine developed for Exercise 2.

4. Write a routine that converts hexadecimal ASCII to binary in a manner similar to Listing 4.5. Allow both upper- and lowercase ASCII for the digits A–F.

5. Write a program that converts hex numbers to decimal.

6. Modify the DecBin routine (Listing 4.5) to accept leading spaces and negative numbers.

7. Write the HexB, HexW, HexL, and TwoDig routines for the Dump program. These routines take binary input in D0 and convert it to ASCII at an address in A0. Routine TwoDig is required to leave A0 at the next byte beyond the converted data. The hex routines must return A0 unchanged.

8. Write a program that numbers the lines in an assembly language source file. Use four-digit line numbers. Use POPEN and PCREATE to open the input and output files.
INTRODUCTION

This chapter begins by introducing topics essential to writing advanced applications. These include data storage techniques, sorting, and searching. It goes on to cover the use of some advanced features of the assembler: conditional assembly and macros. It also contains information on combining high-level languages with assembly language. Finally, it covers the structure of Macintosh Toolbox and operating system calls.

DATA ORGANIZATION

One of the most important considerations in writing a large program is how to organize the data both inside and outside the program. You can organize data in the form of records, arrays, linked lists, trees, queues, and dequeeues. We will look at each of these types in detail.

Records

One of the simplest forms of data structure is called a record (or structure). A record is a set of contiguous memory locations that contains
related data. For instance, a program that organizes data into a telephone
directory would probably have a record with fields for name, address,
and telephone number.

Records can exist either in primary memory or on disk. There is an
almost infinite variety of record formats. Two of the most popular ones are
fixed-length records and variable-length records.

Fixed-Length Records

Fixed-length records (abbreviated FLR) have the same number of bytes in
each record. This has distinct advantages when accessing records randomly.
When the records in a file contain differing amounts of information, how­
ever, fixed-length records waste storage space.

Fixed-length records are a natural outgrowth of the days when punched
cards were used to run programs and enter data into a computer. Cards
had a fixed number of columns, usually 80 or 96. Each column held one
byte of information. When programming machines that used punched
cards, it was common to place each field of the record in a particular
card column. When the card was read into memory, the fields would
always be offset the same distance from the beginning of the card image
in memory.

The FORTRAN language is an example of a holdover from this tech­
nique. FORTRAN statements begin in what would be column 7 of the
card, which is very difficult to do on a terminal! If a FORTRAN statement
overflows from one line to the next, you have to put a nonblank character
in column 6. Fortunately, most systems no longer use cards.

Many present-day storage techniques rely on fixed-length techniques.
This is especially true for records contained in primary memory. The sim­
plicity and speed of the FLR technique often outweigh considerations of
storage inefficiency.

Variable-Length Records

Variable-length records (abbreviated VLR) allow for a different number
of bytes in each record. This technique avoids the problem of wasted
space inherent in fixed-length records, but it makes random access slower
and more difficult. ASCII textfiles often use one of the VLR techniques.
Here are some of the more popular methods:

1. Records are prefixed with a count field that gives the number of
bytes in the record. The Macintosh uses this technique for text
strings in memory. There are minor variations in the way com­
puters use this technique: the number of bytes dedicated to the
count field varies, the count field may or may not include the number of bytes in the count field, and the count field may count units other than bytes. Most implementations of BASIC on microcomputers use the count technique for string variables. This technique is also used to store textfiles on many operating systems for mainframes and minicomputers.

2. Records are terminated with some special character or character sequence that cannot occur within the record itself. For example, Macintosh textfiles terminate lines of text with a carriage-return character (decimal 13). The C language uses a null byte (decimal 0) to terminate strings in memory.

3. The beginning of a record is marked with a unique sequence. This technique is often used in work involving communications, where faulty transmission may distort, add, or delete bytes within a record. A unique sequence of bytes helps resynchronize the receiver and transmitter.

**Hybrid Techniques**

A number of techniques have been devised that combine the desirable features of fixed- and variable-length techniques. These “hybrid” techniques usually allow reasonable random access with reasonable storage efficiency.

For records that are processed sequentially, a fixed portion of the record is often used in combination with a variable portion of the record. The fixed portion of the record contains an indication of how big the variable portion is. This technique is useful for applications that must represent variable-length tables.

Another common technique is to split the fixed and variable portions of the records and store the fixed portions together and the variable portions separately. The fixed portion contains the address of the variable portion. In this way, the capability of fixed-length records to enhance random access is combined with the storage efficiency of variable-length records.

**Describing Records in Assembly Language**

There are some common techniques for manipulating records in assembly language that are advantageous on the 68000 chip. If a record is less than 32K (as most are), the address-register-indirect-with-displacement addressing mode can be used to access the individual fields. This is particularly advantageous when more than one record must be handled at one time.
In coding references to records, it is good practice to use equated names for the different fields in the record. This allows you to go back later and change the size and order of the fields in the record without changing all the references to those fields.

**STORAGE ALLOCATION**

The way in which records are arranged in memory is often critical to a program's performance. There are two techniques commonly used to allocate memory:

1. Allocating the records contiguously; that is, one following the other. A collection of records arranged in this way is called an *array*.

2. Allocating the records noncontiguously, with each record containing the address of the next record in logical order. This is called a *linked list*.

**Arrays**

An array is composed of records arranged contiguously in memory. When used with fixed-length records, the array technique makes random access extremely easy. To access record *n*, this is how you calculate the address:

\[
\text{address} = (n - 1) \times (\text{record size}) + \text{the starting address of the array}
\]

Note that this formula assumes a starting value of 1. Multidimensional arrays require a more complicated formula that depends on the order in which the dimensions are stored.

This technique is used in many programs for matrix calculations, tables, and other data that must be accessed randomly. The same technique can be used for accessing fixed-length records in a disk file. This is sometimes called *direct access*.

The disadvantage of arrays comes when you are adding or deleting items. The rapid retrieval of information often depends on the information occurring in some particular order. Adding or deleting items in an ordered array requires moving all items below the insertion or deletion point. For example, consider the array of numbers displayed in Figure 5.1.

Let's say that we need to insert the number 101 into this array. In order to make room for a new entry between 100 and 103, we must move the
lower three elements down. When manipulating large tables, this process can require a lot of time.

**Linked Lists**

Another technique for allocating storage to a group of records is to use a linked list. With a linked list, each element of the list contains a way of finding the next entry. This is usually accomplished by inserting the address of the next element in each item of the list. There are several variations on the linked-list technique.

Linked lists can be either linear or circular. Examples of both types are shown in Figure 5.2. Both types of linked lists start at some known point called the list head. This is usually a memory location that contains the address of the first element in the list. The linear list terminates with some special value in the link portion of the record (usually zero). This value indicates that there are no more records in the list. The circular list is linked in a circle, with the last element pointing to either the first element in the list or the list head.

Linked lists are extremely flexible for inserting and deleting items. To insert an item, you modify two links: the link in the item before the item to be inserted and the link in the item to be inserted. To delete an item, you need to modify only the link that points to the item to be deleted. The cost of this flexibility is the additional processing time it requires to access a random element of a linked list. To access element $k$ in a linked list, you must access the previous $k - 1$ elements.

<table>
<thead>
<tr>
<th>Address</th>
<th>Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>100</td>
</tr>
<tr>
<td>n+1</td>
<td>103</td>
</tr>
<tr>
<td>n+2</td>
<td>105</td>
</tr>
<tr>
<td>n+3</td>
<td>107</td>
</tr>
</tbody>
</table>

*Figure 5.1 – An array of numbers*
One advantage of a circular list is that you can tell whether one of the links in the list is corrupt. If you cannot reach the list head within a reasonable number of tries, something is amiss. This reliability is purchased at the cost of extra processing time.

A second variation of a linked list is to use two pointers in each record of the list: one to the next record and one to the previous record. This technique is called a doubly-linked list. To insert or delete items from a linked list, you need to know the address of the previous element in the list. The advantage of having a pointer to the previous element is that it speeds insertion and deletion of random elements in the list.

Yet another variation of the linked-list technique is to maintain a pointer to the last element in the list. Such a pointer is known as a tail pointer. This is useful when elements are added to the end of a list. To facilitate removal from the end of a list, you would need to use a doubly-linked list with a tail pointer or, alternatively, a circular doubly-linked list.

It is poor programming practice to use a linked list on a disk or other form of external memory. The reason for this is that in order to add or delete items from a list, you need to modify two items in the list. If the

![Linear and circular linked lists](image)
machine crashes between these updates (and this does happen), the
linked-list structure is no longer consistent. This can lead to situations
where a disk block appears in two files or cannot be used at all. This was
a problem in many early versions of UNIX.

**DATA STRUCTURES**

There are several logical data structures that can be superimposed on
top of arrays or linked lists, such as stacks, queues, and trees. We will now
explore these structures in more detail.

**Stacks**

You are already familiar with the concept of a stack (the 68000 has a
stack implemented in hardware). A stack is a data structure in which the
last item added is the first item removed. This is also called a *Last In First
Out* (LIFO) arrangement.

Stacks can be implemented either as arrays or linked lists. Implementation
of a stack as an array requires a separate variable that defines the top
of the stack. The 68000 hardware stack pointer (register A7) is an example
of such a variable. Implementation of a stack as a linked list requires adding
and removing elements of the list only at the beginning of the list.

There are two types of error conditions that you will probably encounter
when using stacks:

1. You can run out of room for new stack entries. This condition is
   known as a stack *overflow*. This can happen, for example, when
   a program gets caught in an infinite loop that pushes items on
   the stack.

2. You can pop more entries off the stack than were pushed on the
   stack. This condition is known as a stack *underflow*.

**Queues**

A queue is a list of items in which the first item added is the first item
removed. This is also known as a *First In First Out* (FIFO) or a *First Come
First Served* (FCFS) arrangement. FIFO arrangements can be observed in
any environment where people wait in lines for service. The first person
to arrive is the first person served.
You can implement a queue either as an array or as a linked list. Efficient implementation as an array often uses a circular (or ring) buffer. This data structure consists of two pointers: an insertion pointer and a removal pointer.

Items are added using an insertion pointer and removed using a removal pointer. When the pointers are equal, the buffer is empty. If adding an element causes the pointers to become equal, the buffer is full. Notice that this means you can’t use one of the locations in the buffer (that is, if the pointers are equal, you can’t tell if the buffer is empty or full). You can eliminate this problem by keeping a count of the number of items in the buffer.

Figure 5.3 shows an example of a circular buffer. Items are added and removed from left to right. Whenever a pointer runs off the right end of the buffer, it is moved back to the left end. Thus, the pointers move in a circular fashion. The shaded areas represent unused elements in the buffer.

![Figure 5.3 - A circular buffer](image-url)
Implementing a queue with a linked list is best done using a tail pointer. This makes both insertion and deletion operations quite simple.

Several modifications to the basic queue technique are also useful in many applications. For example, a queue can be based on some order other than chronological. The most common example of this technique is the notion of a priority order list of jobs in a larger computer system. A linked list organized according to priorities is often used in an operating system to determine who gets what resources.

A special form of queue, called a double-ended queue or dequeue (pronounced “deck”), allows insertion and removal of elements at both ends. Altered forms of this technique provide for insertion at both ends but removal at only one, or removal at both ends and insertion at only one. These are called output-restricted and input-restricted dequeues, respectively.

**Trees**

A tree is a data structure in which each item can point to more than one item. A tree begins with a single element, called the root. The root points to other nodes, which in turn point to still other nodes, and so on. (An element in a tree is often called a node.) Figure 5.4 shows an example of a tree structure. The elements of the tree are shown as numbered boxes.

Borrowing terminology from genealogy, element 2 is termed a child of the root, as are elements 3 and 4. The root is said to be the parent of these elements. Elements that are children of the same node are termed siblings. Nodes 5 and 6 in Figure 5.4 are siblings. A node that has no children is called a leaf of the tree. Any given node and all its descendants make up a subtree. For example, nodes 2, 5, and 6 form a subtree of the root.

A tree is useful for describing something that can be defined in terms of itself. This is called recursion. For example, on the UNIX operating system, disk devices such as floppies have a directory of files on the disk. It is also possible for one of these files to be another directory. This directory can contain other directories, which can contain other directories, and so on.

A tree is an ideal way to represent this concept. There is a single directory, called the root directory, which corresponds to the root of the tree. Nodes in the tree are either directories or ordinary files. Ordinary files are always leaves of the tree, as are empty directories.

Modifying the definition of a tree so that each node has at most two children gives us a special kind of tree called a binary tree. The children of a binary tree are called the left and right descendants, and the distinction between the two is meaningful. A node with a single right descendant is
different from the same node with a single left descendant. Binary trees are used extensively in many areas of computer science. One of the best examples is an expression tree, which is found in many high-level language compilers and interpreters.

The handling of arithmetic expressions in assignment statements provides an excellent example of an expression tree. For example, the statement

\[ x = \frac{a + b}{2} \]

would cause the compiler to generate instructions to first add \( a \) and \( b \), divide this sum by \( 2 \), and then place the result in \( x \). A compiler would represent this expression in a tree as shown in Figure 5.5.

Note how the assignment for the equal sign operator (\( = \)) is treated as if it were an arithmetic operation. Since most arithmetic operations involve

\[ \text{Figure 5.4 - Example of a tree structure} \]
an operator and two operands, the binary tree is a convenient way of representing expressions.

In evaluating this expression, you evaluate the subtree on the left first, and then the subtree on the right. In order to evaluate the equal sign operator, you must first evaluate the division operator (/). To evaluate the division operator, you must evaluate the plus sign operator (+). This is called traversing the tree. Notice that traversing the binary tree produces the same evaluation order that you would use in evaluating the expression by hand.

ADVANCED PROGRAMMING CONCEPTS

There are three areas of programming that deserve more in-depth study:

1. **Sorting.** The process of taking randomly ordered data and arranging them in a specified order.

2. **Searching.** The process of retrieving a specified piece of information from a large set of data.

3. **Recursion.** The ability to define a particular function or set of functions in terms of itself.

**Sorting**

Sorting is the process of ordering a randomly ordered set of records. Sorting has received considerable attention in programming literature because it is so easy to do poorly. We will discuss some of the simple techniques used to sort records. Our discussion assumes that the data to be sorted are in memory rather than on disk.

**Insertion Sort**

An insertion sort is generally performed as data are being input to a program. To perform such a sort, take the items one at a time and put each item into a separate memory array in sorted order. When you have placed all the records in the array, you have sorted data. Due to the large number of insertions required, this technique is particularly suited to a linked-list structure in memory.

**Interchange Sort**

An interchange sort is usually performed on data that is arranged contiguously in memory. The simplest form of interchange sort involves taking
the top element and comparing it to each element in turn, exchanging where items are out of order. When all the elements have been compared, the top element is certain to be correct. Each element is then compared to all the elements below it. This type of sort requires $n - 1$ passes through the data, where $n$ is the number of records. This means that $n^2$ comparisons are required. The sort time rises dramatically as the number of records increases.

**Bubble Sort**

A more efficient type of sort is the bubble sort, which compares successive pairs of elements throughout an array and then swaps elements that

![Figure 5.5 - An expression tree](image-url)
are out of order. When a pass is made through the data without exchanging any items, the sort is complete. This method takes advantage of data that may already be in a partially correct order.

Listing 5.1 shows a simple bubble sort program that sorts an array of memory words at the label “list”. Lines 5 through 17 constitute a single pass through the data. Register D0.W is used as a flag to indicate whether any exchanges have taken place on the current pass. Lines 7 through 15 perform one pass on the data, with the comparison taking place at lines 7 through 9 and the exchange at lines 10 through 12.

**Searching**

Searching is the process of finding a particular record in a large collection. For large amounts of data or frequent searches, the search algorithm can be extremely important.

**Sequential Searches**

The simplest way to find an entry in a table is to start at the beginning of the table and look at each entry until you find the desired one. If you run

Listing 5.1 - Bubble sort routine

```assembly
1: ;
2: ; Sample bubble sort. Sorts words at "List". Uses
3: ; flag technique.
4: ;
5: Bubble LEA List,A0 ; A0 -> Data
6: LEA EndBuf,Al ; Al -> End of data
7: CLR.W D0 ; D0 is "changed" flag
8: BLoop MOVE.W (AO),D1 ; Load for compare
9: CMP.W 2(AO),D1 ; Need to
10: BLE NoSwap ; swap?
11: MOVE.W 2(AO),(AO) ; Yes,
12: MOVE.W D1,2(AO) ; do swap
13: MOVE.W #1,D0 ; Set flag
14: NoSwap ADDQ.L #2,A0 ; Bump AO to next word
15: CMP.L A1,A0 ; End of buffer yet?
16: BLO BLOOP ; No, continue
17: TST.W D0 ; Is flag set?
18: BNE Bubble ; Yes, another pass required
19: RTS ; If not, we're done
20: List DC.W 6,5,3,4,1,2,0 ; Unsorted data
21: EndBuf EQU *-2 ; Address of last item
```
off the end of the table, you know that the item you want is not in the table. The average number of comparisons using this technique is one-half the number of entries in the table (assuming that all the entries are accessed an equal number of times). Significant improvements in search times can be made if the data is not accessed in an evenly distributed manner. Simply placing the most commonly accessed data at the beginning of the table can make an amazing difference in performance.

The advantage of the sequential technique is that it does not require the data to be in any particular order. Most of the faster search techniques impose some ordering criteria on the data. A sequential search may well be the best method to use, especially if the effort to sort the data outweighs the effort expended in the search. The decision is based on the relative frequency of sorts to searches. For rapidly changing data that is searched infrequently, a sequential search is probably the best technique.

**Binary Search**

For data that are in sorted order, a binary search technique can be used to substantially reduce search time. A binary search works like this:

1. Given a table of $n$ elements in sorted order, establish two pointers to the first and last entries in the table.

2. Compute the element that is halfway between the two pointers. (We'll call this element $H$.) Compare this element to the desired element. If the elements are equal, you have found the desired data. If the element is less than the desired value, move the bottom pointer to element $H$. If element $H$ is greater than the desired element, move the top pointer. Reverse these conditions if the table is in descending order instead of ascending order.

3. If the two pointers are equal or adjacent, the item is not in the table. Otherwise, repeat step 2.

Figure 5.6 shows a sample search sequence. $T$ is the top pointer, $B$ is the bottom pointer, and $H$ is the halfway pointer. In this example, the desired entry is found in three tries, as opposed to five for a sequential search. The desired entry is 135.

The size of the table being considered is reduced by a factor of two for each iteration of the search. For large tables, this is a substantial savings over sequential-search techniques. This is true only if the effort to maintain a sorted table is less than the effort saved by the binary search technique. Effort is measured in terms of program execution time and
programming time. The number of times a program is used determines the wisdom of spending a lot of time putting in features that save execution time.

Hashing

Another technique for reducing search times is called hashing. Hashing imposes a different kind of structure on the table to be searched. A transformation called a hash function is performed on the data to be looked up in the table. The hash function yields a number indicating a position in the table. This number is called a hash code. Entries are placed in the table at the locations dictated by their hash codes. A simple way to generate a hash code for alphanumeric (string) data is to add each of the characters in the string and take the resulting sum as the hash code.

When two or more different table entries have the same hash code, a situation known as a hash collision results. The number of hash collisions is an indication of the quality of the hash function. A good hash function will produce few collisions. A hash collision is usually detected when you need to add an entry to the table and you find that an old entry has the same hash code as the new entry. One solution to this problem is to place the new entry in the next free slot in the table. Then do a sequential search starting at the position indicated by the hash code.

Another technique for dealing with hash collisions is to use a large number of linked-list heads. The hash code determines the list in which a given element belongs. Then the lists are searched sequentially. If the hash

![Figure 5.6 - Example of a binary search](image-url)
function yields a reasonably even distribution of elements across the lists, the savings over a sequential search is the number of list heads divided by two. Thus if you used 50 list heads, you would expect to see an improvement of 25 to 1 over a sequential search.

Recursion

Recursion is the ability to define a function in terms of itself. For example, the factorial function can be defined recursively. A factorial multiplies a number by all the integers less than the desired number. Thus, five factorial (written $5!$) is $5 \times 4 \times 3 \times 2 \times 1$, or 120. Zero factorial is defined to be 1. The factorial function for a number $n$ can be defined recursively:

1. If $n$ is 0 or 1, $n$ factorial is 1.
2. Otherwise, $n$ factorial is $n$ times $n - 1$ factorial.

Listing 5.2 shows a factorial routine that uses this definition to compute factorials.

Lines 8 through 11 handle the case where $n$ is 0 or 1. Lines 12 through 16 handle the case where $n$ is greater than 1. The fact function is called

```assembly
1: ;               Recursive factorial routine
2: ;               " "
3: ;               " "
4: ;               Enter with number in DO.W
5: ;               Exit with answer in DO.W
6: ;
7: XDEF Fact       ; Make linkable
8: Fact CMP.W #1,DO ; Easy?
9: BGT DoFact      ; No, do recursion
10: MOVE.W #1,DO   ; 0! or 1! is 1
11: RTS            ; Done
12: DoFact MOVE.W DO,-(SP) ; Save present value
13: SUB.W #1,DO    ; Decrement
14: BSR Fact      ; Take (n-1)!
15: MULS (SP)+,DO  ; n! = n * (n-1)!
16: RTS            ; Done
```

**Listing 5.2** - Recursive factorial routine
with \( n - 1 \) as the parameter. Note that when \( n \) reaches 1, the recursion will stop.

In general, recursive routines cannot modify registers or static variables without saving and restoring them on the stack. Languages such as C and Pascal, which support recursion, put all variables local to a procedure on the stack. You can do the same in assembly language using the LINK and UNLK instructions to allocate the stack space and the address-register-indirect-with-displacement addressing mode to access the data.

**ADVANCED ASSEMBLY LANGUAGE CONCEPTS**

There are three additional techniques that are commonly employed in writing large programs:

1. Macros
2. Conditional assembly
3. Interfacing assembly and high-level languages

We will now explore these techniques in the Macintosh environment.

**Macros**

A *macro* is a programming shorthand technique. Macros consist of a set of assembly language source statements. These statements can be placed in a program by coding a single line. This technique reduces the size of a source program, although the amount of memory the program takes will often be greater when using macros.

Using a macro in a program requires two operations. First, the assembler must be told which instructions are to be placed in the program when a macro instruction is coded. The method by which a new macro is introduced into a program is called a *macro definition*. Later, when you want to use the macro, you code a *macro call*.

Macros on the Macintosh are identified by a string called the *macro name*. You must specify the macro name when you define the macro. Then you can issue a macro call by coding the macro name in the instruction part of a source line.

As part of the macro definition, you can specify parts of the macro that will be replaced by strings specified on the macro call. These strings are called *macro parameters* or *macro operands*. They are similar in nature to operands used with instructions.
Macintosh Macro Definitions

The Macintosh assembler supports two types of macros. These are called Macintosh-style and Lisa-style macros. The names stem from the history of developing Macintosh applications. When the Macintosh first came out, you had to use a Lisa computer (now called a Macintosh XL) to write Macintosh programs. The development software was an addition to the Lisa Pascal compiler package. This package was called the Lisa Pascal Workshop, and it included an assembler. Macros accepted by this assembler are the Lisa-style macros. The Macintosh-style macros are unique to the Macintosh assembler.

A Lisa-style macro is defined with a .MACRO directive. This directive takes a single operand, the macro name. Following the .MACRO directive, you code the instructions you want placed in the program when the macro is called. These instructions form the macro body. You signal the end of a macro definition with a .ENDM directive. The strings %1 through %9 indicate that a macro parameter is to be substituted in the macro body. %1 corresponds to the first parameter, %2 to the second, and so on.

For example, consider a macro that exchanges the contents of two words in memory. The macro will be named EXGM and will have two operands that are the locations to be exchanged. The macro can be written as follows:

```
.MACRO EXGM
  MOVE.W %1, -(SP) ; Save first operand
  MOVE.W %2,%1 ; Replace first with second
  MOVE.W (SP)+,%2 ; Replace second with first
.ENDM
```

The macro call

```
EXGM A(A5),4(A0)
```

would generate

```
MOVE.W A(A5), -(SP)
MOVE.W 4(A0),A(A5)
MOVE.W (SP)+,4(A0)
```

Note that use of pre-decrement or post-increment addressing modes will cause an error. Since each operand is referenced twice in the macro body, any increment or decrement would be performed twice.

A Macintosh-style macro is defined somewhat differently. The macro begins with a MACRO directive (note the missing "."). The MACRO keyword is followed by the macro name, a list of parameter names, and an
equal sign (=). The end of the macro is denoted by a vertical bar (|). Within the body of the macro, the parameter names from the MACRO directive are enclosed in braces ({}). For example, the EXGM macro above can be written as a Macintosh macro in the following way:

```
MACRO         EXGM src,dest =
  MOVE.W      {src},-(SP) ; Save first operand
  MOVE.W      {dest},{src} ; Replace first with second
  MOVE.W      (SP)+,{ dest} ; Replace second with first
|               
```

None of the parameters in a Macintosh-style macro can be omitted. It is possible to invoke a Lisa-style macro with fewer parameters than the macro requires, but the assembler gives you an error if you attempt this with a Macintosh-style macro.

A Macintosh-style macro can occupy only part of a line; Lisa-style macros cannot. For instance, the macro

```
MACRO         ONA5 label = {label}(A5)
```

can be used in an operand field like this:

```
MOVE.W      ONA5 ABC,A0
```

This will generate the instruction

```
MOVE.W      ABC(A5),A0
```

A second feature found in Macintosh-style macros, but not Lisa-style macros, is the use of only part of a parameter. The notation

```
{arg|n:m}
```

denotes using \( m \) characters of the macro parameter \( arg \), starting with character number \( n \). Characters are numbered from zero. For instance, to take only the first three characters of the parameter “blivot”, you would use the notation

```
{blivot|0:3}
```

### Conditional Assembly

Very large assembly language programs usually require tailoring for specific configurations. Most of this customization involves limited changes to parts of the program. A technique called **conditional assembly** allows you
to select one of two sections of code depending on the value of an expression. This allows you to maintain one version of the program source, which can be configured at assembly time to yield many different custom versions of the program. This process is used rather extensively in the RTL code described in Chapter 8.

The Macintosh assembler IF, ELSE, and ENDIF directives perform conditional assembly. These directives are used as follows:

```
IF  condition
    (lines assembled if condition is true)
ELSE
    (lines assembled if condition is false)
ENDIF
```

The ELSE part of the conditional assembly is optional. The `condition` tests the relationship of two expressions. The expressions can be either numeric or strings.

**Numeric Conditionals**

A numeric condition requires that both expressions be constants or the difference between two labels. A special form of the numeric condition checks to see if a single expression is equal to zero. The statement

```
IF  expression
```

is true if the expression is nonzero and false otherwise. This feature can be used to conditionally assemble code for a feature as follows:

```
FEATURE EQU 0 ; to disable; 1 to enable
.
.
.
IF  FEATURE ; Conditional code for feature
.
. (Code if feature is enabled)
.
ELSE ; Optional else part
.
. (Code if feature is disabled)
.
ENDIF
```

Normal numeric conditionals compare the value of two expressions.
The syntax is

```
IF expr1 comp expr2
```

where `expr1` and `expr2` are two expressions. `Comp` is a comparison operator, which determines how the expressions are to be compared, as shown in the following list:

<table>
<thead>
<tr>
<th>Comparison Operator</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>=</td>
<td>True if <code>expr1</code> is equal to <code>expr2</code></td>
</tr>
<tr>
<td>&lt;&gt;</td>
<td>True if <code>expr1</code> is not equal to <code>expr2</code></td>
</tr>
<tr>
<td>&lt;</td>
<td>True if <code>expr1</code> is less than <code>expr2</code></td>
</tr>
<tr>
<td>&lt;=</td>
<td>True if <code>expr1</code> is less than or equal to <code>expr2</code></td>
</tr>
<tr>
<td>&gt;</td>
<td>True if <code>expr1</code> is greater than <code>expr2</code></td>
</tr>
<tr>
<td>&gt;=</td>
<td>True if <code>expr1</code> is greater than or equal to <code>expr2</code></td>
</tr>
</tbody>
</table>

**String Conditionals**

String conditionals are more limited than numeric conditionals. A string conditional can compare only two strings for equality or inequality using the "=" and "<>" comparison operators.

String conditionals are extremely useful in defining macros. You can use a string conditional to test whether a parameter is present on a Lisa-style macro as follows:

```
.MACRO CTEST
IF '%%1' <> "" ; Parameter 1 is present
MOVE %1,D1 ; Place it in D1
ELSE
    %1,D1 ; Parameter 1 not present
CLR.W D1 ; Use zero
.ENDIF
.ENDM
```

This macro places the first parameter, if present, in D1.W. If the macro was invoked with no parameters, a zero is placed in D1.W.

Conditionals inside macros can also be used to avoid redundant instructions. Often a macro parameter is placed in a register using a MOVE instruction. If the macro is called with the correct register name as the parameter, you can avoid generating the MOVE instruction. For example,
if the first parameter is to be placed in D1.W, you can use the following code:

```assembly
MACRO CTEST1 d1parm =
  IF '{d1parm}' <> 'D1' ; Already in D1?
    MOVE.W {d1parm},D1 ; No, move it there
  ENDIF ; Parameter now in D1.W
.
.
.
```

You can combine the above examples to produce a macro that will load a default value and avoid redundant MOVE instructions by placing one conditional inside the other. This is left as an exercise.

**Interfacing to High-Level Languages**

One of the most common uses for assembly language is to add functionality or speed to a program written in a high-level language. Because this is such a common technique, there are very few high-level language compilers that do not allow it. You can take advantage of this capability in your assembly language programs by calling language run-time support routines. These routines typically include I/O support, conversion, and other useful capabilities. It is often possible to call these routines directly from assembly language.

The technique for interfacing assembly language to a high-level language is different for each compiler. Some compilers insist on having a main program written in a high-level language. Others allow a main program to be in assembly language, but require certain initialization procedures in the main program. Still others have no such restrictions. The proper techniques are usually documented (although not always well) in one of the manuals associated with the high-level language you are using. In interfacing to a high-level language, you need to answer the following questions:

1. Does the language require a high-level main program? Certain languages, such as Microsoft BASIC, do.

2. If the language allows the main program to be in assembly language, does the main program have to do anything to make the run-time library work?
3. How does one call a high-level procedure from assembly language? Is the sequence any different for calling the run-time modules directly?

4. What registers are preserved by the run-time modules and the routines written in the high-level language? What registers are destroyed? What registers must be preserved by an assembly language subroutine?

5. Do you have to do anything special to exit to the operating system? Many languages automatically close all open files upon exiting. If you are coding a main program in assembly language, you may have to code a call to the language exit or stop routine.

6. What techniques are available for accessing global data areas from assembly language? Do you have to pass all data as parameters to the assembly language procedure?

We will now explore mixing assembly language with the following Macintosh high-level languages:

- Microsoft BASIC Version 2.0
- Consulair C Version 1.0
- Lisa Pascal Version 3.9

**Sieve of Eratosthenes Program**

We will write the same program in each of these languages: a program called the *Sieve of Eratosthenes*. This program computes a set of integers called *prime numbers*. A prime number has no factors other than itself and one. The first five prime numbers are 1, 2, 3, 5, and 7. Note that even numbers (other than 2) can never be prime, since they are by definition divisible by 2.

The sieve program uses a large array of flag variables representing the odd integers starting at 3. The first element of the array must be a prime number. The algorithm works by removing multiples of the prime numbers, starting with the first element. After all the multiples are removed, the numbers remaining are prime.

This program is used extensively in benchmarking compiler products, as it reflects compiler efficiency in looping, array manipulation, and simple arithmetic. By placing parts of the program in assembly language, you can save a substantial amount of execution time.
Listing 5.3 contains the sieve program written in Microsoft BASIC. This version of the program measures the time required to find the first 1899 primes. An array of integers called “flags” represents the odd integers from 3 to 16385. Each member of the array contains a 1 if the corresponding integer is a prime number, and a 0 otherwise.

Line 3 reads the TIMER variable, which contains the time since the system was booted, in seconds.

Lines 4 and 20 cause the entire program to be repeated 10 times. This ensures that the execution time is large with respect to the timer interval, minimizing errors due to timer granularity. Microsoft BASIC reports time in units of whole seconds. The maximum error in measuring an interval is one second. You should therefore measure intervals of over 100 seconds. This makes the timer error less than one percent.

Line 5 initializes a counter variable to zero. This variable will be incremented each time a prime number is found.

Lines 6–8 set all members of the flag array to 1 to indicate prime. The program finds prime numbers by eliminating multiples of primes. The first element of the array must be a prime number, and the program initially assumes that all the numbers are prime.

```
1: DEFINT A-Z
2: DIM flags(8191)
3: A# = TIMER
4: FOR j = 1 TO 10
5:   count = 0
6: FOR i = 1 TO 8191
7:   flags(i) = 1
8: NEXT i
9: FOR i = 1 TO 8191
10: IF flags(i) = 0 THEN GOTO NotPrime
11:   prime = i + i + 1
12:   k = i + prime
13: WHILE k <= 8191
14:   flags(k) = 0
15:   k = k + prime
16: WEND
17: count = count + 1
18: NotPrime:
19: NEXT i
20: NEXT j
21: B# = TIMER
22: PRINT count:" Primes. Time = ";B#-A#
```

Listing 5.3 – Sieve of Eratosthenes in Microsoft BASIC
Lines 9–19 form a loop that eliminates multiples of prime numbers. If the number under consideration is not prime (its flag variable is zero), the IF statement at line 10 skips the elimination process. Line 11 calculates the prime number corresponding to the array index i. The first such number (for i = 1) is 1 + 1 + 1, or 3. Line 12 calculates the array index that corresponds to the first multiple of the prime number. Note that since only the odd numbers are represented by the array, this is the first odd multiple of the prime number. Lines 13–16 eliminate the multiples from the flag array. Line 17 increments the count of prime numbers found.

Line 21 reads the TIMER variable at the end of the process. Line 22 prints the number of prime numbers found and the time required.

Two areas of this program consume a lot of time. The first is the loop that sets all the flag variables to 1 (lines 6–8). The second is the elimination loop (lines 9–19). The examples that follow illustrate how to replace these sections of code with assembly language. You can save a considerable amount of time by doing this, as shown in the following table:

<table>
<thead>
<tr>
<th>Language</th>
<th>Unoptimized</th>
<th>Optimized</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>BASIC</td>
<td>308.7</td>
<td>0.259</td>
<td>1191.9:1</td>
</tr>
<tr>
<td>C</td>
<td>0.741</td>
<td>0.241</td>
<td>3.1:1</td>
</tr>
<tr>
<td>Pascal</td>
<td>0.643</td>
<td>0.242</td>
<td>2.7:1</td>
</tr>
</tbody>
</table>

All times are in seconds per iteration. Some of the programs required a large number of iterations to obtain accurate timings.

BASIC fares poorly in this comparison because it is an interpreted rather than a compiled language. A language interpreter is a program that operates on the program source. This means that each statement in the program is retranslated each time it is executed. A compiler, on the other hand, translates the program into machine instructions. This is several hundred times faster, as shown by the timings above.

The exact savings you can achieve by recoding part of a program depends on the algorithm, the language, and the compiler being used. The sieve program is a rigorous test of a compiler. Recoding parts of a more ordinary program might not yield quite the savings indicated above. A ratio of 2:1 might be a bit more realistic.

**Microsoft BASIC Version 2.0**

Microsoft BASIC programs can call assembly language subroutines with the CALL statement. The subroutine must reside in a special disk file known as a machine language library. There is no provision for an assembly language routine to call a part of the BASIC program. You can,
however, call some of the BASIC run-time support routines from assembly language.

The BASIC program that calls an assembly language routine must have a LIBRARY statement which identifies the library file. The format of this statement is

```
LIBRARY    filename
```

where \textit{filename} is the name of the library file. This statement must execute before any calls to subroutines in the library. You can have up to five libraries open at any given time. The LIBRARY CLOSE statement allows you to free up the memory associated with a library.

You invoke the routine from BASIC using a CALL statement. For instance, to call a routine named \textit{STUFF} with two integer parameters, you can write

```
CALL STUFF(A%,B%)
```

or

```
STUFF A%,B%
```

The CALL reserved word is assumed in the second form. Due to an anomaly in BASIC, the syntax

```
STUFF(A%,B%)
```

(using parentheses without the CALL reserved word) is not legal.

BASIC treats the routine names as variables. These variables contain the address of the routine in memory. An integer variable is not large enough to store this information. If your program contains a DEFINT statement, which would cause the routine name to be classified as an integer, you must use either the "!" (single-precision floating point) or "+" (double-precision floating point) characters after the name in the CALL statement. For example, the call to routine \textit{STUFF} in the above example would take the following form:

```
DEFINT A–Z
CALL STUFF#(A,B)
```

or

```
STUFF# A,B
```

Note that the two integer parameters no longer need the "\%" character at the end, because of the DEFINT statement.
Several conventions apply to the use of registers in the subroutine. Upon entry to each subroutine, A4 contains the address of a longword that is unique to the entire library. If the routines in the library need a global data area, you must allocate it with a dynamic memory call (described in Chapter 6), and store the handle in the longword whose address is in A4. Before returning to BASIC, set D0 to a nonzero value if the routine will be called again, and zero otherwise. A return value of zero allows BASIC to reclaim the memory for the routine if needed. Only registers A5 and A7 need be preserved by the subroutine.

The library must have a routine named LIBinit, which BASIC calls while processing the LIBRARY statement. This routine receives the address of a version number record in A0 on entry. The format of a version number record is shown in Figure 5.7.

The first two fields of this record are the BASIC version number. Version numbers are written as a number with a decimal fraction. For instance, Microsoft BASIC version 2.00 has a version number of 2 and a revision number of 0. The first word of the version number record would contain 2 in this case, and the second word would contain 0.

Offset 4 in the version number record indicates the math package in use. A value of 0 in this word indicates decimal (BCD) arithmetic, and a value of 1 indicates the IEEE format mentioned in Chapter 2.

Offset 6 is set by the LIBinit routine to indicate compatibility with the version of BASIC in use. Set this field to -1 if the library is incompatible.

<table>
<thead>
<tr>
<th>Offset</th>
<th>Contents</th>
<th>Label</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>BASIC Version Number</td>
<td>BasicVersion</td>
</tr>
<tr>
<td>2</td>
<td>BASIC Revision Number</td>
<td>BasicRevision</td>
</tr>
<tr>
<td>4</td>
<td>BASIC Math Pack Number</td>
<td>Math</td>
</tr>
<tr>
<td>6</td>
<td>Library Return Value</td>
<td>Result</td>
</tr>
<tr>
<td>10</td>
<td>Reserved (8 bytes)</td>
<td>Reserved</td>
</tr>
</tbody>
</table>

Figure 5.7 – BASIC version record
with BASIC, and 0 otherwise. BASIC will terminate the program with an Illegal Function Call error if the library indicates incompatibility.

Offsets 10–17 are reserved for future expansion, and are set to zero by BASIC version 2.00.

BASIC library routines receive parameters by calling routines supplied by BASIC. There are five such routines that are generally useful:

<table>
<thead>
<tr>
<th>Routine Name</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>GetNextLibArg</td>
<td>Returns address and type of next parameter</td>
</tr>
<tr>
<td>IntegerArg</td>
<td>Converts parameter to 16-bit integer</td>
</tr>
<tr>
<td>LongArg</td>
<td>Converts parameter to 32-bit integer</td>
</tr>
<tr>
<td>BasicErr</td>
<td>Reports error in library routine</td>
</tr>
<tr>
<td>CheckBreak</td>
<td>Checks to see if user aborted program</td>
</tr>
</tbody>
</table>

You must call the GetNextLibArg routine for each parameter. This code returns the parameter type in D0 and the parameter address in A2. The following table lists the parameter types:

<table>
<thead>
<tr>
<th>Value</th>
<th>Data Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>End of parameter list</td>
</tr>
<tr>
<td>1</td>
<td>Null (omitted) parameter</td>
</tr>
<tr>
<td>2</td>
<td>String variable</td>
</tr>
<tr>
<td>3</td>
<td>Integer (16-bit) variable</td>
</tr>
<tr>
<td>4</td>
<td>Single-precision floating point number</td>
</tr>
<tr>
<td>5</td>
<td>Double-precision floating point number</td>
</tr>
</tbody>
</table>

In this book, we will use only integer variables. Documentation on the other variable types is available from Microsoft in a document entitled Microsoft BASIC for the Macintosh—Building Machine Language Libraries.

The IntegerArg and LongArg routines convert a parameter to a 16- or 32-bit integer, respectively. The converted value comes back in register D3. Normally, you call GetNextLibArg and then IntegerArg or LongArg immediately.

The BasicErr routine reports an error to the user. Error codes are listed in the back of the Microsoft BASIC manual. Place the error code desired in D2.W. This routine does not return. Instead, program execution terminates with the error, and BASIC reverts to immediate mode.

The CheckBreak routine allows you to test whether the user typed Command-Period. This routine is similar to the CHKABORT macro discussed in Chapter 4. There are no parameters. The Z bit in the condition
code register is cleared if the user tried to abort the program. The usual calling sequence for this routine is as follows:

```
JSR CheckBreak(A5) ; See if abort desired
BEQ @1 ; EQ = > Z set; no abort
        (Code for abort)
@1:
        ; Here if no abort
```

Note that BASIC checks for abort quite frequently, so you need call this routine only if your assembly language routine takes a lot of time to complete.

Listing 5.4 shows the BASIC program modified to call the two assembly language routines. Note that the number of iterations had to be increased, because the BASIC TIMER variable reports time only in whole seconds.

There are two assembly language routines: one called SetFlags, which initializes the flags array, and one called Sieve, which performs the actual algorithm. SetFlags has two parameters: the first element of the flags array and the number of elements. Sieve has an additional parameter, the count variable. Sieve returns the number of primes found in this variable.

The equates necessary for the machine language routines appear in Listing 5.5. This listing contains only the definitions for the routines defined above (lines 7–11) and for the version number record (lines 15–18).

Listing 5.6 contains the LIBinit routine for the optimized sieve program. This code assumes compatibility with BASIC versions 2.00 and higher. Line 5 clears the result field, and lines 6–7 check the version number. Line 8 handles the case where the version number is less than 2.00. Line 9 clears DO.L to indicate that the LIBinit routine can be purged from memory.

Listing 5.7 contains the SetFlags routine for use with BASIC. SetFlags has

```
1: DEFINT A-Z
2: DIM flags(8191)
3: A# = TIMER
4: LIBRARY "BSieve.RSRC"
5: count = 0
6: FOR j = 1 TO 1000
7:   SetFlags# flags(1),8191
8:   Sieve# flags(1),8191,count
9:   NEXT j
10: B# = TIMER
11: PRINT count;' Primes. Time = ";B#-A#
```

Listing 5.4 – The optimized BASIC sieve program
two parameters. The first parameter is the first element of the flags array. Line 5 fetches the address of this parameter. Lines 6–7 check the parameter type. Note that BASIC does not provide any indication that the parameter is an array element. This makes it impossible to check types completely. Lines 9–10 fetch the value of the second parameter, which is the number of elements in the array. Line 11 places the address of the

```
1: ;                         BASIC.D. Include file for use with BASIC libraries.
2: ;                         Routines available to the machine language code via JSR with
3: ;                         offset from A5:
4: ;                         GetNextLibArg EQU $2A ; Fetch next parameter
5: ;                         IntegerArg EQU $32 ; Convert parameter to integer value
6: ;                         LongArg EQU $3A ; Convert parameter to long (32 bit)
7: ;                         BasicError EQU $42 ; BASIC error routine
8: ;                         CheckBreak EQU $A2 ; Check for "stop" by user
9: ;                         Version number record offsets:
10: ;                        BasicVersion EQU $0 ; BASIC version number
11: ;                        BasicRevision EQU $2 ; BASIC revision number
12: ;                        BasicMath EQU $4 ; Math pack (0=>BCD; l=>IEEE)
13: ;                        BasicResult EQU $6 ; Result (0=>ok; l=>incompatible)
```

Listing 5.5 - BASIC equate file

```
1: ;                         LIBinit routine for sieve program
2: ;                         INCLUDE BASIC.D ; Define BASIC offsets
3: ;                         CLR.W BasicResult(AO) ; Assume compatible
4: ;                         CMP.W $2,BasicVersion(AO); See if version 2 or higher
5: ;                         BGE @1 ; It's OK
6: ;                         MOVE.W #-1,BasicResult(AO); Indicate no good
7: ;                         @1: CLR.L DO ; Indicate OK to purge LIBinit
8: ;                         RTS ; Done
```

Listing 5.6 - LIBinit routine
array into register A0. Lines 11–14 set all bytes in the array to 1. Since the array is an array of integers, only half the space is used. Line 15 sets D0 to –1, indicating that the routine is not to be purged, since it will be called ten times. Lines 18–20 illustrate how to call the BasicErr routine.

The actual prime number (sieve) algorithm appears in Listing 5.8. This code uses an array of bytes, rather than an array of words, to simplify the calculations. Since the BASIC program does not reference any values in the flags array, we use only the first half of the storage.

Lines 5–11 place the array address in register A0 and the number of elements in D1. The integer variables in Listing 5.3 are placed in data registers as follows:

<table>
<thead>
<tr>
<th>BASIC Variable</th>
<th>Data Register</th>
</tr>
</thead>
<tbody>
<tr>
<td>count</td>
<td>D2.W</td>
</tr>
<tr>
<td>i</td>
<td>D3.W</td>
</tr>
<tr>
<td>prime</td>
<td>D5.W</td>
</tr>
<tr>
<td>k</td>
<td>D6.W</td>
</tr>
</tbody>
</table>

D4.W contains the array size for comparison purposes. D1 is used as a

---

**Listing 5.7 - Assembly language SetFlags routine for Microsoft BASIC**

```
1: ;
2: ;  SetFlags routine for optimized BASIC sieve program
3: ;
4:  INCLUDE BASIC.D ; Include BASIC defs.
5:  SetFlags JSR GetNextLibArg(A5); Fetch next parameter
6:  CMP.W #$3,DO ; Integer variable?
7:  BNE @2 ; No, bail out
8:  MOVE.L A2,-(SP) ; Save address on stack
9:  JSR GetNextLibArg(A5); Fetch next parameter
10: JSR IntegerArg(A5); Convert parameter
11: MOVE.L (SP)+,A0 ; A0 -> Array
12: SUB.W #1,D3 ; DBRA-Adjust count
13: @1: MOVE.B #1,(A0)+ ; Set flag byte
14: DBRA D3,@1 ; Loop till done
15: MOVE.W #-1,DO ; Not purgeable
16: RTS ; Return
17: @2: ; Here if parameter mismatch
18: MOVE.W #5,D2 ; "Illegal Function Call"
19: JSR BasicError(A5); Bail out
20: RTS ; Quit
```
Listing 5.8 - Assembly language Sieve routine for Microsoft BASIC
loop counter, allowing the use of a DBRA loop. The reason for placing all the variables in registers instead of in memory is that register operations are smaller and take less time than memory operations on the 68000. Optimizing code on the 68000 generally involves minimizing the number of times the processor must access memory. Shortening the time required by the instructions executed with the highest frequency produces the biggest time savings. The WHILE loop in the sieve algorithm (lines 13–16 of Listing 5.4) contains the most frequently executed instructions. This is the most important section of code to optimize. The loop for elimination of multiples is the second most important section.

BASIC has some important restrictions on generating the library file:

1. Each routine must be assembled separately.
2. Routines cannot have data defined with DS directives.
3. You must use the linker and a program called RMAKER to place each routine in the segment whose name matches the name used in the BASIC program.
4. The starting address is the first location in each routine.

Listing 5.9 contains the linker command file for the BASIC sieve library. The /Output directive causes the linker to place the load module in a file named Bsieve. The "<" characters between the file names cause each routine to be placed in a different segment. A Macintosh segment is a part of a program that can be loaded into memory as a separate entity.

Following the link step, you must run a program called RMAKER to produce the library file. RMAKER is described in detail in Chapter 6. The RMAKER input file for the BASIC sieve library appears in Listing 5.10.

```
1: /Output Bsieve
2: LIBinit.Rel
3: <
4: Bsieve.Rel
5: <
6: BSetFlags.Rel
7: $
```

Listing 5.9 – BASIC sieve linker command file
The first two lines of this file specify the output file (BSieve.RSRC) and the file type (BLIB). Lines 3–6 specify a code resource named LIBinit, which is the first segment in the linker output file. Lines 8–11 cause the next segment to be named Sieve, and lines 13–16 name the last segment SetFlags. The segment order in the RMAKER file must match the order in the linker file. The segments must be numbered consecutively from 1.

Consulair C

The sieve program in C is shown in Listing 5.11. This program is a literal translation of the BASIC version in Listing 5.3. C differs from BASIC in that array elements are numbered from zero instead of from one. This changes the dimension of the flags array, as well as the limits on the for loops.

The timing technique is also different. Location 16A (hex) in memory contains a longword that is incremented every 1/60th of a second. Lines 13–14 and 37 fetch the value of this word before and after the loop. The call to the printf routine in lines 38–40 outputs the difference in the two. The ticks are converted to seconds by a rather complicated formula in lines 39–40. Line 39 calculates the number of whole seconds, and line 40 calculates fractional seconds.

Consulair C is perhaps the easiest language to interface to MDS assembly language. You can call assembly language routines from C or C routines from assembly language. Since the C language uses subroutine calls for I/O, you can call any of the C library routines as well.

Listing 5.10 – BASIC sieve RMAKER input file
Sieve Program for Consulair C

#define ITER 10
#define SIZE 8190
#define TIMELOC 0x16A

main()
{
short i,j,k,count,prime;
char flags[SIZE+1];
long *timeptr,start,end;

timeptr = TIMELOC;
start = *timeptr;
for(j=0;j<ITER;j++)
{
    count = 0;
    for(i=0;i<SIZE;i++)
    {
        flags[i] = 1;
    }
    for(i=0;i<=SIZE;i++)
    {
        if(flags[i])
        {
            prime = i + i + 3;
            k = i + prime;
            while(k<=SIZE)
            {
                flags[k] = 0;
                k += prime;
            }
            count++;
        }
    }
}
end = *timeptr;
printf("%ld.%02ld Seconds ",
(end-start)/60L,
(((end-start)%60L)*100L)/60L);
printf("%d Primes found\n",count);
}

Listing 5.11 - Consulair C sieve program
Version 1.0 of Consulair C has five data types:

<table>
<thead>
<tr>
<th>C Data Type</th>
<th>Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>char</td>
<td>8 bits</td>
</tr>
<tr>
<td>short</td>
<td>16 bits</td>
</tr>
<tr>
<td>int</td>
<td>32 bits</td>
</tr>
<tr>
<td>long</td>
<td>32 bits</td>
</tr>
<tr>
<td>pointer</td>
<td>32 bits</td>
</tr>
</tbody>
</table>

Later versions of this compiler should also support floating point.

The first seven parameters to a subroutine are passed in registers D0-D6. Subsequent parameters are pushed on the stack in reverse order. Parameters less than 32 bits are extended to 32 bits before calling the subroutine.

For instance, consider the following section of C code:

```c
int i1, i2, i3, i4, i5, i6, i9;
char c5, c6, c7, c8;
xyzzy(i1, i2, i3, i4, i5, c7, c8, i9);
```

This generates the following assembly language code:

```
MOVE.L  i9, -(SP) ; Push last parameter
MOVE.B  c8, D0  ; Push
EXT.W   D0      ;     parameter
EXT.L   D0      ;     number
MOVE.L  D0, -(SP) ;
MOVE.B  c7, D6  ; Parameter 7
EXT.W   D6      ;     goes in
EXT.L   D6      ;     D6
MOVE.L  i6, D5  ; Parameter 6 to D5
MOVE.L  i5, D4  ; Parameter 5 to D4
MOVE.L  i4, D3  ; Parameter 4 to D3
MOVE.L  i3, D2  ; Parameter 3 to D2
MOVE.L  i2, D1  ; Parameter 2 to D1
MOVE.L  i1, D0  ; Parameter 1 to D0
JSR     xyzzy   ; Call subroutine
ADD.L   #8, SP  ; Pop two stack parameters
```

Values returned by a C function appear in either D0 or A0. D0 is the return register for all char, short, int, or long data. A0 is used for pointers of any kind. The subroutine can modify the contents of all registers except A5-A7. Note that the calling routine removes the parameters from the stack following the JSR instruction.
The advantage of the Consulair scheme is that most subroutines have seven or fewer parameters. This means that most subroutines can receive parameters in registers, rather than on the stack. Assembly language routines can use the parameters in the registers directly.

Listing 5.12 contains the C portion of the optimized sieve program. The assembly language code is split into the same two functions as in the BASIC version of the sieve. The number of primes is returned as the result of the function rather than as a separate parameter, however.

Listing 5.13 shows the assembly language routine for the optimized C sieve program. This is the same code as in Listings 5.7 and 5.8, except that the parameters are now passed in registers. This makes the code considerably less complex.

Lisa Pascal

The original development system for Macintosh software is something that ran on the Lisa (Macintosh XL) computer. This system is called the Lisa Pascal Workshop. It was originally marketed for writing applications for

---

```
/*
 * Sieve Program for Consulair C
 */
#define ITER 10
#define SIZE 8190
#define TIMELOC 0xl6A

main()
{
    int j, count;
    char flags[SIZE+1];
    long *timeptr, start, end;
    timeptr = TIMELOC;
    start = *timeptr;
    for(j=0; j<ITER; j++)
    {
        setflags(flags,SIZE);
        count = sieve(flags,SIZE);
    }
    end = *timeptr;
    printf("%ld.%02ld Seconds ",
           (end-start)/60L,
           (((end-start)%60L)*100L)/60L);
    printf("%d Primes found\n",count);
}
```

---

Listing 5.12 – Optimized C sieve program
the Lisa Office System, the predecessor to Macintosh. The subroutine calling sequence for this compiler is also used by many of the Macintosh Toolbox routines.

Listing 5.14 contains the Pascal version of the sieve program. Lines 1–4 specify compiler options for generating Macintosh code. Lines 11–15 and 26–33 initialize the Macintosh Toolbox. The other languages perform this initialization automatically. Listing 8.2 (in Chapter 8) contains the assembly language equivalent to this code. This program also uses zero-relative array subscripts.

```
1: . ; Assembler part of optimized C sieve program
2: . ;
3: . ;
4: XDEF setflags ; Set all flag bytes
5: setflags MOVE.L D0,A0 ; A0 -> Array
6: SUB.W #1,D1 ; DBRA-Adjust count
7: @1: MOVE.B #1,(A0)+ ; Set flag byte
8: DBRA D1,@1 ; Loop till done
9: RTS ; Return
10: . ;
11: . ; Sieve routine. Does the main part of the sieve algorithm
12: . ;
13: XDEF sieve ; Make accessible
14: sieve MOVE.L D0,A0 ; A0 -> Flags array
15: MOVE.W D1,D4 ; Replicate count
16: SUBQ.W #1,D1 ; DBRA-Adjust D1
17: CLR.L D2 ; D2 = count
18: CLR.W D3 ; D3 = i
19: @1: TST.B O(A0,D3,W) ; if(flags[i])
20: BBE @4 ; Not prime, skip this one
21: MOVE.W D3,D5 ; D5 = "prime" variable
22: ADD.W D3,D5 ; prime = i + i
23: ADDQ.W #3,D5 ; + 3;
24: MOVE.W D3,D6 ; D6 = k
25: @2: ADD.W D5,D6 ; Add in "prime"
26: CMP.W D4,D6 ; while (k <= SIZE)
27: BGT @3 ; Not <=, do next iteration
28: CLR.B O(A0,D6,W) ; flags[k] = 0;
29: BRA @2 ; Loop again
30: @3: ADDQ.W #1,D2 ; Increment count variable
31: @4: ADDQ.W #1,D3 ; Increment i
32: DBRA D1,@1 ; Loop till done
33: MOVE.L D2,D0 ; Set return value
34: RTS ; Return
```

[Listing 5.13 – Assembly routine for C sieve program]
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Listing 5.14 – Pascal sieve program
The optimized Pascal program appears in Listing 5.15. Lines 28–32 declare the parameters and function return types as dictated by Pascal. The only other change is the use of a Pascal TYPE declaration for the array in lines 21 and 24.

Pascal subroutines receive parameters and return function values on the stack. VAR parameters (those that can be modified by the subroutine) are passed by address. The value of non-VAR parameters that are less than four bytes is pushed on the stack. Any parameter that is longer than four bytes is passed by address. Lisa Pascal has the following simple data types:

<table>
<thead>
<tr>
<th>Name</th>
<th>Length</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>char</td>
<td>1</td>
<td>A single 8-bit ASCII character</td>
</tr>
<tr>
<td>boolean</td>
<td>1</td>
<td>A byte that is zero or nonzero</td>
</tr>
<tr>
<td>integer</td>
<td>2</td>
<td>16-bit signed integer</td>
</tr>
<tr>
<td>longint</td>
<td>4</td>
<td>32-bit signed integer</td>
</tr>
<tr>
<td>real</td>
<td>4</td>
<td>32-bit floating point</td>
</tr>
<tr>
<td>(pointer)</td>
<td>4</td>
<td>32-bit address</td>
</tr>
</tbody>
</table>

The syntax for a pointer variable is simply `^data`, as shown in line 26 of Listing 5.15.

Pascal invokes a subroutine using the following steps:

1. Decrement the stack pointer to make room for the function return value, if any.

```pascal
49: BEGIN (* *)
50:   flags[k] := 'O'; (* Eliminate current *)
51:     k := k + prime; (* Calculate next *)
52:     END; (* One more prime done *)
53:     count := count + 1; (*------------------*)
54:     END; (*=================================*)
55:   END; (*++++++*)
56:   END; (* FOR J := 1 TO ITER *)
57:   stop := timeptr"; (* Fetch stop time *)
58:   writeln(count,' primes ','stop-start,' ticks');(* Output time *)
59:   writeln('Main program');(* Main program *)
60: END. (*************************)
```

Listing 5.14 – Pascal sieve program (continued)
Listing 5.15 - Optimized Pascal sieve program
2. Push the parameters from left to right. Parameters that require an odd number of bytes are padded to keep the stack pointer even. Note that this is the opposite order from C.

3. Call the subroutine with a JSR instruction.

4. Upon return from the subroutine, pop the return value, if any, from the stack.

Note that the caller pushes all values on the stack and the called routine pops off the parameters. The caller pops the function return value, if any. This is also different from C. The subroutine must preserve all registers except D0–D2 and A0–A1. There is no way for an assembly routine to access global data. The address must be passed as a parameter.

Listing 5.16 shows the sieve assembly language routines properly interfaced to Lisa Pascal. Note that the Lisa assembler directives are slightly different from the MDS assembler. The .PROC and .END statements are mandatory.

Macintosh System Calls

Application programs execute routines in the Macintosh ROM by means of system traps. Instructions that have the value 1010 in the upper four bits cause a 68000 exception. Exceptions are explained fully in Chapter 7. The Macintosh designers used the low-order 12 bits of the instruction to define an entire set of calls into the ROM. These calls require only 16 bits of application program memory, while a BSR or JSR would require 32 or 48 bits.

There are two formats of operating system calls, named trap words in the Macintosh documentation. Figure 5.8 shows the layout of these words.

The two formats are distinguished by the value of bit 11. When bit 11 is zero, the trap is an operating system call. Parameters to operating system routines are normally passed in registers. Bit 8 in an operating system call, if zero, indicates that a return value will be placed in A0 by the routine invoked by the trap word. The _NewHandle function, used in Chapter 6, is an example of such a routine. Bits 10–9 are flag bits whose meaning depends on the routine being called.

When bit 11 of the trap word is a 1, the trap is a Toolbox call. Toolbox calls normally use the Lisa Pascal calling conventions described previously, except that the JSR instruction is replaced by the trap word. The Lisa Pascal compiler can generate calls to the Toolbox routines directly by using
Assembler part of optimized PASCAL sieve program

```
1: ;
2: ;
3:  .PROC SieveAsm ; Procedure statement
4:  .DEF setflags ; Declare global
5:  setflags MOVE.L (SP)+,Al ; Al = return address
6:  MOVE.W (SP)+,D1 ; D1 = array size
7:  SUB.W #1,D1 ; DBRA-Adjust count
8:  MOVE.L (SP)+,AO ; AO -> Array
9: @1:  MOVE.B #1,(AO)+ ; Set flag byte
10:  DBRA D1,@1+ ; Loop till done
11:  JMP (Al) ; Return
12: ;
13: ;
14: ;
15:  .DEF sieve ; Make accessible
16:  sieve MOVE.L (SP)+,Al ; Al = Return address
17:  MOVE.W (SP)+,D1 ; D1 = Array size
18:  MOVE.L (SP)+,AO ; AO -> Flags array
19:  MOVEM.W D3-D5,-(SP) ; Save registers
20:  MOVE.W D1,D4 ; Replicate count
21:  SUBQ.W #1,D1 ; DBRA-Adjust D1
22:  CLR.W D2 ; D2 = count
23:  CLR.W D3 ; D3 = 1
24: @1:  TST.B O(AO,D3.W) ; if(flags[i])
25:  BEQ @4 ; Not prime, skip this one
26:  MOVE.W D5,D5 ; D5 = "prime" variable
27:  ADD.W D3,D5 ; prime = i + i + 3;
28:  ADDQ.W #3,D5 ;
29:  MOVE.W D3,D6 ; D6 = "k"
30: @2:  ADD.W D5,D6 ; Add in "prime"
31:  CMP.W D4,D6 ; while (k <= SIZE)
32:  BGT @3 ; Not <=, do next iteration
33:  CLR.B O(AO,D6.W) ; flags[k] = 0;
34:  BRA @2 ; Loop again
35: @3:  ADDQ.W #1,D2 ; Increment count variable
36: @4:  ADDQ.W #1,D3 ; Increment i
37:  DBRA D1,@1 ; Loop till done
38:  MOVEM.W (SP)+,D3-D6 ; Restore registers
39:  MOVE.W D2,(SP) ; Set return value
40:  JMP (Al) ; Return
41:  .END ; Mandatory END statement
```

Listing 5.16 – Assembler routine for Pascal sieve program
the INLINE directive to specify the trap number. This minimizes overhead in calling Toolbox routines from Pascal.

Bit 10 of a Toolbox trap is the auto-pop bit. This is designed for compilers that do not support the INLINE feature. Such compilers must generate a JSR to a trap word. By setting bit 10 of the trap word, you can avoid the overhead of the extra RTS instruction. The Toolbox will return directly to the instruction following the JSR if this bit is set.

**SUMMARY**

In this chapter, we dealt with a number of important topics:

- The concept of records and the various types of records: fixed-length, variable-length, and hybrid
• How records are arranged in memory: arrays and linked lists
• Data structures: stacks, queues, and trees
• Simple methods of sorting data: insertion sorts and interchange sorts
• Sequential, binary, and hash techniques of searching through a table
• The concept of recursive programming
• The use of macros and conditional assembly
• Mixing assembly and high-level languages
• Macintosh system calls

EXERCISES

1. The Fibonacci series of numbers, denoted as F(n), is recursively defined as follows:
   a. F(0) = 0, and F(1) = 1.
   b. For all other numbers, F(n) = F(n - 1) + F(n - 2). (For example, F(2) = F(1) + F(0) = 1; F(3) = F(2) + F(1) = 2, and so forth.)

   Write a recursive function called fib that returns, in D0.W, the Fibonacci number that corresponds to the number originally contained in D0.W.

2. Modify the program in Exercise 1 to be callable from the high-level languages discussed in this chapter.
The Macintosh Programming Environment

He who rides a tiger cannot dismount.

—Chinese proverb

OVERVIEW

In the previous chapters, we have explored programming the Macintosh from a traditional computer science standpoint. In this chapter, we will explore elements of programming that are unique to the Macintosh. This includes several topics:

1. The QuickDraw graphics system
2. Memory layout of a Macintosh program
3. Use of the Macintosh resource capability
4. Windows, dialogs, and alerts
5. Menu operations
6. The Macintosh event system

The last part of the chapter is an explanation of a sample Macintosh application, called MacDoodle, which illustrates these principles.

Macintosh-style user interaction is based on a technique known as the “desktop metaphor,” in which the computer screen (background) is analogous to a desktop containing sheets of paper (the windows), and other objects (the icons). Figure 6.1 illustrates these various areas of the desktop.
The Desktop

At the top of the screen is an area called the menu bar. The words appearing in this area are labels for panels called menus. Each menu contains a list of items that the user can choose with the mouse. The gray area of the screen is known as the desktop or desk area. Inside this area, large display areas called windows appear.

Each window is a separate display. Windows are like sheets of paper on the desktop and can overlap. Clicking the mouse button in a window that is behind another window causes the first window to be placed on top. This operation is akin to shuffling two pieces of paper.

The window that is on top of all the others is designated as the active window. This is the window titled “Book Programs” in Figure 6.1. The active window is identified by the lines on each side of the title. The area in which the title appears is called the title bar, and an active window’s title bar is said to be highlighted.

The title bar of an active window may also contain an area called the close box. Clicking the mouse inside this box causes the window to go away. When you close a window in this way, it either disappears completely or appears in a compacted image known as an icon, depending on the application displaying the window.

Icons are used by the Finder to represent folders (groups of files), documents (files), and applications (programs). The trash can is really a special type of folder, as are disk drives. Files are displayed in folders according to the Finder folder number in the file information area of the file, as described in Chapter 4. Recall that each Macintosh file has a four-byte
field that identifies an application associated with the file, as explained in Chapter 4. This field is called the application's signature. When you open a document file in the Finder, the Finder starts the application whose signature matches the signature in the document file. The application receives the name of the document file as a parameter.

A document's icon is also determined by its application signature. The Finder constructs a file called "Desktop," which contains the icons for all the applications present on a given disk. The application itself usually has an icon different from the documents processed by that application.

**QuickDraw**

Output to the screen and other graphics devices is normally performed using the Macintosh QuickDraw package. QuickDraw is a substantially complete graphics software package. Our discussion only covers those points necessary for understanding the sample application at the end of this chapter. A more complete discussion can be found in *Inside Macintosh*.

The Macintosh screen is a big rectangle made up of bits. Each bit corresponds to a dot or pixel on the screen. There are 175,104 pixels (21,888 bytes) on the Macintosh screen, arranged in a rectangle 342 pixels high and 512 pixels wide. The pixels are stored such that all the pixels in a byte are on the same horizontal line. Bit 7 of each byte is the left-most pixel displayed. A zero bit causes a white pixel to appear on the screen, and a one bit appears as a black pixel. The screen is a 64 × 342 byte array, arranged as shown in Figure 6.2.

**QuickDraw Data Structures**

QuickDraw uses several specialized arrangements of data in memory. These arrangements are called *data structures*. You must understand these data structures in order to use the QuickDraw system calls.

QuickDraw expands the Macintosh screen organization to an arbitrary grid called the *coordinate plane*. This grid is a two-dimensional array of points. Each point has a vertical and a horizontal address. A point specification is written as (v,h), where v and h are the vertical and horizontal coordinates of the point. Coordinates are signed 16-bit numbers, with a range of −32768 to +32767, as shown in Figure 6.3.

A point is stored in memory as two consecutive 16-bit numbers. You can load a point into a 32-bit register with a MOVE.L instruction. The vertical coordinate resides in the high word of the register in this case.
A common data structure in QuickDraw applications is the rectangle. A rectangle consists of two points, the top left and the bottom right. A rectangle data structure is shown in Figure 6.4. The in-memory structure is simply four 16-bit integers. This corresponds to two-point data structures.

An important consideration in using QuickDraw rectangles is that the pixels lie between the grid lines, and the grid lines are assumed to have zero width. A rectangle thus divides the coordinate plane into two sets of points: those inside and those outside the rectangle. In addition, there are more points associated with the rectangle than pixels. In the rectangle in Figure 6.4, there are 200 (20 x 10) pixels, but there are 231 (21 x 11) points.

The QuickDraw coordinate plane is mapped onto the physical screen by a data structure known as a bitmap. A bitmap data structure contains a memory address, called the base address, which is the address of the first byte in the bitmap. The width of the bitmap is given by an integer called rowBytes, which contains the number of bytes in a single horizontal row.

![Figure 6.2 - Macintosh screen organization](image)

![Figure 6.3 - The QuickDraw coordinate plane](image)
of the bitmap. Finally, there is a rectangle, called the \textit{bounds rectangle}, which gives the number of bits in a row and the number of rows. Figure 6.5 shows the relationship between a bitmap data structure and an actual array of pixels.

The high bit of the byte at the base address usually corresponds to the pixel at (0,0), although this need not be the case. The bounds rectangle

\begin{figure}[h]
\centering
\includegraphics[width=0.7\textwidth]{figure6_4.png}
\caption{QuickDraw rectangle structure}
\end{figure}

\begin{figure}[h]
\centering
\includegraphics[width=0.7\textwidth]{figure6_5.png}
\caption{The QuickDraw bitmap structure}
\end{figure}
can be used to impose any arbitrary coordinate system on the bitmap. The top-right point of the bounds rectangle always corresponds to the high bit of the byte at the base address. Another requirement is that the width of the bitmap as indicated by rowBytes be greater than or equal to the width of the bounds rectangle.

Filling an area of the screen (such as the gray background) requires a data structure known as a pattern. A pattern is a 64-bit image, organized as an 8 × 8-bit rectangle. A pattern therefore has a row width of one byte. The Edit Pattern option in MacPaint and the desktop background feature in the Control Panel desk accessory are two examples of the use of patterns. Each of these allows you to change the pattern used to fill a large area of the screen.

Another common QuickDraw data structure is the cursor. A cursor data structure is used to define the appearance of the screen image controlled by moving the mouse. The cursor consists of two 16 × 16-bit rectangles and a point. The first rectangle, called the data rectangle, contains the image to be drawn on the screen. The second rectangle, called the mask rectangle, determines what happens to the bits underneath the displayed cursor. These bits can be ignored, painted over, or inverted, as shown in Table 6.1.

The point contained in a cursor data structure specifies a single point in the cursor that indicates the location of the mouse. Figure 6.6 illustrates the structure of some cursors commonly used in Macintosh applications.

A more versatile structure than the rectangle is the QuickDraw region. A region can describe any arbitrary area on a QuickDraw bitmap. The data structure for a region consists of a word that indicates the total region size in bytes, a rectangle that completely contains the region on the bitmap, and an area of variable length that describes the region. The format

<table>
<thead>
<tr>
<th>Data Bit</th>
<th>Mask Bit</th>
<th>Resulting Pixel on the Screen</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>Always white</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>Always black</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>Unchanged from image under cursor</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>Inverted from image under cursor</td>
</tr>
</tbody>
</table>

Table 6.1 – Cursor and Mask Bit Values
of this area is not documented by Apple. A region can change size during a graphics operation on the region and, as a result, its location in memory may change. For this reason, the normal way of referring to a region is via a pointer to a pointer to the region. This doubly-indirected pointer is called a handle. Handles are described in the “Dynamic Memory Allocation” section in this chapter. None of the applications in this book makes extensive use of the region data structure.

The most important QuickDraw data structure is the GrafPort. A GrafPort imposes a coordinate system on a bitmap. The bitmap coordinate system is often called the global coordinate system, while the GrafPort coordinate system is termed the local coordinate system. More than one GrafPort may use the same bitmap structure. Each window on the screen, for instance, has a separate GrafPort.

A GrafPort contains a great deal of drawing state information. The pen is used for all drawing operations inside the GrafPort. It is rectangular in shape and writes a pattern onto the GrafPort. Pen width, height, and pattern are all controlled by the current application.

**QuickDraw Copy Modes**

The pen may affect the GrafPort in eight different ways or modes, called transfer modes. These modes specify the Boolean (bitwise) operation to be used in transferring data from the pen to the GrafPort. Table 6.2 lists the eight transfer modes.

![Common Macintosh cursors](image)
The Copy, Or, and Xor copy modes are analogous to the MOVE, OR, and EOR 68000 instructions, respectively, except that they work on an arbitrary number of bits. The Bic copy mode is an AND-NOT instruction (an AND with the one’s complement of the source). The NOT forms of the transfer modes are formed by taking the one’s complement of the source and then performing a standard Copy, Or, Xor, or Bic transfer.

The Xor transfer mode is particularly useful. If you draw an object on the screen with the Xor transfer mode and then redraw it, the screen will be left in the same state as before you drew the object the first time. This is how MacPaint draws lines, circles, and boxes with the mouse. Drawing an object with the mouse requires that the object change size as the mouse moves. MacPaint draws the object once in Xor mode. When the mouse moves, MacPaint redraws the object in the old location. This erases the object from the screen. MacPaint then redraws the object at the new location. This causes the object to change size on the screen as the mouse moves. The sample application later in this chapter also uses this technique.

Basic QuickDraw Procedures

In this section, we will explore some simple QuickDraw procedure calls. These calls all conform to the Lisa Pascal calling sequences given in the last chapter. This is by no means a complete list of QuickDraw functions, and you should consult Inside Macintosh for additional details.

The first two functions are used to get and set QuickDraw's idea of the current GrafPort. You can have as many GrafPorts as you have memory

<table>
<thead>
<tr>
<th>Mode Name</th>
<th>Pen Pixel Black</th>
<th>Pen Pixel White</th>
</tr>
</thead>
<tbody>
<tr>
<td>srcCopy</td>
<td>Always black</td>
<td>Always white</td>
</tr>
<tr>
<td>srcOr</td>
<td>Always black</td>
<td>Unchanged</td>
</tr>
<tr>
<td>srcXor</td>
<td>Inverted</td>
<td>Unchanged</td>
</tr>
<tr>
<td>srcBic</td>
<td>Always white</td>
<td>Unchanged</td>
</tr>
<tr>
<td>NotsrcCopy</td>
<td>Always white</td>
<td>Always black</td>
</tr>
<tr>
<td>NotsrcOr</td>
<td>Unchanged</td>
<td>Always black</td>
</tr>
<tr>
<td>NotsrcXor</td>
<td>Unchanged</td>
<td>Inverted</td>
</tr>
<tr>
<td>NotsrcBic</td>
<td>Unchanged</td>
<td>Always white</td>
</tr>
</tbody>
</table>

Table 6.2 - QuickDraw Transfer Modes
for, but you can draw in only one of them at a time. The following code illustrates how to obtain the current GrafPort address and restore it at a later time, using two functions called _GetPort and _SetPort.

```
PEA Port(A5) ; Push address of return value
_GetPort
.
.
MOVE.L Port(A5),-(SP) ; Push port address (value)
_SetPort
.
.
Port DS.L 1 ; Port address storage location
```

One of the most useful features of QuickDraw is the ability to specify an area of the GrafPort outside which no drawing can occur. This area is called the clipping region, and can be an arbitrary collection of areas inside the GrafPort. This is especially useful in dealing with multiple overlapping windows, for instance. A simplified call that sets the clipping region to a rectangle is all that is required for our sample application.

```
PEA CRect(A5) ; Push address of clip rectangle
_ClipRect
.
.
CRect DS.W 4 ; Top-left bottom-right storage
```

The _ClipRect procedure is called ClipRect in Pascal.

QuickDraw offers a number of functions that affect the pen within a given GrafPort. Two of these functions, _GetPenState and _SetPenState, save and restore all the information associated with a QuickDraw pen. Figure 6.7 shows the format of this data.

The pen location is a point that defines the pen's position within the GrafPort. The pen size is a point that gives the width of the line drawn when the pen is moved. The pen transfer mode is one of the transfer modes described previously. The pen pattern fills the rectangle created by moving the pen. Figure 6.8 shows the pen operation.

The dark line at the top indicates the pen path, specified by the application that moves the pen. The pen location is always the top-left corner of the rectangle defined by the pen size.
The _GetPenState and _SetPenState functions are called as follows:

```
PEA PenState(A5) ; Push address of pen area
_GetPenState ; Save pen

PEA PenState(A5) ; Push address of pen area
_SetPenState ; Restore pen

PenState DS.W 9 ; Pen state storage area
```

Use these functions when you need to change the pen temporarily and then restore it to what it was previously.

QuickDraw also offers functions that get and set individual pen fields. They are listed in Table 6.3.

These functions are called as follows:

```
PEA PenLoc(A5) ; Push return area address
_GetPen ; Returns a point
MOVE.L PenLoc(A5), -(SP) ; Push new pen location
_MoveTo ; Moves pen with no drawing
MOVE.L PenSize(A5), -(SP) ; Push new pen size
_PenSize ; Set pen to new size
MOVE.W XMode(A5), -(SP) ; Push transfer mode
_PenMode ; Set transfer mode
```

<table>
<thead>
<tr>
<th>Field</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Pen location (v)</td>
</tr>
<tr>
<td>2</td>
<td>Pen location (h)</td>
</tr>
<tr>
<td>4</td>
<td>Pen size (v)</td>
</tr>
<tr>
<td>6</td>
<td>Pen size (h)</td>
</tr>
<tr>
<td>8</td>
<td>Transfer mode</td>
</tr>
<tr>
<td>10</td>
<td>Pen pattern (8 bytes)</td>
</tr>
</tbody>
</table>

**Figure 6.7 - The pen state data structure**
Push pattern address
Set new pen pattern

Vertical coordinate
Horizontal coordinate
Pen height
Pen width
Pen transfer mode
Pen pattern

Figure 6.8 - The graphics pen operation

<table>
<thead>
<tr>
<th>Function Name</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>_GetPen</td>
<td>Returns the pen location</td>
</tr>
<tr>
<td>_MoveTo</td>
<td>Sets the pen location</td>
</tr>
<tr>
<td>_PenSize</td>
<td>Sets the pen size</td>
</tr>
<tr>
<td>_PenMode</td>
<td>Sets the pen transfer mode</td>
</tr>
<tr>
<td>_PenPat</td>
<td>Sets the pen pattern</td>
</tr>
</tbody>
</table>

Table 6.3 - QuickDraw Pen Functions
Note the use of the MOVE.L instruction to move a point. The normal Pascal calling conventions for PenSize and MoveTo require separate 16-bit parameters for the two components of a point. In assembly language, you can save space and time using a single MOVE.L instead.

**QuickDraw Drawing Procedures**

QuickDraw can draw a number of different objects. In this section, we will explore the three objects used in the MacDoodle program: lines, rectangles, and ovals. This is an extremely tiny subset of the functions offered by QuickDraw, but it is adequate for our purposes.

You draw lines with the _LineTo call. This draws a line from the current pen position to a point you supply. Call it like this:

```assembly
MOVE.L   Point(A5), -(SP) ; Push end point
_LineTo ; Draw the line
```

```assembly
Point:   DS.W 2 ; Desired end point
```

To draw a rectangle, use the _FrameRect call. This draws a box on the screen. The area of the screen inside the box is not affected. Thus, items behind the rectangle you draw will show through. Other functions can be used to erase the inside of the rectangle, invert all the bits in the rectangle, or fill the inside of the rectangle with a pattern.

For each function that works on a rectangle, there is an analogous function that works on an oval. Thus, a _FrameOval call draws an oval on the screen. Table 6.4 gives the QuickDraw rectangle and oval function calls. These functions are called as follows:

```assembly
PEA     Rect(A5) ; Push rectangle address
_FrameRect ; Draw a rectangle
PEA     Rect(A5) ; Push rectangle address
_FrameOval ; Draw an oval
PEA     Rect(A5) ; Push rectangle address
_PaintRect ; Fill with pen pattern
PEA     Rect(A5) ; Push rectangle address
_PaintOval ; Fill with pen pattern
PEA     Rect(A5) ; Push rectangle address
_EraseRect ; Erase (background fill)
PEA     Rect(A5) ; Push rectangle address
_EraseOval ; Erase (background fill)
PEA     Rect(A5) ; Push rectangle address
_InvertRect ; Invert rectangle
```
The Macintosh Programming Environment

PEA Rect(A5) ; Push rectangle address
_InvertOval ; Invert oval

; _FillRect and _FillOval have an extra parameter
;
PEA Rect(A5) ; Push rectangle address
PEA Patt(A5) ; Push pattern address
_FillRect ; Fill the rectangle
PEA Rect(A5) ; Push rectangle address
PEA Patt(A5) ; Push pattern address
_FillOval ; Fill the oval
;
;
Rect DS.W 4 ; Top-left bottom-right
Patt DS.B 8 ; Eight-byte pattern

_PaintRect uses the pen’s current transfer mode to do the filling. _FillRect and _EraseRect always use copy mode.

QuickDraw Text Procedures

QuickDraw also handles text. Together with a related part of the system called the Font Manager, QuickDraw can place text of any font, size, and characteristic on the screen. The MacDoodle application draws text on the screen, using a subset of QuickDraw’s text routines. We will discuss only the routines needed for MacDoodle.

Text drawing, like any other drawing, is done with the pen. Figure 6.9 shows three characters from the Chicago font. The base line is the vertical position of the pen when drawing text. The pen starts drawing a character at the character origin. The maximum height of a character is given by the

<table>
<thead>
<tr>
<th>Function Name</th>
<th>Function Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>_FrameRect</td>
<td>Draws a “hollow” figure on the screen</td>
</tr>
<tr>
<td>_FrameOval</td>
<td></td>
</tr>
<tr>
<td>_PaintRect</td>
<td>Fills figure with the pen pattern</td>
</tr>
<tr>
<td>_PaintOval</td>
<td></td>
</tr>
<tr>
<td>_EraseRect</td>
<td>Fills figure with the background pattern</td>
</tr>
<tr>
<td>_EraseOval</td>
<td></td>
</tr>
<tr>
<td>_FillRect</td>
<td>Fills figure with a specified pattern</td>
</tr>
<tr>
<td>_FillOval</td>
<td></td>
</tr>
<tr>
<td>_InvertRect</td>
<td>Inverts (complements) bits inside figure</td>
</tr>
<tr>
<td>_InvertOval</td>
<td></td>
</tr>
</tbody>
</table>

Table 6.4 – QuickDraw Rectangle and Oval Functions
ascent line, and the maximum depth of the character by the descent line. The leading line shows the amount of space between lines of single-spaced text. This line would be the ascent line of text on the next line. Note that the lowercase j character has one pixel to the left of its character origin. This is a technique called kerning, whereby a character (usually a lowercase descender) is placed closer than normal to the preceding character.

There are three types of text routines: one specifies how the text is to be drawn, one actually draws the text, and one provides information about the text. Table 6.5 gives a summary of the text routines used in this chapter.

The _GetFName and _RealFont calls are documented in the Font Manager chapter of Inside Macintosh; the others are in the QuickDraw chapter. _GetFName is called FontName in the Pascal documentation.

Fonts are stored as resources, usually in the System file on the bootstrap disk. Resources are discussed later in this chapter. You identify a particular font by a 16-bit number called a resource ID. All of the calls in Table 6.5 that deal with fonts use the resource ID of the font. Therefore, you don’t have to know the actual structure of a font. The font routines are called as follows:

```
MOVE.W FontID(A5), -(SP) ; Push font ID
PEA Buffer(A5) ; Push buffer address
_GetFName ; Fetch the font name

CLR.W -(SP) ; Make room for return
MOVE.W FontID(A5), -(SP) ; Push font ID
MOVE.W Size(A5), -(SP) ; And size in points
_RealFont ; See if font exists
TST.W (SP)+ ; Test return word
BNE WasReal ; NE means yes

MOVE.W FontID(A5), -(SP) ; Push font ID
_TextFont ; Set font
```

FontID DS.W 1 ; Font ID storage
Size DS.W 1 ; Text size in points
Buffer DS.B 256 ; Font name storage

The _GetFName call returns the name associated with the font ID in the buffer specified in the second parameter. This name is in Pascal string format. A zero is returned in the first byte of the buffer if the font does not exist.

If a font exists, there are certain sizes of the font that look better than other sizes. Each font and size combination is stored separately in the resource file. If the specified size does not exist for a font, it is created by
scaling an existing size. The results can be coarse and unattractive. You can test to see whether a font/size combination is available by using the _RealFont call illustrated above.

The _TextFont call sets the font to be used in subsequent QuickDraw text drawing. You can use the _GetFName call to see if the font exists (in any size).

The _TextFace, _TextMode, and _TextSize calls specify the text attributes, transfer mode, and point size, respectively. Call these routines as follows:

\[
\begin{align*}
\text{MOVE.W} & \quad \text{Attr(A5), (SP)} \quad \text{Push attribute word} \\
& \quad \_	ext{TextFace} \quad \text{Set text attributes} \\
\text{MOVE.W} & \quad \text{Size(A5), (SP)} \quad \text{Push text size} \\
& \quad \_	ext{TextSize} \quad \text{Set text size} \\
\text{MOVE.W} & \quad \text{Xfer(A5), (SP)} \quad \text{Push transfer mode} \\
& \quad \_	ext{TextMode} \quad \text{Set transfer mode}
\end{align*}
\]

\[
\begin{align*}
\text{Attr} & \quad \text{DS.W} \quad 1 \quad \text{Text attributes} \\
\text{Size} & \quad \text{DS.W} \quad 1 \quad \text{Text size in points} \\
\text{Xfer} & \quad \text{DS.W} \quad 1 \quad \text{Text transfer mode}
\end{align*}
\]

The attributes word used by the _TextFace call is a set of independent bits, with one bit per attribute. The possible attributes are shown in Figure 6.10. You can specify any desired combination of text attributes by adding the values together.

<table>
<thead>
<tr>
<th>Routine</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>_GetFName</td>
<td>Gets name of a font</td>
</tr>
<tr>
<td>_RealFont</td>
<td>Determines whether a font exists</td>
</tr>
<tr>
<td>_TextFont</td>
<td>Sets text font for subsequent characters</td>
</tr>
<tr>
<td>_TextFace</td>
<td>Sets character style (bold, italic, etc.)</td>
</tr>
<tr>
<td>_TextMode</td>
<td>Sets text transfer mode (srcCopy, srcOr, etc.)</td>
</tr>
<tr>
<td>_TextSize</td>
<td>Sets text size</td>
</tr>
<tr>
<td>_DrawChar</td>
<td>Draws a single character</td>
</tr>
<tr>
<td>_DrawString</td>
<td>Draws a set of characters from a Pascal string</td>
</tr>
<tr>
<td>_CharWidth</td>
<td>Determines the width of a character</td>
</tr>
</tbody>
</table>

*Table 6.5 - QuickDraw Text Routines*
Text size is measured in points. A point is a typesetter's unit of length, roughly equivalent to 1/72 inch. Macintosh text sizes are slightly different from traditional text sizes, due to the resolution of the Macintosh screen and printer.

The text transfer modes are identical to the pen transfer modes discussed previously. The two modes work independently, however.

The _DrawChar, _DrawString, and _CharWidth calls are used to actually draw text. These routines are called as follows:

```
MOVE.W Char(A5), -(SP) ; Push character
_DrawChar ; Draw it
```
The character parameter to _DrawChar and _CharWidth must be a word with the character in the low-order byte.

**Miscellaneous QuickDraw Routines**

QuickDraw offers many other useful routines for manipulating graphics objects. In our sample program, we will use five of them:

1. The *CopyBits* routine, which copies a rectangle from one bitmap structure to another
2. The *PtlnRect* routine, which determines if a point is within a given rectangle
3. The *EqualRect* routine, which determines whether two rectangles are equal
4. The *PackBits* routine, which compresses bitmap data into a much smaller space
5. The *UnPackBits* routine, which expands the compressed data back into bitmap form

The *CopyBits* routine is probably the most complicated. This routine copies a portion of a bitmap to another bitmap. The MacDoodle program uses this function to save the contents of the screen in a memory buffer. This routine is called as follows:

<table>
<thead>
<tr>
<th>Instruction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>PEA</td>
<td>SBitMap(A5) ; → Source bitmap</td>
</tr>
<tr>
<td>PEA</td>
<td>DBitMap(A5) ; → Destination bitmap</td>
</tr>
<tr>
<td>PEA</td>
<td>SrcRect(A5) ; → Source rectangle</td>
</tr>
<tr>
<td>PEA</td>
<td>DstRect(A5) ; → Destination rectangle</td>
</tr>
<tr>
<td>MOVE.W</td>
<td>TrnMode(A5), -(SP) ; = Transfer mode</td>
</tr>
<tr>
<td>PEA</td>
<td>MaskRgn(A5) ; → Mask region</td>
</tr>
</tbody>
</table>
The first parameter is the address of the bitmap data structure that contains the source data. The second parameter is the address of the destination bitmap. The third and fourth parameters are rectangles that describe the area of the source bitmap that will be copied and the area of the destination bitmap that will receive the information. These rectangles need not be of equal size. CopyBits will scale them if necessary. The fifth parameter indicates the transfer mode to be used. The final parameter is the address of a region that masks the source rectangle, permitting the transfer of arbitrary areas. If this address is zero, the entire rectangle will be transferred.

The PtlnRect and EqualRect procedures are called as follows:

```
CLR.W -(SP) ; Room for result
MOVE.L Point(A5), -(SP) ; Push point
PEA Rect1(A5) ; Push rectangle address
_PtlnRect
TST.W (SP)+ ; Check result
BNE InRect ; NE means yes

CLR.W -(SP) ; Room for result
PEA Rect1 ; → First rectangle
PEA Rect2 ; → Second rectangle
_EqualRect
TST.W (SP)+ ; Check result
BNE Equal ; NE means yes
```

The rectangles and point must be in the same coordinate system for these calls to function properly.

Graphics data typically contain many bytes that have the same value. A technique called run-length encoding is often used to reduce the size of...
such data in memory or on disk. The Macintosh ROM provides two procedures for converting between bitmap and run-length encoded data. These routines are PackBits and UnPackBits and are called as follows:

```
PEA SrcAddr(A5)  ; → → Source data
PEA DstAddr(A5)  ; → → Destination data
MOVE.W ByteCnt(A5), -(SP) ; # bytes to pack
_PackBits

PEA SrcAddr(A5)  ; → → Source data
PEA DstAddr(A5)  ; → → Destination data
MOVE.W ByteCnt(A5), -(SP) ; # bytes to unpack
_UnPackBits
```

The source and destination addresses are updated to the first byte unused by the system call. The byte-count parameter always refers to the number of bytes in the unpacked (bitmap) data. The normal method of converting a bitmap is to pack or unpack each row individually.

**Macintosh Memory Management**

A second major area of concern to Macintosh application writers is that of memory management. At this writing there are four memory configurations for the Macintosh:

- The 128K Macintosh
- The 512K Macintosh
- The 512K Macintosh XL (Lisa)
- The 1024K Macintosh XL (Lisa)

**Macintosh Memory Layout**

Figure 6.11 shows the memory layout for a 512K Macintosh. The sizes of each of the items shown are in decimal, while the addresses are hexadecimal. A 128K Macintosh has a 16.5K system heap instead of a 46K system heap, and two of the address bits are not present. All the addresses in Figure 6.11 of the form "07xxxx" are "01xxxx" on a 128K Macintosh. The first 2816 bytes contain the 68000 interrupt vectors and system global variables. Interrupt vectors are described in Chapter 7.
The Macintosh has two dynamic memory areas: the system heap and the application heap. The system heap is a fixed-size area, but the application heap is allowed to grow toward higher addresses. The stack is placed at the upper end of the application heap and grows toward lower addresses.

The system heap contains memory that remains relatively constant. It is used for data structures that must remain in place across applications, such as information about disk drives, device drivers, and other system-related information.

Figure 6.11 – The Macintosh memory layout
The application heap is reinitialized each time an application program runs. Most memory that is allocated dynamically comes from the application heap, such as the memory for the application code and data. The application can also allocate memory dynamically from this area. Many system calls allocate memory from the heap as well.

The application's uninitialized global variables are placed at the high-address end of the application heap, along with the parameter area passed from the Finder and the jump table used for overlays. Register A5 is used to address all of these areas. Negative offsets from A5 contain data locations defined by DS directives in the assembler. Locations \(-1(A5)\) to \(-256(A5)\) are used by QuickDraw and are automatically reserved by the linker. The application is required to voluntarily relinquish control of these locations, as shown in Listing 8.2 (Chapter 8).

Positive offsets from A5 contain both parameters passed to the application from the Finder and the jump table used for loading overlays. The application parameters are described later in this chapter. None of the programs in this book use the jump table.

The alternate screen buffer and alternate sound buffer are used by specialized applications. They provide a way to maintain two copies of the screen and sound output. Most applications do not require this feature, and these buffers are normally not present.

The main screen buffer contains the memory used for the Macintosh screen display. Storing data in this area directly affects the appearance of the screen. QuickDraw uses a bitmap data structure (which contains the screen address in the base address field as seen in Figure 6.5) for drawing on the screen.

The system error handler storage is used by the component that displays the “Bomb” template on the screen when an application fails and the system must be rebooted.

The main sound buffer is used to hold data waiting to be used in sound generation. This area is also used by the disk software to control speed changes.

**Macintosh XL Memory Layout**

Figure 6.12 shows the memory layout of a Macintosh XL (formerly known as a “Lisa running MacWorks”). The Lisa hardware supports either 512K or 1024K (1M) of memory. The memory layout is very similar to a Macintosh, except that there is no alternate screen or sound buffer. In addition, the screen is a different size \((364 \times 720)\), necessitating a 32K screen buffer. The hardware interface area contains code that simulates the Macintosh hardware and ROM on the Lisa.
The addresses shown are for a 1024K (1M) Lisa. Simply subtract 80000 hex to obtain the corresponding addresses on a 512K Lisa. Addresses of the form Fxxxxx become 7xxxxx, and addresses of the form Cxxxxx become 4xxxxx.

**Dynamic Memory Allocation**

Macintosh software makes extensive use of dynamically allocated memory. QuickDraw’s use of variable-length data structures makes it imperative that an area of memory be able to grow when necessary. Therefore, dynamically allocated blocks of memory must be moved to accommodate growth.

The Apple solution to this rather knotty problem is to use one pointer for each dynamically allocated memory area. This pointer is called a master pointer. Code that refers to the dynamic region uses a pointer, called a

![Figure 6.12 – The Macintosh XL (Lisa) memory layout](image-url)
handle, which contains the address of the master pointer. The relationship between master pointers and handles is shown in Figure 6.13. Each separately allocated memory area has a master pointer.

Applications code that references a dynamic area uses a technique called double indirection, making it necessary to use two MOVE.L instructions where, ordinarily, only one would suffice:

```
MOVE.L Handle(A5),A0 ; Fetch the handle contents
MOVE.L (A0),A0 ; Convert to address handle
DS.L Handle 1 ; Handle storage
```

The second MOVE.L would not be required if the area were not dynamically allocated.

There is a big problem with this technique, particularly for assembly language applications. Because the dynamic memory scheme is used by most of the operating system, practically any system call you make can move your dynamically allocated memory. If you make a system call with the address of a dynamic area in an address register, forget to reload the address register from the handle, and subsequently use the address register, it might no longer point to the dynamic area. It might instead point to some other unrelated dynamic area. Modifying the dynamic area can cause unpredictable program behavior.

![Figure 6.13 - Dynamic memory pointers](image-url)
This scenario is called the *dangling pointer problem*. It is particularly bad in assembly language because you must code extra instructions to dereference the handle. It is very easy to forget. Worse, a program with this problem may behave normally for a long time. The problem occurs only when a lot of memory is used. Thus, your program may work fine until you try to run it with a desk accessory or with some other system feature that uses more memory, such as a laser printer, network connection, or hard disk.

You can prevent the system from moving a block of dynamic memory by *locking* the memory, using the `_HLock` system call described below. You can then freely use the address of the dynamically allocated area across system calls. However, this is not a general solution to the dangling pointer problem. In programs that use dynamic memory extensively, locking can cause the system to run out of memory due to a condition known as *fragmentation*. Locked blocks limit the flexibility the system usually has in allocating memory. There might be enough memory to satisfy a request for more memory, but, due to the presence of locked areas, the system might not be able to get a single piece large enough.

**Dynamic Memory System Calls**

Most dynamic memory allocation can be done using only four system calls:

1. The `NewHandle` function, which allocates a new block
2. The `_HLock` function, which prevents the system from moving a block
3. The `_HUnlock` function, which allows the system to move a block
4. The `DisposHandle` function, which frees a block

These routines are called as follows:

```
MOVE.L Size(A5),D0         ; D0 = # bytes needed
_NewHandle
TST.W D0                   ; Try to allocate it
BMI                      ; Success?
MOVE.L A0,Handle(A5)      ; Save the handle

MOVE.L Handle(A5),A0      ; Handle to A0
_HLock                    ; Lock it
```
MOVE.L  Handle(A5),A0 ; Handle to A0
_HUnlock

MOVE.L  Handle(A5),A0 ; Handle to A0
_DisposHandle ; Free dynamic area

Handle  DS.L  1       ; Handle storage

All the routines return a completion code in D0. A TST.W D0/BMI sequence tests for errors on any of the above calls. The _NewHandle call requires a size in D0.L, and returns the handle in A0. A0 will be set to zero if the memory is not available.

Resources

A concept related to Macintosh memory management is the resource feature. Most applications use large numbers of small data structures that contain only constant values. The Macintosh resource feature provides the application with a means of fetching a small (or large) data structure from disk on demand. Use of this feature accomplishes two ends:

1. You can write programs such that all user-visible displays can be modified without touching the program source code. This is very useful in writing programs that must be used in many different countries. You can translate all of the program's messages to a different language quite easily.

2. You can save memory since only the items that are needed are loaded from disk into memory.

Macintosh resources are kept in the resource fork of a disk file. Resources can be associated with a document file, an application file, or the system file.

Resource Types

Six bytes are required to identify a resource. Four of these bytes, called the resource type, specify the general class of the resource. Resource types are generally four ASCII letters. For instance, a menu template has a resource type of MENU (four ASCII characters). The remaining two bytes make up a binary number that identifies a specific instance of the resource class. A resource can also have a name, but this feature is not normally used.
Table 6.6 contains some of the more common resource types. This is not a complete list. However, all programs in this book require only this short list of resource IDs. The STR resource ID and all other three-character resource IDs are padded with a trailing space to make four characters.

You can also define resources other than the Macintosh predefined resource types. Any four-byte value can be used. This is generally not required for normal applications.

**RMAKER**

You can create a resource file for an application using the RMAKER program in the Macintosh Development System. With the run-time library described in Chapter 8, you can either place the resources in the same file as your program or use a separate resource file. It is better to use a separate resource file while developing your program, as this reduces the time required to make a change. When the program is finished, you can then combine the program and resource files so that only one file must be copied to move the application to another disk.

RMAKER uses a textfile to define the resources to be created in the output file. The first nonblank, noncomment line of the file is the name of the output file. Placing an exclamation point in front of the file name causes

<table>
<thead>
<tr>
<th>Resource Type</th>
<th>Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALRT</td>
<td>Alert template</td>
</tr>
<tr>
<td>BNDL</td>
<td>&quot;Bundle&quot; resource</td>
</tr>
<tr>
<td>CNTL</td>
<td>Control (e.g., scroll bar) definition</td>
</tr>
<tr>
<td>CODE</td>
<td>Application program code segment</td>
</tr>
<tr>
<td>CURS</td>
<td>Mouse cursor definition</td>
</tr>
<tr>
<td>DITL</td>
<td>Dialog item list</td>
</tr>
<tr>
<td>DLOG</td>
<td>Dialog template</td>
</tr>
<tr>
<td>DRVR</td>
<td>Device driver or desk accessory code</td>
</tr>
<tr>
<td>REF</td>
<td>File reference</td>
</tr>
<tr>
<td>ICN#</td>
<td>List of icons</td>
</tr>
<tr>
<td>ICON</td>
<td>Single icon</td>
</tr>
<tr>
<td>MENU</td>
<td>Menu definition</td>
</tr>
<tr>
<td>STR</td>
<td>String</td>
</tr>
<tr>
<td>STR#</td>
<td>List of strings</td>
</tr>
<tr>
<td>WIND</td>
<td>Window template</td>
</tr>
</tbody>
</table>

*Table 6.6 – Common Macintosh Resource Types*
RMAKER to append resources to an existing file. Thus, for a separate
resource file, the first line of the file might be

```
program.RSRC
```

To add the resources to the end of an existing program, use

```
!program
```

"Program" is the name of the file produced by the linker. The run-time
library appends the string .RSRC to the name specified in the PROGRAM
macro for the application-specific resource file. The file RTL.RSRC is used
if the custom resource file does not exist.

For instance, if you specify the PROGRAM macro as

```
PROGRAM Blivot
```

the run-time library will try to open Blivot.RSRC as the resource file. If
Blivot.RSRC does not exist, the run-time library will open RTL.RSRC
instead.

The remaining lines in the file describe resources to be placed in the
output file. Perhaps the simplest way to do this is to include an existing
resource file in the textfile. The RMAKER INCLUDE statement performs
this function. The syntax of this statement is

```
INCLUDE filename
```

The RMAKER TYPE statement defines a new resource for inclusion in
the output file. A TYPE statement has the following form:

```
TYPE rtyp
[ name1],ID1
(Definition data)
[ name2],ID2
(Definition data)
.
.
```

"Rtyp" is the four-character resource type from Table 6.10. A single TYPE
statement can be used to define multiple instances of the same resource
type. Each resource definition consists of an optional name and a
resource ID (a decimal number). One or more type-specific lines follow.
For example, a string resource (type STR ) requires only the string as
definition data. You can define string resources as follows:

```
TYPE STR
String1,1
This is a named string
,2
This is an unnamed string
,3
Third string
LastString,34
Bench Warmer
```

This example defines four strings, with resource IDs 1–3 and 34. The first and last strings have names.

Other resource types are explained in the description of the sample application later in this chapter.

**Resource IDs**

Resource IDs are 16-bit integers. Different types of resources can have the same ID. A second definition of a resource ID that has already been defined will render the first definition inaccessible. Resource files are searched in reverse order from which they were opened. Thus the current document is searched first, followed by the application file, followed by the system file. This allows you to override application resources in a document file, or to override system resources with either the application file or a document file.

Certain conventions apply to resource ID values. All negative values are used for special purposes by the system. Values 0–127 are also used by the system. Only values 128–32767 are guaranteed to be available for whatever purpose you wish.

**Resource Attributes**

Each resource is associated with a word, called the resource attribute, which contains additional resource characteristics. Figure 6.14 illustrates the format of this word.

Bit 1 of this word indicates whether an in-memory resource has been altered and needs to be rewritten to the resource file. Bit 2 of this word indicates whether the resource is to be loaded into memory when the resource file is first opened. Preloading resources, especially those in an application file, can appreciably improve application performance. Bit 3 is set if the resource is protected. Protected resources cannot be modified on disk except to change the attributes. Bit 4 is set to prevent the resource
from being purged or moved after loading. Bit 5 is set to allow the resource to be purged during a memory allocation operation. Bit 6 is set to cause the resource to be loaded into the system heap.

You can specify resource attributes in the RMAKER input file. Simply enclose the decimal value in parentheses following the resource ID. For example, to preload a string resource, you would specify the following:

```
TYPE STR
  ,1(4)
This string is preloaded
```

**Windows**

Another important Macintosh feature is the window concept. Information presented to the computer user usually appears in a window on the screen. There are three types of windows used in the programs in this book:

1. Document windows
2. Alerts
3. Dialogs

Document windows represent data selected or input by the user, while alerts and dialogs are used for temporary displays (such as error messages).
Document Windows

The windows used by most applications are called document windows. Figure 6.15 shows the structure of a standard Macintosh document window. Most document windows have a title bar, close box, and three areas called controls: the vertical scroll bar, the horizontal scroll bar, and the grow box. The rest of the window is called the content region.

The content region is the area of the window where information is displayed. Each window contains a QuickDraw GrafPort, whose origin is the upper-left corner of the content region. Drawing in the window’s GrafPort causes information to appear on the screen in the content region.

QuickDraw includes the controls in the content region. Normal drawing does not affect the controls because of the QuickDraw _ClipRect call. The run-time library uses this call to prevent the application from drawing in the control area of the window.

The horizontal and vertical scroll bars allow the user to change the area of the document displayed in the window. When the user clicks the mouse in the arrow region of one of the scroll bars, the visible part of the document moves in the indicated direction by a small amount. For text windows, this is usually one line of text. When the user clicks the mouse between the arrow and the thumb, the screen scrolls by a “page” (the size of the window).

The user can also elect to move the thumb along the scroll bar. The screen then displays the area of the document that is proportional to the thumb’s new position in the scroll bar. For example, moving the thumb to the top of the vertical scroll bar displays the beginning of the document. Moving the thumb to the end of the vertical scroll bar displays the end of the document. Moving the thumb to the midpoint of the scroll bar displays the midpoint of the document, and so on.

The run-time library provides several macros that display the correct

![Figure 6.15 - A Macintosh document window](image-url)
position of the thumb following a scrolling operation:

- **SElVMIN** Sets the vertical low value
- **SElVMAX** Sets the vertical maximum value
- **SElVVAL** Sets the vertical current value
- **SETHMIN** Sets the horizontal low value
- **SETHMAX** Sets the horizontal maximum value
- **SETHVAL** Sets the horizontal current value

Each of these macros takes a single 16-bit parameter, which is the value to be set. Normally, you should use the **SElVMIN**, **SElVMAX**, **SETHMIN**, and **SETHMAX** macros at initialization time. This sets the values for the endpoints of the scroll bar. When a scrolling event occurs, call **SElVVAL** or **SETHVAL** to position the thumb correctly within these two endpoints.

The window *grow box* allows the user to change the size of the active window.

**Alerts**

Error conditions in a Macintosh application usually result in the execution of a run-time library ALERT macro, which creates a special window called an *alert box* to appear on the screen. The alert box may have one or more buttons or other input mechanisms. The program continues when the user clicks the mouse on one of the buttons.

There are four types of alerts, as shown in Figure 6.16. The only difference is the icon in the upper-left corner of the alert box. These four alerts are generated by the **ALERT**, **CAUTIONALERT**, **NOTEALERT**, and **STOPALERT** macros. These macros take the resource ID of an alert template as the only parameter. The alert template is a resource that defines the appearance of the alert box. Following the macro, DO.W contains the number of the button selected by the user. A **CAUTIONALERT** (with the question mark) almost always has more than one button, since the user must make some kind of a selection between alternatives.

Associated with each alert template is a 16-bit number called the *stages word*. This word is a series of four-bit fields that define actions on the first, second, third, and subsequent occurrences of the alert. These are the actions the stages word defines:

1. Whether or not the alert box is drawn
2. What kind of sound is emitted
3. Which button is the default (if the user hits Return)

The format of the stages word is shown in Figure 6.17.

The low-order nibble of the stages word defines the action on the first occurrence of the alert. Subsequent nibbles define actions on subsequent
occurrences of the alert. The high-order nibble defines the action on occurrence number 4 and later.
For example, if you wanted the default button to be the first button defined, the alert box to be always drawn, and the sound to increment from 0 beeps to 3 beeps, the alert stages word would be 7654 hex.

Figure 6.16 – Macintosh alerts

Figure 6.17 – The alert stages word
**Dialogs**

Another mechanism employed when the user must make a choice is a dialog. A dialog is similar to an alert, except that no icon is automatically drawn and no stages word defines the action. The DIALOG macro has a single parameter, the resource ID of a dialog template. The dialog template defines a special window, called the dialog box. The DIALOG macro causes the dialog box to be displayed on top of existing windows, and it returns the item number selected by the user in D0.W.

**Menus**

Another method of interacting with the user is the Macintosh menu facility. This feature allows the user to select from a number of options regarding a particular topic. For instance, the File menu normally has options for creating a new file, opening an existing file, saving changes to a file, and printing a file. This menu usually contains the Quit choice, to allow the user to exit back to the Finder.

The normal technique for using menus in a program is to define the menus in the program's resource file. A menu selection is indicated by the menu number and the selection number within that menu. Menus are numbered by their order in the menu bar, starting with menu number 1. Selections within a menu are numbered from top to bottom, with selection number 1 at the top.

Figure 6.18 shows a menu selection in progress. The Apple menu is menu number 1. The selection being made is the last selection in the menu, selection number 9. The gray line between About MacDoodle and Scrapbook counts as a choice, although it cannot be selected.

The run-time library provides for three operations on menus:

1. Enabling and disabling a menu selection
2. Checking and unchecking a menu selection
3. Setting the type style of a menu selection

Figure 6.19 shows the effects of these functions.

**Enabling and Disabling a Menu Selection**

The ENABLE and DISABLE macros allow and disallow selection of an item within a menu. Items that have been disabled are dimmed, as shown...
in Figure 6.19. These macros have the following calling sequence:

```
ENABLE menu,item
DISABLE menu,item
```

"Menu" is the menu number, and "item" is the item number. Both are 16-bit quantities.

![Menu selection](image)

**Figure 6.18** – *Menu selection*

![Menu item attributes](image)

**Figure 6.19** – *Menu item attributes*
Checking and Unchecking a Menu Selection

The CHECK and UNCHECK macros cause the menu item to be preceded by a check mark or a space, respectively. This visually confirms the menu item selection. When selecting a menu item causes subsequent actions to be interpreted differently, you should use the CHECK feature.

These macros have the following calling sequence:

```
CHECK    menu, item
UNCHECK  menu, item
```

"Menu" and "item" are the menu number and item number, respectively. Both are 16-bit quantities.

Setting Menu Item Style

The STYLE macro sets the text style associated with a menu item. This macro has the following calling sequence:

```
STYLE    menu, item, style
```

"Menu" and "item" are the menu and item numbers. "Style" is a 16-bit quantity described in Figure 6.10.

Events

Typical Macintosh applications are event-driven. These programs wait for an external event, process it, and wait for the next event. The Macintosh Toolbox defines 16 basic event types. The run-time library handles a few of the Macintosh events directly and partially processes others. This allows the application code to be small because a lot of event-handling code is in the run-time library.

The GETEVENT Macro

The GETEVENT macro is the center of the event code in an application that uses the run-time library. This macro has one optional parameter, the resource ID of whatever cursor is to be used when the mouse is inside the application window. If the parameter is omitted, the I-beam (text) cursor is used. The system provides five standard cursors, which you can use without any definition:

<table>
<thead>
<tr>
<th>Code</th>
<th>Resulting Cursor</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Arrow</td>
</tr>
<tr>
<td>1</td>
<td>I-beam (text)</td>
</tr>
</tbody>
</table>
These cursors are shown in Figure 6.6. In addition, you can define a CURS resource in the application resource file for use with the GETEVENT macro. This will be described in detail in the sample application.

The macro returns two registers: D0.L and D1.L. The low word of D0 is a code indicating the type of event. D1 and the high word of D0 are additional parameters for some of the event types. Table 6.7 shows the return values from the GETEVENT macro.

Normal applications ignore null (0), mouse-up (2), key-up (4), disk-inserted (7), abort (9), network (10), driver (11), and the application (12–15) events. Events with codes greater than 15 are run-time library extensions to the Macintosh events.

**Mouse Down**

A mouse-down event is generated when the mouse button is pressed and the mouse is inside the content region of the application window. All other uses of the mouse, such as menu selection, window dragging, scrolling, and window sizing are at least partially handled by the run-time library. All of the extra events defined by the library are partially processed mouse-down events.

A mouse-down event reports the mouse position as a point in D1.L. The vertical coordinate is in the high word, and the horizontal coordinate is in the low word. The point is in the local coordinate system of the application window, so you can use it directly in QuickDraw calls.

**Key Down and Repeated Key Down**

A key-down event returns the character code in the low byte of D1. The high-order word of D0 contains a word that gives the status of the modifier keys on the keyboard. The bits of this word are arranged as follows:

<table>
<thead>
<tr>
<th>Bit</th>
<th>Meaning If Set</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–7</td>
<td>(Not used)</td>
</tr>
<tr>
<td>8</td>
<td>Command key down</td>
</tr>
<tr>
<td>9</td>
<td>Shift key down</td>
</tr>
<tr>
<td>10</td>
<td>Caps Lock key down</td>
</tr>
<tr>
<td>11</td>
<td>Option key down</td>
</tr>
</tbody>
</table>
When the user holds a key down, the key begins to repeat after a certain amount of time. Settings on the Control Panel desk accessory control the time before repeating begins and the rate of repetition. Repeated keys are identical to regular keystrokes, except that they have different event codes.

**Window Update**

A window-update event indicates that some portion of the window needs to be redrawn. The run-time library takes care of everything except the window content area. The normal way of handling this type of event is to redraw the entire window. Register D1.L contains the address of the window to be updated.

Update events are generated any time window overlapping changes. Dialog and alert boxes generate an update event once the user selects an

<table>
<thead>
<tr>
<th>Code</th>
<th>D0 Low</th>
<th>D0 High</th>
<th>D1 High</th>
<th>D1 Low</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>No event is ready</td>
</tr>
<tr>
<td>1</td>
<td>–</td>
<td>Mouse V</td>
<td>Mouse H</td>
<td>–</td>
<td>Mouse down (D1 = point)</td>
</tr>
<tr>
<td>2</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>Mouse up</td>
</tr>
<tr>
<td>3</td>
<td>Modifier</td>
<td>–</td>
<td>Character</td>
<td>–</td>
<td>Key down</td>
</tr>
<tr>
<td>4</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>Key up</td>
</tr>
<tr>
<td>5</td>
<td>Modifier</td>
<td>–</td>
<td>Character</td>
<td>–</td>
<td>(Repeated) Key down</td>
</tr>
<tr>
<td>6</td>
<td>–</td>
<td>Window Address</td>
<td>–</td>
<td>–</td>
<td>Update-window event</td>
</tr>
<tr>
<td>7</td>
<td>–</td>
<td>–</td>
<td>Drive #</td>
<td>–</td>
<td>Disk-inserted event</td>
</tr>
<tr>
<td>8</td>
<td>–</td>
<td>Window Address</td>
<td>–</td>
<td>–</td>
<td>Activate event</td>
</tr>
<tr>
<td>9</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>Abort event</td>
</tr>
<tr>
<td>10</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>Network event</td>
</tr>
<tr>
<td>11</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>Driver event</td>
</tr>
<tr>
<td>12–15</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>Application event #1–#4</td>
</tr>
<tr>
<td>16*</td>
<td>–</td>
<td>Menu #</td>
<td>Item #</td>
<td>–</td>
<td>Menu selection</td>
</tr>
<tr>
<td>17*</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>Close-window event</td>
</tr>
<tr>
<td>18*</td>
<td>–</td>
<td>Height</td>
<td>Width</td>
<td>–</td>
<td>Resize window event</td>
</tr>
<tr>
<td>19*</td>
<td>SType</td>
<td>Control ID</td>
<td>–</td>
<td>–</td>
<td>Plain scroll event</td>
</tr>
<tr>
<td>20*</td>
<td>Value</td>
<td>Control ID</td>
<td>–</td>
<td>–</td>
<td>Vertical thumb scroll</td>
</tr>
<tr>
<td>21*</td>
<td>Value</td>
<td>Control ID</td>
<td>–</td>
<td>–</td>
<td>Horizontal thumb scroll</td>
</tr>
</tbody>
</table>

* Run-time library extension

* Table 6.7 - The GETEVENT macro return values
item and the box disappears. A desk accessory can also cause an update event. A menu selection does not generate an update event, however.

**Window Activate**

A mouse click inside an inactive window results in an activate event for the inactive window and a deactivate event for the active window. A 1 in bit 16 of D0 activates a window and a 0 deactivates a window. D1.L contains the address of the affected window. The run-time library handles the normal actions (such as highlighting the title bar) for activate events, so most applications can ignore them. When a window is activated, it need not be redrawn. An update event will exist to do this (if necessary).

**Menu Selection**

Menu selection causes an event to be generated by the run-time library. The menu number is in the high word of D1, and the selection number in the low word. Menu selection using both the mouse and keyboard equivalents results in a menu-selection event.

A menu-selection event is a run-time library extension to the Macintosh event system. The library processes mouse and keyboard events, filtering out and reporting menu selections separately. This technique is used for all events with codes 16 or greater.

**Close Window**

Another extension to the Macintosh event system is the close-window event. This event results when the user clicks the mouse in the close box of the application window. The application usually reacts to this kind of event by simply closing the file displayed in the active window. Some Macintosh applications, such as MacPaint and MacWrite, close the window and also require the user to perform an Open or New operation before any further data is displayed.

**Window Sizes**

The run-time library automatically handles user resizing of the application window. When the user clicks the mouse in the window's grow box, run-time code performs the operations necessary to change the window size. The code then generates a resize event. Register D1 contains the new size of the window's content region. Your application should redraw the content region based on the new window size.
**Scrolling**

If the run-time library is configured to operate with window size and scrolling controls, it can generate three events associated with the scroll bars:

1. Line/page scroll (19)
2. Vertical thumb scroll (20)
3. Horizontal thumb scroll (21)

These three events are extensions to the standard Macintosh event set. The line/page-scroll event covers all scrolling done using the arrows and page scroll regions of both scroll bars. The two thumb-scroll events cover the movement of the thumb in a single scroll bar.

*Line/Page Scroll*  Figure 6.20 shows the layout of a standard scroll bar. (The vertical scroll bar is exactly equivalent.)

Clicking the mouse in the line or page scroll region is reported through a line/page-scroll event. D1.L contains the control handle for the scroll bar. The high word of D0 contains a code that indicates the type of scrolling selected by the user:

<table>
<thead>
<tr>
<th>Scroll Code</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Line scroll up</td>
</tr>
<tr>
<td>1</td>
<td>Line scroll down</td>
</tr>
<tr>
<td>2</td>
<td>Page scroll up</td>
</tr>
<tr>
<td>3</td>
<td>Page scroll down</td>
</tr>
</tbody>
</table>

*Figure 6.20 – Scroll bar regions*
Scroll Code  Meaning
4       Line scroll left
5       Line scroll right
6       Page scroll left
7       Page scroll right

The application is responsible for scrolling the document in the window by the proper amount in the proper direction. Also, the application must set the thumb value using the SETVVAL or SETHVAL macros.

Macintosh applications typically repeat the above scrolling actions until the mouse button is released. Using the run-time library, you can accomplish this easily with the TRACK macro. This is the calling sequence:

```
TRACK controlid,scrollproc
```

"Controlid" is the control handle from the event (as returned by events 19–20), and "scrollproc" is the address of a procedure that performs a single instance of the desired scrolling. This procedure is called repetitively as long as the mouse button remains down.

A Pascal calling sequence (such as described in Chapter 5) is used to call the scrolling procedure. Figure 6.21 shows the structure of the stack on entry to the scrolling procedure.

Your scrolling procedure must pop the parameters off the stack before returning to the caller. The scroll bar handle is a copy of the contents of D1 when the event was reported by the GETEVENT macro. The "part code" indicates which part of the scroll bar is affected. If this quantity is zero, the mouse button is still down, but the mouse has been moved outside of the original scroll bar region. Your scroll procedure should simply return if this is the case. Nonzero part codes include the following:

<table>
<thead>
<tr>
<th>Part Code</th>
<th>Scroll Bar Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>Up (left) arrow</td>
</tr>
<tr>
<td>21</td>
<td>Down (right) arrow</td>
</tr>
<tr>
<td>22</td>
<td>Page up (left) region</td>
</tr>
<tr>
<td>23</td>
<td>Page down (right) region</td>
</tr>
</tbody>
</table>

```
<table>
<thead>
<tr>
<th>Return Address</th>
<th>0(SP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Part Code</td>
<td>4(SP)</td>
</tr>
<tr>
<td>Scroll Bar Handle</td>
<td>6(SP)</td>
</tr>
</tbody>
</table>
```

*Figure 6.21—Scrolling procedure parameters*
If you store the original code from the scrolling event, you will not need the parameters to the scrolling procedure. Listing 6.28 (later in the chapter) illustrates the use of a scrolling procedure.

**Thumb Scrolling** A thumb-scroll event indicates that the user has manipulated the thumb in a scroll bar. The event code in D0.W indicates which scroll bar has been changed. The high word of D0 contains the final value of the thumb position. You should set the minimum and maximum values for the scroll bar during initialization and after resizing the window. The value reported in D0 will be in the range defined by the minimum and maximum values. You need only redisplay the appropriate part of the document in the window to respond to a thumb-scroll event. A judicious choice of minimum and maximum values will facilitate finding the right portion of the document to display.

**MACINTOSH PROGRAMMING RESTRICTIONS**

The structure of the Macintosh systems software imposes some limitations on your flexibility in writing 68000 assembly language code. These are the most serious constraints:

- The requirement for position-independent code
- Size limitations on code and data segments
- Heap compaction requirements

**Position-Independent Code**

Many 68000 systems perform an operation known as *load-time relocation* when loading a program into memory. The linker on those systems prepares a section of the program file called a *relocation dictionary*. The information contained in the relocation dictionary identifies each memory address within the program. The linker assumes an address called the link address for the first location in the program. If the load address is different from the link address for the first location in the program, the loader uses the relocation dictionary to adjust all the addresses in the program.

The Macintosh does not do this. Macintosh programs must not contain absolute addresses. This means that you cannot use absolute addressing for labels within your program or data. You can use absolute addresses for locations outside your program, such as the low address area used for system globals. Code that meets these requirements is called *position independent*, and can be loaded anywhere in memory with no relocation.
Program references must, therefore, use either the PC-relative or address-register-relative addressing modes in instructions. The assembler automatically generates the PC-relative mode for instructions that reference labels which are not on a DS directive. Unfortunately, the PC-relative addressing modes are not legal for the destination operand of an instruction. This means that you cannot modify a data item defined with a DC directive using a simple instruction reference. You must use an address register reference similar to the one in Listing 3.1. Data that require modification should therefore be defined with a DS directive. This means that each reference to these data must specify an address register with displacement mode using A5. (The assembler could and should do this for you. It does not.) If you forget to specify this mode on a source reference, the assembler will cheerfully generate an instruction that references incorrect data. The assembler will report such an error on a destination operand, however. If the data require an initial value, you must add code to explicitly initialize it.

Address constants present another problem that stems from the Macintosh loader. On systems with relocation, you can specify a DC.L directive with a label as an operand. This generates a longword containing the absolute address of the label, which is then relocated by the loader. On the Macintosh, you must construct the address by defining the constant as the difference between two labels and performing the appropriate relocation by adding the effective address of one label to get to the other label.

**Size Limitations**

A problem related to the lack of relocation is the size limitation on program code and data segments. This stems from the use of 16-bit addressing modes. The 68000 has no modes allowing 32-bit address displacements (other than for absolute addresses). The best that can be done is a 16-bit signed offset (+/− 32K) relative to some base address in an address register or the program counter (PC). Program code and initialized data cannot be larger than 32K (32,768) bytes. You can have more than 32K of program space by using the segment loader (described in *Inside Macintosh*) to load code in 32K chunks.

The uninitialized (AS-relative) data area is also limited to 32K by the 16-bit displacement on the address-register-relative addressing mode. Larger data areas must be dynamically allocated with memory management calls.

**Heap Compaction Problems**

Of course, dynamically allocated arrays are subject to the dangling pointer problems presented previously. This implies that handles, not
addresses, of dynamic areas must be used. Using handles can be cumbersome, particularly in linked-list manipulation.

SAMPLE APPLICATION

The remainder of this chapter describes the code for a sample application called MacDoodle. MacDoodle is a "poor man's MacPaint." This sample application illustrates the very basic concepts behind a paint program, including simple geometric shapes, text, and printing. It is not nearly as sophisticated as MacPaint, but it is small enough to be readily understood.

MacDoodle Menu Operation

The MacDoodle program can be started by opening the application file or by opening or printing a MacDoodle document from the Finder. MacDoodle documents are compatible with all versions of MacPaint; MacDoodle can read a MacPaint document and MacPaint can read a MacDoodle document. The program that last saved a particular document will be invoked when the document is opened from the Finder.

MacDoodle has a single window and seven menus. The window is a standard Macintosh document window, with scroll bars and a size box. Figure 6.18 shows the MacDoodle menu bar. The first menu is the Apple menu, which contains a standard "About ..." choice and the desk accessories. The other menu selections are File, Edit, Draw, PenSize, Font, and Style. They are described below.

File

Figure 6.22 shows the File menu selections. The New choice clears the window and the internal file buffer. Open reads an existing file into memory, using the POPEN macro to display the file names. Save saves the file using its existing name. Save As allows the user to specify a new name for the file using the PCREATE macro dialog. Save behaves like Save As if the file has not been created. Print prints the document, and Quit returns the user to the Finder.

Edit

The Edit menu in Figure 6.23 has the standard Undo, Cut, Copy, and Paste choices. Only the Undo choice is supported by MacDoodle. The others are used by desk accessories invoked while MacDoodle is running. These programs rely on the presence and position of these items.
Draw

The Draw menu is shown in Figure 6.24. The option you choose from this menu determines what effect dragging the mouse in the window content area will have.

Selecting Lines lets the user draw straight lines from the point where the mouse button is pressed to the point where it is released. Boxes and Ovals draw rectangles and ellipses, respectively, while the mouse button is down. Freehand acts like the pencil selection in MacPaint—while the mouse button is down, each movement of the mouse is plotted as a point on the screen. Text allows the user to enter a line of text. All the text fonts and attributes are supported by MacDoodle. The Eraser selection performs like freehand drawing, except that the area under the mouse form is erased rather than plotted. Erase Screen erases the area of the document displayed in the window.

![Figure 6.22 – The MacDoodle File menu](image)

![Figure 6.23 – The MacDoodle Edit menu](image)
**PenSize**

The PenSize menu (shown in Figure 6.25) controls the size of the graphics pen. The pen shape is always square, and the pen pattern is always solid black.

Pen sizes range from a 1 x 1 to a 16 x 16-pixel square. The PenSize menu affects the thickness of the objects drawn by Lines, Boxes, Ovals, Freehand, and Eraser selections on the Draw menu. The mouse cursor for the Lines and Freehand selections is a solid black square the same size as the pen size. The cursor for the Eraser is a hollow square that corresponds to the pen size. The cursor for Boxes and Ovals is always a cross.

**Font**

The Font menu is shown in Figure 6.26. Fonts not present in the System file are disabled automatically.

**Style**

The Style menu, shown in Figure 6.27, allows the user to select text attributes and scaling. The user can select any combination of attributes, with two exceptions. Selecting Plain text disables all of the other attributes, and the Compressed and Expanded options are mutually exclusive. Real font sizes are indicated by changing the proper menu selections. The 12 point selection in Figure 6.27 illustrates this technique. This indicator changes each time the user selects a new font from the Font menu.

![Figure 6.24 - The MacDoodle Draw menu](image-url)
Structure of MacDoodle

The MacDoodle code is divided into three parts:

1. The main program containing the event loop
2. Routines associated with menu processing
3. Routines associated with drawing

These routines communicate by means of shared global variables and subroutine calls. The picture being drawn resides in dynamically allocated buffers. The main routine consists of a loop that calls GETEVENT and then calls the appropriate routine in each of the other modules to process the event. The entire application is based on responses to external events. A complete source listing is available in Appendix E.

![PenSize menu](image)
Buffers

The MacDoodle buffering structure is a key element in understanding the way this program works. There are three buffers: a file buffer, a screen buffer, and an undo buffer. Each of these is dynamically allocated and can therefore be moved as a result of a system call. Figure 6.28 shows the relationship of these buffers.

A MacPaint document covers an 8.5 x 11 sheet of paper, or 576 x 720 pixels. Only part of such a document can be displayed on the screen at one time. MacPaint documents are stored on disk in packed form, using the _PackBits routine described previously. A document is packed one row at a time (576 pixels or 72 bytes). There is also a 512-byte header at the beginning of the file.

The file buffer contains the information that is not displayed on the screen. It consists of two separate areas, one at the beginning of the file and one at the end. These areas are stored in packed format to reduce memory usage. Information between these two regions is stored in the screen buffer.

The screen buffer consists of a bitmap image of the portion of the document currently displayed on the screen. Because the information is packed a row at a time, the screen buffer contains complete rows. The number of rows in the screen buffer depends on the size of the window.

Figure 6.26 – The MacDoodle Font menu
The undo buffer contains a packed version of the previous data in the screen buffer. When an Undo operation is selected, the contents of this buffer replace the contents of the screen buffer. MacDoodle packs a copy of the screen buffer data into the undo buffer before each drawing operation. This effectively allows the user to back up one operation.

Another buffer contains the MacPaint file header. A file created with MacDoodle will have 512 bytes of zero in the header. MacPaint uses this area to store the patterns for the document. MacDoodle preserves the header when opening an existing file.

**Global Variables**

State information, such as current menu selections, is kept in global variables. These variables are generally set by the menu routines when the

![Figure 6.27 - The MacDoodle Style menu](image)

*Figure 6.27 - The MacDoodle Style menu*
user selects options, then referred to by the drawing routines as the user
performs drawing actions.

Information that can be encoded in a single bit is contained in the Flags
byte. There are macros that clear a flag, set a flag, and test a flag. These
macros are called CLRFLAG, SETFLAG, and TSTFLAG, respectively. They
each have a single parameter, the name of the flag. The possible flag
names are listed below:

<table>
<thead>
<tr>
<th>Bit</th>
<th>Name</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>F_File</td>
<td>Set when the buffer has a valid file name</td>
</tr>
<tr>
<td>1</td>
<td>F_Change</td>
<td>Set when the buffer has been changed but the changes have not been saved in a file</td>
</tr>
<tr>
<td>2</td>
<td>F_Text</td>
<td>Set during text entry</td>
</tr>
</tbody>
</table>

In addition to the Flags byte, there are a number of global variables that
are used by all modules in the program. They are listed below:

<table>
<thead>
<tr>
<th>Name</th>
<th>Data Type</th>
<th>Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cursor</td>
<td>Word</td>
<td>Resource ID of current cursor</td>
</tr>
<tr>
<td>DrwType</td>
<td>Word</td>
<td>Current Draw menu selection number</td>
</tr>
<tr>
<td>FBEnd</td>
<td>Word</td>
<td>Bytes in last part of file buffer</td>
</tr>
<tr>
<td>FBStart</td>
<td>Word</td>
<td>Bytes in first part of file buffer</td>
</tr>
<tr>
<td>FBufSiz</td>
<td>Long</td>
<td>Size of file buffer</td>
</tr>
<tr>
<td>FileBuf</td>
<td>Long</td>
<td>File buffer handle</td>
</tr>
<tr>
<td>FName</td>
<td>String</td>
<td>File name in buffer</td>
</tr>
<tr>
<td>FontNum</td>
<td>Word</td>
<td>Current font resource ID</td>
</tr>
<tr>
<td>FontSel</td>
<td>Word</td>
<td>Current Font menu selection number</td>
</tr>
</tbody>
</table>

![Diagram of buffer structure](image)

*Figure 6.28 – The MacDoodle buffer structure*
<table>
<thead>
<tr>
<th>Name</th>
<th>Data Type</th>
<th>Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>PenSize</td>
<td>Word</td>
<td>Current PenSize menu selection number</td>
</tr>
<tr>
<td>PenType</td>
<td>Word</td>
<td>1 for eraser, 2 for drawing</td>
</tr>
<tr>
<td>SPoint</td>
<td>Point</td>
<td>Point for window origin</td>
</tr>
<tr>
<td>SRow</td>
<td>Word</td>
<td>First row number in screen buffer</td>
</tr>
<tr>
<td>SSize</td>
<td>Point</td>
<td>Window content region size</td>
</tr>
<tr>
<td>TextFlg</td>
<td>Word</td>
<td>Current text attribute word</td>
</tr>
<tr>
<td>TextSel</td>
<td>Word</td>
<td>Current Text Size menu selection number</td>
</tr>
<tr>
<td>TextSiz</td>
<td>Word</td>
<td>Current text size in points</td>
</tr>
<tr>
<td>VolRef</td>
<td>Word</td>
<td>Volume reference number for file</td>
</tr>
<tr>
<td>WPointer</td>
<td>Long</td>
<td>Window address</td>
</tr>
</tbody>
</table>

Macros and global variables are defined in the part of the program that is not listed in this chapter. See Appendix E for these definitions.

**Event Code**

Listing 6.1 contains the MacDoodle main routine. This part of the program executes first and controls the operation of the rest of the program.

Lines 5–6 save the window address and size from the PROGRAM macro in global variables. Line 7 clears the Flags variable. Lines 8–9 call the initialization routines for the draw and menu code. Lines 14–18 form the event loop for MacDoodle. The return code from the GETEVENT macro serves as an index into a table of JMP instructions. The JSR at line 17 transfers control to the proper JMP instruction, which transfers control to the proper routine. The jump table occupies lines 22–44. The codes returned by GETEVENT appear in the comment field of each entry in the table.

The cursor global variable is the resource ID or the cursor displayed in the document window. The cursor is determined by the Draw and PenSize menus.

**Menu Code**

The menu module of the MacDoodle program contains code that modifies the global data area to allow changes in the drawing mode. This code consists of an initialization routine, a dispatch routine, and code for each menu selection.

**Initialization**

The first part of the menu initialization code allocates the dynamic buffers. Listing 6.2 contains this code.
1: Program MacDoodle, DEBUGOFF, nMenu
2: ;
3: ; Perform initialization code
4: ;
5: MOVE.L AO, WPointer(A5) ; Save window address
6: MOVE.L DO, SSize(A5) ; " " size
7: CLR.B Flags(A5) ; Clear Flags byte
8: JSR Drawinit ; Call initialization routines
9: JSR Menuinit ;
10: ;
11: ; This is the top of the event loop. Get an event from the run-time
12: ; library routine, and call the proper routine to process it.
13: ;
14: EVLoop: GETEVENT Cursor(A5) ; Get next event
15: LSL.W #2, DO ; Multiply by 4
16: LEA JmpTab, AO ; AO -> Jump array
17: JSR 0(AO, DO) ; Jump to event handler
18: BRA EVLoop ; Get next event
19: ;
20: ; Event Jump Table
21: ;
22: JmpTab:
23: JMP NullEvt ; 0 No event, get next
24: JMP Mouse ; 1 Mouse down in window
25: JMP NullEvt ; 2 Mouse up, ignore
26: JMP KeyDown ; 3 Key down
27: JMP NullEvt ; 4 Key up, ignore
28: JMP KeyDown ; 5 Autokey (same as key down)
29: JMP Update ; 6 Update event
30: JMP NullEvt ; 7 Disk event, ignore
31: JMP NullEvt ; 8 Activate event, ignore
32: JMP NullEvt ; 9 Abort event, ignore
33: JMP NullEvt ; 10 Network event, ignore
34: JMP NullEvt ; 11 Driver event, ignore
35: JMP NullEvt ; 12 Application event #1
36: JMP NullEvt ; 13 Application event #2
37: JMP NullEvt ; 14 Application event #3
38: JMP NullEvt ; 15 Application event #4
39: JMP MenuEvt ; 16 Menu choice
40: JMP CloseEvt ; 17 Close window event
41: JMP ReSize ; 18 Resize window event
42: JMP DoScroll ; 19 Scroll event
43: JMP VScroll ; 20 Scroll V with thumb
44: JMP HScroll ; 21 Scroll H with thumb
45: NullEvt RTS ; Null event handler
46: ENDP

Listing 6.1 - MacDoodle event code
Lines 1–5 illustrate how to define Macintosh trap numbers. On a 512K Macintosh, you would normally use the MacTraps.D Include file supplied with the Macintosh Development System to define all the trap numbers. Defining the trap numbers individually allows you to conserve memory space during assembly. Large files will not assemble on a 128K Macintosh unless you do this.

Lines 7–12 allocate the file buffer. Buffer sizes are done with equates in this program. A fancier version of MacDoodle might allocate the buffers when a file is opened (or the New selection is chosen). This code is duplicated for the undo buffer, the screen buffer, and the header buffer in subsequent lines.

The next part of the initialization code checks to see which fonts exist in the System file. The code uses the _RealFont system trap to perform this function, as shown in Listing 6.3.

There is a table of font resource IDs at the label “Fonts”. The table is terminated by a word containing –1. The loop in lines 3–13 calls

```
1: .TRAP _NewHandle $Al22 ; NewHandle trap word
2: .TRAP _HLock $A029 ; Lock dynamic area
3: .TRAP _HUnlock $A02A ; Unlock dynamic area
4: .TRAP _GetFName $ABFF ; Get font name trap
5: .TRAP _RealFont $A902 ; Real font trap
6: MenuInit
7: MOVE.L #FileSize,DO ; File buffer size
8: MOVE.L DO,FBufSiz(AS) ; Remember for later
9: _NewHandle ; Get buffer
10: MOVE.L AO,FileBuf(A5) ; Store handle
11: TST.L FileBuf(A5) ; Really got it?
12: BEQ MemError No, complain
13: MOVE.L #UnDoSize,DO ; Allocate
14: MOVE.L DO,UnDoBufSiz(A5) ;
15: _NewHandle undo buffer
16: MOVE.L AO,UnDoBuf(A5) ;
17: TST.L UnDoBuf(A5) ; Got it?
18: BEQ MemError No
19: MOVE.L #ScrSize,DO ; Get
20: MOVE.L DO,ScrBufSiz(A5) ; screen buffer
21: _NewHandle ;
22: MOVE.L AO,ScrBuf(A5) ; Set buffer handle
23: TST.L ScrBuf(A5) ; Got it?
24: BEQ MemError No
25: MOVE.L #HdrSize,DO ; Get
26: MOVE.L DO,HdrBufLen(A5) ; header buffer
27: _NewHandle ;
28: MOVE.L AO,HdrBuf(A5) ; Set buffer handle
29: TST.L HdrBuf(A5) ; Got it?
30: BEQ MemError No
```

[Listing 6.2 – The MacDoodle dynamic buffer initialization]
GetFName for each font ID in the table. If no name exists for the font ID, the font is not in the System file. The corresponding menu selection is disabled at line 11 in this case. Note that the table and the menu definition must agree. If you change either of these, you must also change the other.

The final initialization code sets up default values for the menu settings. This code is shown in Listing 6.4.

Line 1 initializes the file name to the null string. Lines 2–6 set the default values for the Draw menu. Lines 7–8 set the text style for the Compressed and Expanded selections in the Style menu. Text style for the other menu

```
1: LEA Fonts,A3 ; A3 -> Font table
2: MOVEQ.L #1,D3 ; D3 counts menu items
3: RFontLoop ; Top of loop
4: MOVE.W (A3)+,D0 ; Fetch font ID
5: BLT RPDone ; LT => End of list
6: MOVE.W D0,-(SP) ; Push font ID
7: PEA FName(A5) ; -> Return name space
8: GetFName
9: TST.B FName(A5) ; Any bytes in string??
10: BNE WasFont ; Yes, font must exist
11: DISABLE #mFont,D3 ; Disable the entry
12: WasFont ADDQ.L #1,D3 ; Bump entry number
13: BRA RfontLoop ; Loop till fonts exhausted
14: RPDone:
```

Listing 6.3 – The MacDoodle Font menu initialization

```
1: CLR.B FName(A5) ; Initialize file name to null
2: MOVE.W #2,DrwType(A5) ; Set DrwType variable
3: MOVE.W #2,PenType(A5) ; Set pen type for cursor
4: MOVE.W #1, PenSize(A5) ; Set pen size
5: CHECK #mDraw,#2 ; Check Freehand
6: CHECK #mPen,#1 ; Check 1 x 1 pen size
7: STYLE #mStyle,#7,#mCompress; ; Change Compressed style
8: STYLE #mStyle,#8,#mExpand; ; Change Expanded style
9: BSR Plain ; Make text plain
10: MOVE.W #SizeBase,D1 ; Set size to minimum
11: MOVE.W D1,TextSel(A5) ; Set up so UNCHECK won't bomb
12: BSR TSize ; Go set size
13: MOVE.W #1,D1 ; Check first font entry
14: MOVE.W D1,FontNum(A5) ; Set up so UNCHECK won't bomb
15: BSRSetFont ; Set it
16: MOVE.W #1,D1 ; Go init cursor
17: BSR SetPen ; Choose single-pixel pen
18: BSR New ; Clear out junk
```

Listing 6.4 – The final menu initialization
items is set in the resource file. Lines 10–12 set the text size part of the Style menu. Lines 13–15 initialize the Font menu to the first selection. Lines 16–17 select the 1 x 1 entry in the PenSize menu. Line 18 initializes the buffer by calling the New File menu selection routine.

**Application Parameters**

After initialization, MacDoodle checks for application parameters. When you select one or more documents in the Finder, and then choose Open or Print from the File menu, the Finder passes the file names to the application by means of an area of memory called the application parameter area. The format of this area is shown in Figure 6.29.

Offset 16 from register A5 contains a handle to the application parameter area. The action code word contains a 0 if the files are to be opened, and a 1 for printing. The file count word contains the number of file descriptions that follow. This word is zero if the user opens the application instead of a document. The file descriptions that follow contain the volume reference number, file type, version number, and file name. Note that the file name is a variable-length Pascal string. File descriptions always begin on a word boundary. There might be an unused byte at the end of a file name to allow the next volume reference number to begin on a word boundary.

Listing 6.5 contains the code that processes the application parameters for MacDoodle. Lines 1–2 compute the address of the parameter area. Lines 3–5 check the file count and do nothing if there are no file descriptions present. Lines 6–11 move the file name from the parameter area into the FName global variable. Line 12 copies the volume reference number to another global variable. Lines 13–17 open the file, checking for errors. At line 18, code from the normal open routine is called as a subroutine. This code displays the file in the window, and sets the window title to the file name. Line 19 checks the file flag. If this flag was set, the file was processed properly. Lines 21–27 decide whether to start processing events (if the action code is open) or to print the file and exit (if the action code indicates print). Lines 28–30 list the error routine for memory allocation failure.

**Dispatching**

Now that the menu initialization is done, let's see how menu events are dispatched. MacDoodle handles menu events using a common section of code. This code takes the menu number and selection number, indexes them into a two-dimensional array of routine addresses, and jumps to a routine that handles the event. There is an entry in the table that
corresponds to each possible menu/selection combination. Listing 6.6 shows the menu dispatcher.

Lines 1–2 change a window close event to a New menu selection. Lines 10–12 close any open text entry before processing the event. Lines 13–17 place the menu item number in D2 and the menu number in D3. This code also makes these numbers zero-relative, for use in indexing.

![Figure 6.29 - Application parameters](image)
Remember that the run-time library handles menu number 1. This is the reason why line 16 subtracts two from the menu number. Lines 19–21 compute the table index, and lines 22–23 jump to the right routine. Note that the menu item number (still 1-relative) remains in D1.W as a result of the SWAP instruction at line 18. Many of the menu routines need this quantity for the CHECK or STYLE macros. Lines 24–25 show the code which handles menu items that cannot be selected unless there is an error in the program.

Lines 29–50 define the menu routine address table. The JTAB macro generates a word for each operand, containing the difference between the operand and the label JBASE. The code generated looks like this:

```
DC.W %1-JBASE ; First operand
DC.W %2-JBASE ; Second operand
(etc.)
```

```
1: MOVE.L ParmHdl(A5),A4 ; A4 -> Parameter area
2: MOVE.L (A4),A4
3: TST.W PCount(A4) ; Any files there?
4: BNE @1 ; Yes, go process
5: RTS
6: @1 LEA PName(A4),AO ; AO -> Finder-supplied name
7: LEA FName(A5),Al ; Al -> File name area
8: CLR.W DO ; DO = Count byte
9: MOVE.B (AO),DO
10: @2 MOVE.B (AO)+,(Al)+ ; Move to expected area
11: DBRA DO,@2
12: MOVE.W PVref(A4),VolRef(A5); Save volume reference #
13: OPEN FName(A5),DEFAULT,PVRef(A4); Open file
14: MOVE.W DO,d2 ; Save file number
15: BPL @3 ; If OK
16: StopAlert #OErr ; tell user we couldn't do it
17: @3 EXIT ; then quit
18: @4 BSR OpenOK ; Complete the open
19: TstFlag F File ; Did it go ok?
20: BEQ @3 ; EQ => No, alert already done
21: MOVE.L ParmHdl(A5),A4 ; Reload
22: MOVE.L (A4),A4
23: TST.W PMsg(A4) ; Open or print
24: BEQ @5 ; EQ => Just open
25: BSR xPrint ; Else, print file
26: EXIT ; and quit
27: @5 RTS ; File now open
28: MemError ; Here if out of memory
29: StopAlert #MemErr ; Quit
30: EXIT
```

**Listing 6.5 – Application parameter handling**
1: CloseEvt:                 ; Called from the event loop
2:     MOVE.L #$20001,D1   ; Fake out menu handler
3:     ;
4: Menu Event Handler. Entered with constant 10 (hex) in DO.W,
5: and the menu number in DL.W. The high word of DL has the selection
6: number. The menu number is in the range 2-n and the choice number
7: is in the range 1-n. (RTL handles menu #1, the Apple menu.)
8:     ;
9: MenuEvt:                 ; Here for a menu choice
10:    TstFlag F Text      ; Text open?
11:     BEQ @1            ; No, continue
12:     JSR CloseText     ; Yes, close first
13: @1:     MOVE.W D1,D2  ; Copy menu choice to D2
14:     SUBQ.W #1,D2      ; Force choice zero relative
15:     SWAP DL           ; Menu number to DL.W
16:     SUBQ.W #2,D1      ; Force zero relative
17:     MOVE.W DL,D3      ; Copy to D3
18:     SWAP DL           ; Choice back to DL.W
19:     MULU #Menu-1,D2   ; Multiply D2 by # menus
20:     ADD.W D2,D3       ; Add in menu choice
21:     LSLW #1,D3        ; Multiply by entry size (word)
22:     MOVE.W JBASE(D3.W),D3 ; Fetch offset word
23:     JMP JBASE(D3.W)  ; Go to routine
24: Void:                     ; Here if a real problem
25:     EXIT              ; Fade away
26:     ;
27: Define menu jump table
28:     ;
29: JBASE:                     ; Offset for jump
30:     ;
31:     |----|----|----|----|----|----|
32:     |File| Edit| Draw| Pensize| Font| Style|
33:     |-----|-----|-----|--------|-----|------|
34:     |JTAB| New,| Undo,| Lines,| SetPen,| SetFont,| Plain ; 1|
35:     |JTAB|xOpen,| Void,| FreeH,| SetPen,| SetFont,| TStyle ; 2|
36:     |JTAB| Save,| Cut,| Boxes,| SetPen,| SetFont,| TStyle ; 3|
37:     |JTAB| SaveAs,| Copy,| Ovals,| SetPen,| SetFont,| TStyle ; 4|
38:     |JTAB| Void,| Paste,| Text,| SetPen,| SetFont,| TStyle ; 5|
39:     |JTAB| xPrint,| Void,| Void,| SetPen,| SetFont,| TStyle ; 6|
40:     |JTAB| Void,| Void,| Eraser,| SetPen,| SetFont,| TExpand ; 7|
41:     |JTAB|xQuit,| Void,| Void,| SetPen,| SetFont,| TExpand ; 8|
42:     |JTAB| Void,| Void,| EraseA,| SetPen,| SetFont,| Void ; 9|
43:     |JTAB| Void,| Void,| Void,| SetPen,| SetFont,| TSize ;10|
44:     |JTAB| Void,| Void,| Void,| SetPen,| SetFont,| TSize ;11|
45:     |JTAB| Void,| Void,| Void,| SetPen,| Void,| TSize ;12|
46:     |JTAB| Void,| Void,| Void,| SetPen,| Void,| TSize ;13|
47:     |JTAB| Void,| Void,| Void,| SetPen,| Void,| TSize ;14|
48:     |JTAB| Void,| Void,| Void,| SetPen,| Void,| TSize ;15|
49:     |JTAB| Void,| Void,| Void,| Void,| Void,| TSize ;16|
50:     |JTAB| Void,| Void,| Void,| Void,| Void,| TSize ;17|
51:     |JTAB| Void,| Void,| Void,| Void,| Void,| TSize ;18|

Listing 6.6 – The menu dispatch routine
This technique is different from the one used in the event code in Listing 6.1, which uses JMP instructions. Each entry in the menu table takes only a single word, while in the event code two words are required. The words must contain the difference between two addresses because the Macintosh does not perform program relocation, as discussed previously. Either technique is valid only for labels that lie within 32K of the base address.

The rest of the menu code consists of routines called by the menu dispatcher. Each of these routines handles a particular menu selection.

**New File**  Listing 6.7 shows the code that handles a New selection from the File menu.

Line 2 calls the ChkSave routine. This routine displays the “Save Changes Before Closing?” dialog box if there are unsaved changes in the buffer. If the user selects Yes, the routine saves the buffer in a file. If the buffer has no file name, the user is asked to enter one.

Lines 3–8 initialize the file header buffer to all zeros. Lines 9–18 calculate the address at which to begin storing the null pattern in the file buffer. An entire row of zeros in packed form compresses to two bytes. Lines 19–21 store this null pattern in the last 720 words of the file buffer. Since a document has 720 rows, this is equivalent to reading in a completely

```
1: New:          ; Check for save first
2: BSR ChkSave  ; AO ->
3: MOVE.L HdrBuf(A5),AO  ; Header buffer
4: MOVE.L (AO),AO  ; DO = Byte count
5: MOVE.L HBufLen(A5),DO  ; Adjust for DBRA
6: SUBQ.L #1,DO  ; Clear out
7: CLR.B (AO)+  ; header buffer
8: DBRA DO,@1  ; A4 ->
9: MOVE.L FileBuf(A5),A4  ; File buffer
10: MOVE.L (A4),A4  ;
11: MOVE.L #FLength*2,D3  ; Buffer length
12: MOVE.L D3,D4  ; Copy to D4
13: MOVE.W D3,DO  ; and to DO
14: LSR.W #1,DO  ; Adjust DO for word count
15: SUBQ.W #1,DO  ; and DBRA
16: SUB.L FBufSiz(A5),D4  ; Compute buffer offset
17: NEG.L D4  ; Copy to AO
18: LEA 0(A4,D4.L),A4  ; Fill buffer with
19: MOVE.L A4,A0  ; Compressed zero pattern
20: @2: MOVE.W #NullPat,(AO)+  ; No file name for buffer now
21: DBRA DO,@2  ; Set the window title
22:ClrFlag F File  ; Otherwise, it's just like a finished read
23: W1rite '(No File)'  ;
24: BRA DoUpdate  ;
```

_Listing 6.7 – The New File routine_
blank drawing. Line 22 clears the file flag bit, indicating that the window has no associated disk file. Line 23 sets the window title to "(No File)". Line 24 merges with the code that reads a file into memory.

**Open File** Listing 6.8 contains the code that opens an existing document for MacDoodle to use.

The routine is called xOpen because the assembler cannot distinguish between an Open label and the OPEN macro. Line 1 calls the ChkSave

```assembly
1: xOpen
2: BSR ChkSave ; Check for unsaved changes
3: MOVE.W POpen, DEFAULT ; Open new file
4: SAVE.D 0, D2 ; Save file reference number
5: BPL OpenOK ; If > 0, then OK
6: CMP.D #Cancelled, DO ; Cancelled?
7: BNE @l ; No
8: RTS ; Yes, just return
9: @l MOV.E #0Err, DO ; Indicate Open error
10: BRA Bail ; Bail out
11: OpenOK SCursor #Watch ; Indicate patience required
12: MOVE.W D1, VolRef(A5) ; Save volume reference number
13: GETINFO Fname(AS), InfoBuf(A5), VolRef(A5); Get file info
14: LEA InfoBuf(A5), AO ; AO -> File information
15: MOV.E DFSize(A0), D4 ; Copy file size to D4
16: SUB.E HBufLen(A5), D4 ; Subtract file header size
17: MOV.E HdrBuf(A5), AO ; AO = Buffer handle
18: MOV.E (AO), A4 ; Dereference
19: MOV.E HBufLen(A5), D3 ; Byte count to D3
20: BSR IssueRd ; Go read it
21: MOV.E D4, D3 ; Main byte count to D3 now
22: CMP.E FBufSiz(A5), D3 ; Enough room in buffer?
23: BLT BufOK ; Yes
24: MOV.E #MemErr, DO ; No, notify user
25: BRA Obail ; Bail out
26: BufOK ;
27: MOV.E FileBuf(A5), AO ; AO -> Buffer pointer
28: MOV.E (AO), A4 ; A4 -> Buffer offset to bottom
29: SUB.E FBufSiz(A5), D4 ; Calculate
30: NEQ.D 0 ; A4 -> File offset in buffer
31: LEA 0(A4,D4.L),A4 ; Do the read
32: BSR IssueRd ; Close the open file
33: CLOSE D2 ; Set the window title
34: WTitle FName(A5) ; Now have a file in the buffer
35: SetFlag F_file ; Now get ready to update screen
36: DoUpdate: ; No bytes in buffer beginning
37: CLR.W FBStart(A5) ; Screen buffer is row #0
38: CLR.W SRow(A5) ; Set up proper # of bytes
39: MOV.E D3, PBBend(A5) ; Convert to screen image
40: JSR UnBuf ; No changes now
41: CLRFlag F_Change ; Set Size variable
42: MOV.E SSize(A5), D1 ; Reinit screen
43: JMP Resize
```

[Listing 6.8 - The Open File routine]
routine to ensure that the user has a chance to save any changes made to the buffer before reading in the new file. Lines 3–10 present the Open dialog and check for Open errors. If the user cancelled the Open (lines 6–8), control reverts back to the event code in Listing 6.1. Any other error (lines 9–10) causes an alert box to be displayed. When the user clicks OK, control reverts back to the event code.

At line 11, the file is open. Line 11 changes the mouse cursor to the watch symbol. Lines 13–16 compute the size of the data portion of the file. Lines 17–20 read the header file, using a subroutine that both locks the buffer and performs the read. Lines 21–25 check to see that the file will fit in the file buffer. Lines 27–32 place the entire file at the high-address end of the file buffer. Line 33 closes the open file. Line 34 changes the window title to the name of the file selected by the user. Line 35 sets the file flag. Subsequent Save menu choices will overwrite this file.

At line 36, the file is completely contained in the end portion of the file buffer. The code in Listing 6.7 branches to the label DoUpdate. Code following this label unpacks the first part of the file into the screen buffer and updates the display. Lines 37–38 indicate that the first part of the file is to be displayed. The beginning part of the file buffer contains no data, and row number zero is the first row in the screen buffer. Lines 39–40 call the UnBuf routine to split the file buffer into three pieces: the beginning part of the file buffer, the screen buffer, and the ending part of the file buffer. Line 41 clears the change flag, so that closing the window will not display the Save Changes dialog. Lines 42–43 call the ReSize routine, which is normally used to redisplay the window after it has been resized. In this case, it simply displays the data in the screen buffer.

Listing 6.9 shows the IssueRd routine, which reads data into a dynamic buffer. This code locks the buffer before use. Lines 2–3 lock the buffer, line 4

```
1: IssueRd
2:  MOVE.L  AO,-(SP) ; Save handle
3:  _HLock   ; Lock it
4:  READ     D2,(A4),D3 ; Read desired data
5:  MOVE.L (SP)+,AO ; Restore handle address
6:  MOVE.L DO,-(SP) ; Save returned byte count
7:  _HUnLock ; Unlock handle
8:  CMP.L (SP)+,D3 ; Read OK?
9:  BNE @l ; No
10: @l RTS ; Yes, just return
11: @l ADDQ.L #4,SP ; Pop off return address
12: MOVE.L #ReadErr,DO ; Set error code
13: BRA O Bail ; Bail out
```

*Listing 6.9 – IssueRd routine*
performs the read, and lines 5-7 unlock the buffer. Lines 8-13 check for a successful read and issue an error alert on read failure.

**Save and Save As** The two menu selections that save the buffer contents in a disk file appear in Listing 6.10.

Code that destroys the buffer contents calls ChkSave first. This routine determines whether there are unsaved changes to the buffer (lines 2-3) and issues a dialog box if there are (line 4). Lines 5-6 determine if the item selected by the user was the OK button.

<table>
<thead>
<tr>
<th>ChkSave:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1: ChkSave:</td>
</tr>
<tr>
<td>2: ChkSave:</td>
</tr>
<tr>
<td>3: ChkSave:</td>
</tr>
<tr>
<td>4: ChkSave:</td>
</tr>
<tr>
<td>5: ChkSave:</td>
</tr>
<tr>
<td>6: ChkSave:</td>
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<tr>
<td>7: ChkSave:</td>
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<tr>
<td>8: ChkSave:</td>
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<td>9: ChkSave:</td>
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<tr>
<td>10: ChkSave:</td>
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<tr>
<td>11: ChkSave:</td>
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<tr>
<td>12: ChkSave:</td>
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<tr>
<td>13: ChkSave:</td>
</tr>
<tr>
<td>14: ChkSave:</td>
</tr>
<tr>
<td>15: ChkSave:</td>
</tr>
<tr>
<td>16: ChkSave:</td>
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<tr>
<td>17: ChkSave:</td>
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<tr>
<td>18: ChkSave:</td>
</tr>
<tr>
<td>19: ChkSave:</td>
</tr>
<tr>
<td>20: ChkSave:</td>
</tr>
<tr>
<td>21: ChkSave:</td>
</tr>
<tr>
<td>22: ChkSave:</td>
</tr>
<tr>
<td>23: ChkSave:</td>
</tr>
<tr>
<td>24: ChkSave:</td>
</tr>
<tr>
<td>25: ChkSave:</td>
</tr>
<tr>
<td>26: ChkSave:</td>
</tr>
<tr>
<td>27: ChkSave:</td>
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<tr>
<td>28: ChkSave:</td>
</tr>
<tr>
<td>29: ChkSave:</td>
</tr>
<tr>
<td>30: ChkSave:</td>
</tr>
<tr>
<td>31: ChkSave:</td>
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<tr>
<td>32: ChkSave:</td>
</tr>
<tr>
<td>33: ChkSave:</td>
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<tr>
<td>34: ChkSave:</td>
</tr>
<tr>
<td>35: ChkSave:</td>
</tr>
<tr>
<td>36: ChkSave:</td>
</tr>
<tr>
<td>37: ChkSave:</td>
</tr>
<tr>
<td>38: ChkSave:</td>
</tr>
<tr>
<td>39: ChkSave:</td>
</tr>
<tr>
<td>40: ChkSave:</td>
</tr>
</tbody>
</table>

Listing 6.10 - The ChkSave routine
ChkSave falls through to the Save menu selection at line 7. This code determines if the buffer has an associated file name in lines 7–8. If not, the SaveAs procedure is used instead. The buffer gets a file name as the result of an Open or Save As menu selection. Opening or printing a file from the Finder is essentially the same as selecting Open from the File menu. If the buffer has a file name, Lines 9–11 create a new copy of the file. Any previously existing copy of the file will be overwritten. Line 12 sets the file flag, and line 13 changes the mouse cursor to the watch symbol. Note that the next call to GETEVENT changes the cursor back to whatever it was before. Lines 14–17 set up the registers for a call to the IssueWr routine to write the file header.

Line 22 calls the RePack routine, which packs the entire file into the end section of the file buffer. Lines 23–30 compute the address and length of this data. Line 31 calls the IssueWr routine to write the packed data to the file. Line 32 closes the file. Line 33 calls the UnBuf routine to set up the three buffer areas. Line 34 clears the change flag, indicating that there are now no unsaved changes in the buffer. Lines 35–39 change the file type and application signature to PNTG and DOOD, respectively. The file type is the same as the one used by MacPaint. The DOOD signature causes MacDoodle to be activated when the user double clicks on the document icon.

The IssueWr routine appears in Listing 6.11. This routine writes data to disk from a dynamic buffer and is similar to the IssueRd routine (Listing 6.9).

The SaveAs code is shown in Listing 6.12. Line 1 invokes the PCREATE macro to obtain the file name from the user and create the file. Lines 2–5 set up the registers and branch back to the label DoWrite in Listing 6.10. Lines 6–12 make up the common error routine for all errors in the File menu code. There are two labels: Bail and OBail. Bail is called to change the mouse cursor to the arrow and display the alert box. OBail closes the open file first.

```
1: IssueWr MOVE.L A0,-(SP) ; Save the handle
2:     HLock
3:     WRITE D2,(A4),D3 ; Lock down the buffer
4:     MOVE.L (SP)+,A0 ; Do request
5:     MOVE.L D0,-(SP) ; Restore handle address
6:     HUnLock ; and keep byte count
7:     CMP.L (SP)+,D3 ; Unlock it
8:     BNE @l ; All written?
9:     RTS ; No, bail out
10:    @l ADDQ.L #4,SP ; Return to caller
11:    MOVE.L #Werr,D0 ; Pop return address
12:    BRA OBail ; Tell the user we didn't
13:     MOVE.L #Werr,D0 ; Close file and exit
```

Listing 6.11 – The IssueWr routine
### Print

Selecting Print from the File menu causes the code in Listing 6.13 to run. Line 1 sets the mouse cursor to the watch symbol. Lines 3 and 8 open and close the printer driver, using routines contained in the PrLink.Rel file supplied with the Macintosh MDS system. The PrDraw routine actually does the printing. This routine is part of the drawing code and will be explained later.

### Quit

Listing 6.14 shows the code executed when Quit is chosen from the File menu. Line 1 checks for unsaved changes to the file buffer. Line 2 exits back to the Finder.

#### Listing 6.12 - The SaveAs routine

<table>
<thead>
<tr>
<th>Line</th>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>SaveAs PCREATE 'Save As', Fname(A5), Fname(A5), DEFAULT</td>
<td>Save file ref number</td>
</tr>
<tr>
<td>2</td>
<td>MOVE.L DO, D2</td>
<td>Save file ref number</td>
</tr>
<tr>
<td>3</td>
<td>BLT CFileErr</td>
<td>Error, quit</td>
</tr>
<tr>
<td>4</td>
<td>MOVE.W DL, VolRef(A5)</td>
<td>Save volume reference number</td>
</tr>
<tr>
<td>5</td>
<td>BRA DoWrite</td>
<td>Now go write the file</td>
</tr>
<tr>
<td>6</td>
<td>CFileErr</td>
<td>Can't create file</td>
</tr>
<tr>
<td>7</td>
<td>MOVE.L #Cerr, DO</td>
<td>Set error code</td>
</tr>
<tr>
<td>8</td>
<td>BRA Bail</td>
<td>Quit</td>
</tr>
<tr>
<td>9</td>
<td>OBail CLOSE D2</td>
<td>Open bail out routine</td>
</tr>
<tr>
<td>10</td>
<td>Bail SCursor #Arrow</td>
<td>Set the cursor to the arrow</td>
</tr>
<tr>
<td>11</td>
<td>StopAlert DO</td>
<td>Do the alert</td>
</tr>
<tr>
<td>12</td>
<td>RTS</td>
<td>Return to caller</td>
</tr>
</tbody>
</table>

#### Listing 6.13 - The xPrint routine

<table>
<thead>
<tr>
<th>Line</th>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>xPrint</td>
<td>Here when print selected</td>
</tr>
<tr>
<td>2</td>
<td>SCursor #Watch</td>
<td>Set cursor to watch</td>
</tr>
<tr>
<td>3</td>
<td>JSR PrDrvOpen</td>
<td>Open the printer driver</td>
</tr>
<tr>
<td>4</td>
<td>;</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>;</td>
<td>Call print draw routine (in MacDoodleDraw.Asm)</td>
</tr>
<tr>
<td>6</td>
<td>;</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>JSR PrDraw</td>
<td>Do print drawing</td>
</tr>
<tr>
<td>8</td>
<td>JSR PrDrvrclose</td>
<td>Close the printer driver</td>
</tr>
<tr>
<td>9</td>
<td>RTS</td>
<td>Return to caller</td>
</tr>
</tbody>
</table>

#### Listing 6.14 - The xQuit routine

<table>
<thead>
<tr>
<th>Line</th>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>xQuit: BSR ChkSave</td>
<td>Check on unsaved changes</td>
</tr>
<tr>
<td>2</td>
<td>EXIT</td>
<td>Back to the Finder</td>
</tr>
</tbody>
</table>
**Edit** Listing 6.15 shows the code for the Edit menu. The Undo function is the only one supported by MacDoodle.

Lines 2–9 unpack the undo buffer to the screen buffer. Line 10 redraws the content area of the window. The UnPack and ReDraw routines are in the MacDoodleDraw file and will be explained later. Lines 11–14 cause the Cut, Copy, and Paste choices to be ignored.

**Draw** Listing 6.16 contains code for the Draw menu choices. The code beginning at line 7 handles everything except the Erase Screen choice. Lines 7–9 change the menu check mark to the new selection. Memory location DrwType contains the last selection, for use by the UNCHECK macro in line 7.

The mouse cursor for drawing Lines, Freehand, and Eraser depends both on the Draw menu selection and the PenSize menu selection. The cursor is a solid rectangle for the Lines and Freehand choices, and a hollow rectangle for the Eraser choice. The global variable PenType contains either a 2 for a solid rectangle or a 1 for a hollow rectangle. The PenSize menu setting determines the size of the rectangle. Lines 10–13 set up the PenType variable. Lines 14–17 set up the cursor variable. The CurTbl contains cursor resource IDs for each selection in the Draw menu. A zero means that the cursor ID must be calculated by routine SetCursor (in Listing 6.17 below).

The Erase Screen selection executes the code in lines 36–37. Routine EScreen in MacDoodleDraw.asm performs the erase function.

**PenSize** Listing 6.17 contains the code that handles a PenSize menu selection. Lines 1–2 delete the check mark from the previous selection. Line 3 puts a check next to the new selection. Line 4 stores the new selection for use when the menu is changed again. Lines 5–9 use the cursor

```
1:  Undo
2:    MOVE.L UndoBuf(A5),A0 ; A0 -> Undo buffer
3:    MOVE.L (A0),A0       ;     AO -> Undo buffer
4:    MOVE.L ScrBuf(A5),Al ; Al -> Screen buffer start
5:    MOVE.L (Al),Al      ;          DO = Number of rows to unpack
6:    MOVE.W SSize(A5),DO ;          Calculate
7:    ADDA.L SBufSiz(A5),A6 ;          limit
8:    BSR    UnPack        ; Unpack data to screen buffer
9:    JMP    ReDraw        ; Now redraw screen
10:   RTS
```

*Listing 6.15 – Edit menu routines*
table from Listing 6.16 to see if the cursor needs adjusting; it will if the Draw menu is set to Lines, Freehand, or Eraser.

Lines 10–17 perform any necessary cursor adjustment. The cursor resource ID for the variable-size cursors is a byte consisting of a 1 or a 2 in the high nibble, and the PenSize menu selection minus 1 in the low nibble. Thus, the cursor for drawing $8 \times 8$ lines would be 17 hex. The cursor for erasing $12 \times 12$ rectangles would be 2B hex. These cursors reside in the resource file.

**Font** Listing 6.18 shows the code that supports Font menu selections. Lines 2–3 move the check mark to the desired font. Line 4 stores the

```
1: Lines
2: FreeHand
3: Boxes
4: Ovals
5: Text
6: Eraser
7: UNCHECK #mDraw,DwType(A5); Uncheck old item
8: CHECK #mDraw,Dl; Check new item
9: MOVE.W Dl,DwType(A5); Save item number
10: SUBQ.W #1,Dl; Convert to zero-relative
11: MOVE.B PenTbl(Dl),DO; Fetch pen byte
12: EXT.W DO; Out to word
13: MOVE.W DO,PenType(A5); Set pen type
14: MOVE.B CurrTbl(Dl),DO; Fetch cursor
15: BCQ SetCursor; None, compute it
16: MOVE.W DO,Cursor(A5); Set cursor
17: RTS; and return
18: PenTbl DC.B 2; Lines
19: DC.B 2; Freehand
20: DC.B 0; Boxes
21: DC.B 0; Ovals
22: DC.B 0; Text
23: DC.B 0; (Unused)
24: DC.B 1; Eraser
25: CurrTbl DC.B 0; Lines
26: DC.B 0; Freehand
27: DC.B Cross; Boxes
28: DC.B Cross; Ovals
29: DC.B !Beam; Text
30: DC.B 0; (Unused)
31: DC.B 0; Eraser
32: ; Erase Screen routine. Calls routine EScreen in
33: ; MacDoodleDraw to erase window area in document.
34: ;
35: EraseA
36: BSR EScreen; In draw code
37: RTS; Back to event code
```

**Listing 6.16 - The Draw menu routines**
Listing 6.17 – The PenSize menu routine

1: SetPen
   MOVE.W Pensize(A5),D2 ; Fetch old item
2: UNCHECK #mPen,D2 ; Uncheck old item
3: CHECK #mPen,D1 ; Check new item
4: MOVE.W D1,PenSize(A5) ; Store pen size
5: MOVE.W DrawType(A5),D0 ; Fetch draw type
6: SUBQ.W #1,D0 ; Convert to zero-relative
7: MOVE.B CurTbl(D0),D0 ; Need new cursor?
8: BEQ SetCursor ; EQ => Yes, do it
9: RTS ; Otherwise, return
10: SetCursor
11: MOVE.W PenType(A5),D0 ; Fetch pen type
12: LSL #4,D0 ; Shift left 4
13: MOVE.W PenSize(A5),D3 ; Adjusted pen size
14: SUBQ.W #1,D3 ; Cursor resource ID
15: ADD.W D3,D0 ; Set cursor
16: MOVE.W D0,Cursor(A5) ; Back for more
17: RTS

Listing 6.18 – Font menu routines

1: SetFont:
2: UNCHECK #mFont,FontSel(A5); Uncheck old selection
3: CHECK #mFont,D1 ; Check new selection
4: MOVE.W D1,FontSel(A5) ; Remember selection #
5: SUBQ.W #1,D1 ; Convert to font number
6: ADD.W D1,D1 ; Double for word index
7: MOVE.W Fonts(D1),FontNum(A5); Set new font number
8: LEA r-PVE.W Points,A3 ; A3 -> Table of point sizes
9: MOVE.W #SizeBase,D4 ; D4 = 1st size selection
10: FindPoint
11: CLR.W -(SP) ; Room for result
12: MOVE.W FontNum(A5),-(SP); Push font num
13: MOVE.W (A3),-(SP); and size
14: RealFont
15: TST (SP)+ ; Is it real or is it...
16: BNE @1 ; NE => Real, continue
17: STYLE #mStyle,D4,#0 ; Clear style word
18: BRA @2 ; Branch to end of loop code
19: @1
20: @2
21: ADDQ.W #1,D4 ; Bump menu selection
22: TST (A3)+ ; Bump pointer
23: RTS ; If none real, leave alone
25: DC.W SanFrancisco,Toronto,Cairo,LosAng, Seattle, -1
selection number for use in the next selection. Lines 5–7 convert the selection number to a font resource ID. Lines 10–22 change the type style of all the entries in the type size (lower) portion of the Style menu. Sizes for the selected font that do not require scaling have the outline attribute set. Sizes that require scaling are left as plain text. Lines 24–25 consist of a table of the font resource IDs in the same order as the menu. The list is terminated by a −1. This list must be close to the instruction in line 7, which uses the PC-relative-with-index addressing mode. The table must be within +126 to −128 bytes of the second word of that instruction, because the addressing mode has a one-byte displacement field.

**Style** The Text Style menu code appears in Listing 6.19. The Plain selection code starts at line 1. This code clears the TextFlg global variable, which contains the currently selected text attributes. For plain text, no bits are set. Lines 2–8 clear all check marks in the upper half of the menu. The ExpSel symbol is equated to the Expanded selection, which is the last attribute in the menu. Line 9 checks the Plain selection.

```
1: Plain: CLR.W TextFlg(A5) ; Clear all attribute bits  
2: MOVE.W #mStyle,D2 ; D2 = Menu number  
3: MOVE.W #BoldSel,D3 ; D3 = First style selection  
4: PLoop: UNCHECK D2,D3 ; Loop till done  
5: 6: ADDQ.W #l,D3 ; Bump D3  
7: CMP.W #ExpSel,D3 ; Last one?  
8: BLE PLoop ; No, continue  
9: CHECK #mStyle,#PlainSel; Now check Plain  
10: RTS ; and return  
11: ;  
12: ; TStyle routine. Add a style bit to TextFlg word.  
13: ;  
14: TStyle: UNCHECK #mStyle,#PlainSel; Uncheck plain  
15: CHECK #mStyle,D1 ; Check whatever  
16: SUB.W #BoldSel,D1 ; Subtract base  
17: BSET.B D1,TextFlg+l(A5); Set the bit in memory  
18: RTS ; Done  
19: ;  
20: ; Compress and Expand are different. Treat them as  
21: ; mutually exclusive.  
22: ;  
23: TCompress ; Compressed selected  
24: BCLR.B #Expand,TextFlg+l(A5); Clear expanded bit  
25: UNCHECK #mStyle,#ExpSel; Uncheck it  
26: BRA TStyle ; Otherwise, it's the same  
27: TExpand ; Expanded selected  
28: BCLR.B #Compress,TextFlg+l(A5); Clear Compressed bit  
29: UNCHECK #mStyle,#CompSel; Uncheck it  
30: BRA TStyle ; Go select it
```

*Listing 6.19 – The Text Style menu code*
All attribute selections except Plain, Compressed, and Expanded jump to line 14. Line 14 eliminates the check next to the plain selection, and line 15 puts a check by the desired attribute. Lines 16–17 set the desired attribute bit in the TextFlg variable.

The Compressed and Expanded selections go to lines 23 and 27, respectively. The code for Compressed turns off Expanded and vice versa. After turning off the incompatible option, the routines branch to the TStyle label.

The lower part of the Style menu selects text size. Listing 6.20 contains this code.

Lines 1–2 move the check mark to the new selection. Line 3 stores the item number for use in the next selection. Lines 4–6 stores the point size equivalent to the item number in the global variable TextSiz. Lines 8–9 form a table of the point sizes in the same order as the menu selections. The table is terminated by a zero entry.

**Draw Code**

Code associated with drawing handles all functions associated with output to the screen and printer. This code also deals with data conversion, scrolling, and text entry.

**Initialization**

Listing 6.21 contains the Drawlnit routine, which initializes graphics-related information. Lines 2–3 set the minimum value for the vertical and horizontal scroll bars. Line 4 initializes the SPoint variable. This point is the origin in the screen buffer for display in the window.

```
1: TSize: UNCHECK #mStyle,TextSel(A5); Uncheck previous
2: CHECK #mStyle,Dl ; Check current
3: MOVE.W Dl,TextSel(A5); Remember for next time
4: SUB.W #SizeBase,Dl ; Subtract size base
5: ADD.W Dl,Dl ; Double for word index
6: MOVE.W Points(Dl),TextSiz(A5); Remember size in points also
7: RTS ; Done
8: Points DC.W 9,10,12,14,18,20,24,36,72; Point sizes
9: DC.W 0 ; End of table flag
```

*Listing 6.20 – The Text Size menu routine*
ReSize

The Open code in Listing 6.8 ends with a jump to the ReSize routine. Since the code in Listing 6.8 executes at initialization time, the ReSize routine is part of the startup process. This code appears in Listing 6.22.

The ReSize routine expects the new screen size in D1.L on entry. Line 1 saves the old screen size in D2.L. Lines 2-4 calculate the new horizontal maximum and lines 5-9 calculate the vertical maximum. In each case, the maximum value is the width of the document in pixels minus the screen size in pixels.

Lines 10-13 determine if the new size is the same as the old size. If so, the BEQ instruction at line 13 skips the Pack and UnPack operations (which are relatively slow). If the size is different, the RePack and UnBuf routines save the old screen data and restore the screen buffer to the new size. Lines 18-19 refresh the window if the size does not change.

1: DrawInit ; Here to initialize
2: SetVMin #0 ; Set vertical min to zero
3: SETHMin #0 ; Set horizontal min to zero
4: CLR.L SPoint(A5) ; Init point to (0,0)
5: RTS ; Quit

Listing 6.21 – The DrawInit routine

1: ReSize MOVE.L SSize(A5),D2 ; Fetch old size
2: MOVE.W #$SWidth*8-1,D3 ; Number of pixels in HScroll
3: SUB.W D1,D3 ; Subtract screen width
4: SetHMax D3 ; Set new max
5: SWAP D1 ; Vertical to low word
6: SWAP D2 ; " " "
7: MOVE.W #FLength-1,D3 ; D3 = # pixels in VScroll
8: SUB.W D1,D3 ; Subtract screen length
9: SetVMax D3 ; Set new max
10: MOVE.W D1,D4 ; Save swapped version
11: SWAP D1 ; Restore to original
12: CMP.W D2,D4 ; Compare new to old
13: BEQ @1 ; Same size, just redraw screen
14: BSR RePack ; Pack screen to one buffer
15: MOVE.L D1,SSize(A5) ; Set size value
16: BSR UnBuf ; Unpack screen buffer
17: RTS ; Done
18: @1 MOVE.L D1,SSize(A5) ; Save new size
19: BRA ReDraw ; Go do redraw

Listing 6.22 – The ReSize routine
**UpDate and ReDraw**

MacDoodle responds to update events and other changes to the window by redrawing the entire window contents. The UpDate routine responds to an update event by calling ReDraw. Code for these routines appears in Listing 6.23.

Updating a window requires issuing a _BeginUpdate system call before the update, and an _EndUpdate call afterwards. Both system calls require the window address as a parameter. The UpDate routine calls ReDraw bracketed by a _BeginUpdate/EndUpdate pair in lines 2–6.

The ReDraw routine works by transferring the screen buffer to the window with the _CopyBits system call. Line 9 calls a routine that sets up the data areas for _CopyBits. Lines 10–17 invoke _CopyBits to transfer the screen buffer to the window GrafPort. Lines 18–19 unlock the buffer (which was locked by CopySetup).

The SaveScreen routine performs the opposite function and appears in Listing 6.24. This routine is the same as ReDraw, except for the reversal of the source and destination operands in lines 5–9.

The CopySetup routine constructs the parameters for the _CopyBits call. This code appears in Listing 6.25.

Lines 5–8 construct a rectangle for the window (on the screen) in a temporary variable called TmpRect. This rectangle starts at zero and ends at the screen size. Variable SSize contains the screen size. Lines 14–20

```assembly
1: UpDate: ;
2: MOVE.L WPointer(A5),-(SP); ; Push window pointer
3: _BeginUpdate ; ; Signal update begin
4: BSR ReDraw ; ; Refresh screen
5: MOVE.L WPointer(A5),-(SP); ; Push window pointer
6: _EndUpdate ; ; Signal update end
7: RTS ; ; Back to event handler
8: ReDraw PUSHALL ; ; Save registers
9: BSR CopySetup ; ; Set up for CopyBits
10: MOVE.L PortAdr(A5),AO ; ; AO -> Window's GrafPort
11: PEA SBitMap(A5) ; ; Source bitmap address
12: PEA PortBits(AO) ; ; Destination bitmap address
13: PEA SrcRect(A5) ; ; Source rectangle address
14: PEA TmpRect(A5) ; ; Destination rectangle address
15: MOVE.W #$SrcCopy,-(SP) ; ; Blatant copy mode
16: PEA 0 ; ; No mask region
17: _CopyBits ; ; Redraw entire window
18: MOVE.L ScrBuf(A5),AO ; ; AO = Screen buffer handle
19: HUnlock ; ; Unlock it
20: POPALL ; ; Restore registers
21: RTS ; ; Return to caller
```

Listing 6.23 – The UpDate and ReDraw routines
Listing 6.24 – The SaveScreen routine

Listing 6.25 – The CopySetup routine
construct a similar rectangle for the screen buffer. The rectangle is stored in a memory area called SrcRect. Computing this rectangle is a bit harder. The origin is contained in variable SFPoint, and the end is the sum of SFPoint and SSize. Lines 24–25 lock the screen buffer in memory. Lines 26–31 construct a bitmap data structure for the screen buffer. Lines 32–33 fetch the window Grafrort address using a _GetPort call.

**EScreen (Erase Screen)**

Listing 6.26 contains the EScreen routine, which erases the screen. Areas of the document outside the screen region are unaffected.

Lines 2 and 9 save and restore the registers on the stack. The PackU routine called at line 3 saves the screen buffer contents in the undo buffer. The data is saved in packed format. Choosing Undo from the Edit menu redisplay this information. Lines 4–7 erase the window on the screen, and line 8 calls the SaveScreen routine to copy the new screen to the screen buffer.

**PrDraw (Print Document)**

Listing 6.27 contains the PrDraw routine, which prints the entire document. The menu code in Listing 6.13 calls this routine after opening the printer driver.

Lines 2–6 reset the printer before starting to print. The PrCtlCall routine is contained in the PrLink.rel file supplied with the Macintosh Development System. Line 7 copies the current screen position within the document to register D7. Register D6 contains the screen position currently being printed. Line 8 initializes D6 to zero.

Lines 9–11 position the screen at the next position to be printed. Routine VScroll is the thumb positioning routine. To move to a place within the document, you load the row number into D1 and call VScroll. On

```
1: EScreen            ; Called from menu code
2:                ; Save registers
3:     JSR PackU      ; Save screen in undo buffer
4:      CLR. L TmpRect(A5)   ; Clear origin
5:     MOVE. L SSize(A5),TmpRect+4(A5); Set screen size
6:     PEA TmpRect(A5)    ; Push rectangle address
7:     _EraseRect       ; Erase it
8:     BSR SaveScreen   ; Now update screen buffer
9:                ; Pop registers
10:    RTS              ; Return to menu code
```

**Listing 6.26 – The EScreen routine**
Listing 6.27 – The PrDraw routine

1: PrDraw  PUSHALL       ; Save the registers
2: MOVE.W  #PrCtl1,-(SP) ; Printer device control code
3: MOVE.L  #PrReset,-(SP) ; Code for printer reset
4: CLR.L   - (SP)         ; Two null parameters
5: JSR     PrCtlCall      ; Do a reset before starting to print
6: MOVE.W  SRow(A5),D7   ; Remember current screen position
7: CLR.L   D6             ; D6 counts rows
8: @1      MOV.E   D6,D0  ; Set D0 for scroll operation
9: SWAP    D0             ; to high word for VScroll
10: BSR     VScroll       ; Do the scroll
11: MOVE.W  D6,D5         ; Copy row number
12: SUB.W   SRow(A5),D5   ; Normalize to displayed screen
13: MOVE.W  D5,TmpRect(A5) ; Set
14: CLR.W   TmpRect+2(A5) ; destination
15: MOVE.W  SSize(A5),TmpRect+4(A5); rectangle
16: MOVE.W  #SWidth*8,TmpRect+6(A5); rectangle
17: MOVE.L  ScrBuf(A5),A0 ; Fetch
18: _Lock   ; screen address (locked)
19: MOVE.L  (A0),A3       ; Store in bitmap structure
20: MOVE.L  A3,SBitMap(A5);
21: MOV.E   #SWidth,SBytes(A5); Set row bytes
22: CLR.W   SBounds(A5)   ; Origin is
23: CLR.W   SBounds+2(A5);
24: MOV.W   SSize(A5),SBounds+4(A5); Destination
25: MOV.W   #SWidth*8,SBounds+6(A5); (SSize-D5.W,576)
26: SUB.W   D5,SBounds+4(A5); is
27: MOV.W   #SWidth*8,SBounds+6(A5); (SSize-D5.W,576)
28: MOV.W   #PrBits,-(SP); Specify bitmap print
29: PEA     SBitMap(A5)   ; Push source bitmap address
30: PEA     TmpRect(A5)   ; Destination rectangle address
31: MOV.E   #PrPaint,-(SP); Specify square resolution
32: JSR     PrCtlCall     ;
33: MOV.E   ScrBuf(A5),A0 ; Unlock
34: _Unlock  ; screen buffer
35: ADD.W   SSize(A5),D6  ; Bump row number
36: CMP.L   #Length,D6   ; See if done
37: BLT     @1           ; If less, not done
38: MOVE.W  D7,D0        ; Restore
39: SWAP    D0           ; vertical
40: JSR     VScroll       ; position
41: MOVE.W  #PrCtl1,-(SP) ; Device control code
42: MOVE.L  #PrPaint,-(SP); Indicate end of page
43: CLR.L   - (SP)        ; Two
44: CLR.L   - (SP)        ; Two nulls
45: JSR     PrCtlCall     ; Eject page
46: POPALL       ; Page is printed
47: RTS           ; Done
return from VScroll, the screen buffer, display, and thumb position in the scroll bar reflect the new document position.

Lines 12–17 set up a rectangle for the printer. This rectangle is the same height as the window and 576 pixels wide. Lines 19–20 lock the screen buffer in memory. Lines 20–27 set up a bitmap structure for the screen buffer. Lines 29–32 call the PrCtlCall routine to transfer the bitmap to the printer.

This bitmap printing technique is used only for preconstructed images, such as MacPaint documents or screen dumps. The normal technique is to open a special GrafPort that references the printer. QuickDraw operations on this GrafPort cause output to go to the printer. This technique produces better images on devices that do not match the Macintosh screen resolution, such as a LaserWriter. The Macintosh Development System includes a program that illustrates this method of printing.

Lines 33–34 unlock the screen buffer. Lines 35–37 form the end of the printing loop. When the loop completes, lines 38–40 restore the screen's vertical position to the value saved in line 7. Lines 41–45 call the PrCtlCall routine to eject the page.

**Line and Page Scrolling**

Listing 6.28 contains the routines that handle line and page scrolling events.

Routine DoScroll receives control from the event code in Listing 6.1 for a scrolling event. This routine saves the scrolling type value in variable ScrType at line 3. A TRACK macro causes routine XScroll to execute repeatedly until the mouse button is released.

Parameters to the XScroll routine are shown in Figure 6.21. Lines 8–11 pop the part code and control handle off the stack, leaving only the return address. If the part code is zero, the routine simply returns to the caller at line 14.

Line 16 places the original scroll type word (from the scroll event) in D2.W. The next section of code places the number of pixels to scroll in D3.W, the page size in D4.W, and the starting position in D5.W. Lines 17–18 assume a vertical line scroll. Lines 20–23 reload the registers if the desired scroll is horizontal. Lines 24–26 replace the contents of D3 with the correct number of pixels for a page scroll. Lines 27–29 negate D3 if the scrolling direction is up or right. Line 30 converts the number of pixels to scroll in D3 to an absolute pixel number. This quantity indicates the pixel to be displayed in the upper-left corner of the window (the GrafPort origin). Lines 31–35 simulate a thumb scroll event with this absolute value.
Thumb Scrolling

All scrolling in MacDoodle is handled by the two routines in Listing 6.29. These routines are invoked directly by thumb scroll events and indirectly by the code in Listing 6.28.

The VScroll routine handles a vertical thumb scroll. The pixel number of the document to appear at the top of the window is in the high word of D0 on entry. Lines 3–6 clear D0 if it contains a negative value. Lines 7–11 change any values that are too large to the maximum permissible value. This range checking is necessary because the line scroll routines can ask for values that are out of range. For example, scrolling up past the top of the document generates a negative value for the pixel to display.

Lines 11–15 perform the scrolling operation. The RePack routine called at line 12 converts the entire document to packed form at the end of the

```
1:  DoScroll
2:    SWAP    DO ; Type to low word
3:    MOVE.W DO,ScrType(A5) ; Remember type
4:    TRACK   D1, XScroll ; Do the scroll
5:    RTS ; Return
6:
7:  XScroll
8:    MOVE.L (SP)+,A0 ; Fetch return address
9:    MOVE.W (SP)+,D1 ; and part code
10:   MOVE.L (SP)+,DO ; and control handle
11:   MOVE.L A0,-(SP) ; Restack return address
12:   TST.W  D1 ; Still in right spot?
13:   BNE   @1 ; Yes, continue
14:   RTS
15:   @1  PUSHA ; No, quit now
16:   MOVE.W ScrType(A5),D2 ; Fetch scroll type
17:   MOVE.W #LScroll,d3 ; Move pixel count to D3
18:   MOVE.W SSize(A5),D4 ; D4 = Vertical page size
19:   MOVE.W SRow(A5),D5 ; D5 = Vertical position of (0,0)
20:   BTST  #2,D2 ; Vertical or horizontal?
21:   BBQ  @2 ; EQ => Vertical
22:   MOVE.W SSize+2(A5),D4 ; Correct page size
23:   MOVE.W SPoint+2(A5),D5 ; D5 = Horizontal position
24:   @2  BTST  #1,D2 ; Page or line scroll?
25:   BBQ  @3 ; EQ => Line
26:   MOVE.W D4,D3 ; Correct pixel count for page
27:   @3  BTST  #0,D2 ; Left (up) or right (down)?
28:   BNE  @4 ; EQ => Right (down)
29:   NEG.W  D3 ; Negate # pixels
30:   @4  ADD.W D5,D3 ; Make absolute
31:   MOVE.W D3,D0 ; Move to
32:   SWAP  DO ; D0 high word
33:   BTST  #2,D2 ; Vertical or horizontal?
34:   BNE  xHScroll ; NE => Horizontal
35:   BRA  xVScroll ; Else, go do vertical
```

Listing 6.28 – The line and page scrolling routines
file buffer. Line 13 sets the new value for the first row of the document to be displayed. Line 14 sets the new value of the scroll bar thumb. The UnBuf routine called at line 15 splits the single buffer into three: the top area of the file buffer, the screen buffer, and the bottom area of the file buffer. The UnBuf routine calls ReDraw to display the correct area of the document in the window.

Horizontal scrolling is simpler. Lines 23–31 perform the proper range checking, correcting out of range values. Line 32 sets the new thumb value, and line 33 sets the new display point in the SPoint variable. The branch to ReDraw at line 35 updates the screen. Since the screen buffer contains complete horizontal rows, none of the buffers is modified by horizontal scrolling.

Listing 6.29 – The thumb scroll routines
Mouse Down

Listing 6.30 contains the code that handles mouse-down events. Action taken by this code depends on the setting of the DrwType global variable, which contains the last Draw menu selection number.

Lines 2–4 close out any open text entry. Line 5 saves the mouse point in a temporary variable. Line 6 saves the screen contents in the undo buffer. Lines 7–8 save the graphics pen state, and lines 9–12 set the proper pen size. Lines 13–14 move the pen to the mouse point. Lines 15–19 call the proper routine from the table at line 32. Routines in this table correspond to the selections in the Draw menu. Note that the Erase Screen selection is handled by the menu code in Listing 6.16. Lines 20–21 restore the pen state. Line 22 sets the change indicator flag.

Lines 23–25 save the updated screen in the screen buffer if the Draw menu selection was other than Text. Text entry starts with a mouse-down

```
1: Mouse:
2: TstFlag F Text ; Text open?
3: BB ; No, continue
4: @1 CloseText ; Yes, close first
5: MOVE.L Dl,Pointl(A5) ; Save original point
6: BSR Pack1 ; Save screen in undo buffer
7: PEA OldPen(A5) ; Save pen state
8: _GetPenState ;
9: MOVE.W PenSize(A5),Dl ; Fetch pen size
10: MOVE.W Dl,-(SP) ; Push
11: MOVE.W D1,-(SP) ; 2 copies
12: _PenSize ; Set new pen size
13: MOVE.L Pointl(A5),-(SP) ; Push mouse point
14: _MoveTo ; Move pen to mouse point
15: MOVE.W DrwType(A5),DO ; Fetch draw routine index
16: SUBQ.W #1,DO ; Force zero relative
17: LSL.W n,00 ; Multiply x 2 for word index
18: MOVE.W JBASE(Do.W),Do ; Fetch offset
19: JSR JBASE(DO.W) ; Call proper routine
20: PEA OldPen(A5) ; Now
21: _SetPenState ; restore pen
22: _SetFlag F_Change ; Mark a change to file
23: CMPI.W #5,DrwType(A5) ; Just start text?
24: BB @2 ; Yes, don't save screen
25: JSR SaveScreen ; Save screen in screen buffer
26: @2 RTS ; Back for next event
27: Void: StopAlert #ProgramErr ; Fatal error!
28: EXIT ; Back to Finder
29: ;
30: ; Jump table for draw routines
31: ;
32: JBASE JTAB Lines, FreeH, Boxes, Ovals
33: JTAB Text, Void, Eraser, Void

Listing 6.30 - The Mouse routine
```
event and terminates with the first event that is not a key-down event. The screen buffer is not updated until the text entry terminates.

**Lines**

Listing 6.31 contains the code that draws straight lines on the screen. Lines 2–3 set the pen mode to XOR. Lines 4–5 move the original mouse point to D3.L and D4.L. Lines 6–9 fetch the current mouse position and compare it to the last position. If the mouse position has changed, lines 10–12 erase the previous line and draw a new line from the original mouse point to the current mouse point. Lines 13–16 check to see if the mouse button is still down. If so, the routine loops back to continue tracking the mouse position. If not, the code at lines 17–19 redraws the line in copy mode.

The subroutine in lines 25–30 draws a line from the point in D4.L to the point in D3.L. Lines 26–27 move the pen to the original mouse point. Lines 28–29 draw a line to the current mouse point.

```
1: Lines:                        ; Line handler
  2: MOVE.W #PatXor,-(SP)        ; Set pen to XOR for dragging
  3: _PenMode                    ;
  4: MOVE.L Point1(A5),D3       ; Save mouse point
  5: MOVE.L D3,D4               ; Need original point
  6: @1: PEA Point1(A5)          ; Temp point
  7: _GetMouse                  ; Fetch mouse in local coords
  8: CMP.L Point1(A5),D3        ; Check against old
  9: BEQ @2                     ; Equal, don't update
10: BSR DrawLine               ; Cancel old line
11: MOVE.L Point1(A5),D3       ; Save new point
12: BSR DrawLine               ; Draw new line
13: @2: CLR.W -(SP)            ; Room for result
14: StillDown                  ; Mouse still down?
15: TST.B (SP)+                ;
16: BNE @1                     ;
17: MOVE.W #PatCopy,-(SP)      ;
18: _PenMode                   ;
19: BSR DrawLine               ;
20: RTS                        ; Return to caller
21: ;
23: : to point in D3.L.
24: :
25: DrawLine                   ;
26: MOVE.L D4,-(SP)            ; Draw a line
27: Moveto                     ; Reposition pen
28: MOVE.L D3,-(SP)            ; Cancel old line
29: Lineto                     ; thusly
30: RTS                        ; Return to caller

Listing 6.31 – The Line Drawing routine
Eraser and Freehand

Listing 6.32 contains the code that handles eraser and freehand drawing. Erasing is the same as freehand drawing, except that the pen mode is patBic instead of patOr. You can think of the eraser as freehand drawing with white pixels instead of black pixels.

Lines 2–3 set the pen mode to patBic for erasing. Line 6 saves the previous mouse point in D3.L. Lines 7–8 fetch the current mouse point. Lines 9–10 compare the previous and current mouse points to see if the mouse has moved. If so, lines 11–13 draw a line from the previous mouse point to the current mouse point. Lines 14–17 check to see if the mouse button is still down. If so, the routine continues to track the mouse. Line 18 returns to the caller when the mouse button is released.

Boxes and Ovals

Listing 6.33 contains the code that draws boxes and ovals. Register D7 is used to choose between boxes and ovals throughout this code. Line 2 clears D7 for boxes, and line 4 sets D7 to -1 for ovals.

This routine uses three rectangles: two for comparison purposes and a temporary rectangle for drawing. These rectangles are called NewRect, OldRect, and TmpRect. Lines 7–9 load the rectangle addresses into A3, A2, and A4. Lines 10–11 initialize NewRect and OldRect to empty rectangles at the original mouse point. Lines 12–13 set the pen mode to patXor.

Lines 14–34 form a loop that tracks the mouse and redraws the figure each time the mouse moves. Lines 15–18 test to see if the mouse button is

Listing 6.32 - The Eraser and FreeH routines

```
1: Eraser:                          ;
2:   MOVE.W  #patBic,-(SP)         ;   Push desired mode
3:    _PenMode                     ;   Set the pen mode
4: ;
5: FreeH:                           ;
6:   MOVE.L  Point1(A5),D3         ;   Sketch handler
7:   @1:   PEA  Point1(A5)         ;   Save mouse point
8:    GetMouse                     ;   Temp point
9:   CMP.L  Point1(A5),D3          ;   Fetch mouse in local coords
10:   @2:    EQX  @2              ;   Check against old
11:    BBQ                            ;   Equal, don't update
12:    MOVE.L  Point1(A5),D3        ;   Save new point
13:    MOVE.L  D3,-(SP)             ;   Push point
14:    _Lineto                      ;   Draw a line to new point
15:    _StillDown                   ;   Room for result
16:    _TST.B  (SP)+                ;   Mouse still down?
17:    BNE  @1                      ;   If NE, yes, still down
18:    RTS                            ;   Return to caller
```
Listing 6.33 - The Boxes and Ovals routines
still down. If not, the routine draws the final figure using the patCopy pen mode. Lines 19–20 fetch the mouse point into the bottom-right point of NewRect. Lines 21–25 compare the resulting rectangle to OldRect. If the two are equal, the branch at line 25 restarts the loop. Otherwise, lines 26–28 copy OldRect to the scratch area pointed to by A4, and routine DoDraw erases the old figure. Then lines 29–31 draw the new figure. Lines 32–34 copy OldRect to NewRect and repeat the loop.

Lines 36–37 set the pen mode to patCopy. The code then drops into routine DoDraw to draw the figure a last time in copy mode. Lines 40–50 adjust the temporary rectangle so that the top coordinate is less than the bottom and the left coordinate is less than the right. Lines 51–57 issue either a _FrameRect or a _FrameOval call to draw the figure on the screen.

**Text Initialization**

Listing 6.34 contains the code executed when a mouse-down event occurs with Text selected.

Lines 2–9 set the pen mode, font, text attributes, and text size. The mode is patXor to allow a backspace character to erase the last character typed. Lines 10–12 initialize a buffer that will contain characters typed by the user. Line 13 sets the flag indicating that text entry is in progress. Each routine that processes an event other than a keystroke will call the CloseText routine to close out the text entry. This structure is necessary if the program is to have a single event loop. Alternatively, the text code could use a separate event loop and branch back to the main event loop when the text entry is closed. The variable Point2 contains the point where the next character will be drawn. Line 14 copies the mouse point to this location. Line 15 branches to the routine that draws the cursor.

```
1: Text
2: MOVE.W #patXor,-(SP) ; Set text
3: TextMode ; mode to XOR
4: MOVE.W FontNum(A5),-(SP); Set proper font
5: TextFont ;
6: MOVE.W TextFlg(A5),-(SP); Set text attributes
7: TextFace ;
8: MOVE.W TextSiz(A5),-(SP); Set text size
9: TextSize ;
10: CLR.W BuffCnt(A5) ; Clear text buffer count
11: LEA TBuffer(A5),AO ; AO -> Buffer
12: MOVE.L AO,BuffPtr(A5) ; Save it
13: SetFlag F_Text ; Remember we're doing text
14: MOVE.L Pointl(A5),Point2(A5); Set pen location
15: BRA DrawCurs ; Draw cursor
```

**Listing 6.34** – The text initialization routine
Key Down

The code that handles key-down and autokey events appears in Listing 6.35. Lines 2–5 reject keystroke events before the mouse down event has selected a starting point. Line 7 sets the buffer change flag. Lines 8–11 single out backspace (decimal 8) and carriage return (decimal 13) characters for special processing. Any other character is placed in the buffer and on the screen. Lines 12–15 place the character in the temporary buffer. Line 16 erases the previous cursor by drawing it again. Lines 17–20 draw the character, and lines 21–22 get the point at which to draw the next character. Line 23 branches to the routine that draws the cursor. This draws the cursor at the location of the next character.

Lines 24–43 handle backspacing. Lines 25–26 reject a backspace character if there are no characters in the buffer. Line 27 erases the previous cursor. Lines 28–29 decrement the count of characters in the buffer. Lines 30–32 fetch the last character from the buffer and decrement the address at which to store the next character. Lines 33–36 call the _CharWidth system trap to get the width of the character being erased. Lines 37–39 move the pen to the beginning of this character. Lines 40–41 erase the character, and line 42 redraws the cursor at the location of the erased character.

Close Text

Listing 6.36 contains the code that finishes text entry. Line 4 erases the cursor character. Lines 5–6 set up the count byte for the text buffer. The label TBufCnt appears directly in front of the text buffer. Setting this byte to the number of characters in the buffer yields a Pascal-format string. Lines 7–8 change the text mode to patCopy, and lines 9–12 redraw the buffer contents in copy mode using the _DrawString call. Note that scaled fonts may be redrawn slightly differently with _DrawString than with successive _DrawChar calls. The text may appear slightly longer on the screen after it is redrawn. Line 13 clears the text entry flag. Line 14 transfers the window on the screen to the screen buffer. Choosing Undo will cause the entire line of text to disappear.

Draw Curs

Code for drawing the cursor appears in Listing 6.37. The cursor used in this program is a simple underline character, not the flashing cursor used by most Macintosh programs. The underline character places no timing requirements on the program event code, making the code smaller and easier to understand.

Lines 2–3 position the pen to the origin of the cursor character. Lines 4–5 actually draw the cursor.
**UnPack and Pack**

The code that translates compressed data into a form suitable for display appears in Listing 6.38. This routine expects its input parameters in the following registers:

<table>
<thead>
<tr>
<th>Register</th>
<th>Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>A0.L</td>
<td>Address of data in packed format</td>
</tr>
<tr>
<td>A1.L</td>
<td>Address of buffer to receive unpacked data</td>
</tr>
</tbody>
</table>

1: KeyDown
2: TstFlag F_Text
3: BNE Drawtext
4: StopAlert #NotText
5: RTS
6: DrawText

<table>
<thead>
<tr>
<th>Register</th>
<th>Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>AO.L</td>
<td>Address of data in packed format</td>
</tr>
<tr>
<td>Al.L</td>
<td>Address of buffer to receive unpacked data</td>
</tr>
</tbody>
</table>

7: SetFlag F_Change
8: CMP.R #BS,D1
9: BBQ IsBS
10: CMP.B #CR,D1
11: BBQ IssR
12: MOVE.L BuffPtr(A5),AO
13: ADD.W #1,BuffCnt(A5)
14: MOVE.B DL,(AO)+
15: MOVE.L AO,BuffPtr(A5)
16: BSR DrawCurs
17: MOVE.L Point2(A5),-(SP)
18: MoveTo
19: MOVE.W DL,-(SP)
20: DrawChar
21: PEA Point2(A5)
22: _GetPen
23: BRS DrawCurs
24: IsBS:
25: MOVE.W BuffCnt(A5),D1
26: BBQ CantBS
27: BSR DrawCurs
28: SUBQ.W #1,D1
29: MOVE.W DL,BuffCnt(A5)
30: MOVE.L BuffPtr(A5),AO
31: MOVE.B -(AO),D3
32: MOVE.L AO,BuffPtr(A5)
33: CLR.W -(SP)
34: MOVE.L D3,-(SP)
35: _CharWidth
36: MOVE.W (SP)+,D4
37: SUB.W D4,Point2+2(A5)
38: MOVE.L Point2(A5),-(SP)
39: MoveTo
40: MOVE.W D3,-(SP)
41: DrawChar
42: BSR DrawCurs
43: CantBS RTS

Listing 6.35 – The KeyDown routine
Listing 6.36 – The CloseText routine

1: IsCR: ; Also carriage return
2: CloseText: ;
3: MOVEM.L DO-D7/A0-A6,-(SP); ; Save registers
4: BSR DrawCurs ; Erase cursor character
5: MOVE.W BuffCnt(A5),D3 ; Get character count
6: MOVE.B D3,TBufCnt(A5) ; Set byte
7: MOVE.W #patCopy,-(SP) ; Set text
8: TexMode ; to copy mode
9: MOVE.L Point1(A5),-(SP); ; Go back
10: MoveTo ;
11: PEA TBufCnt(A5) ; Push string address
12: DrawString ; Redraw in copy mode
13: ClrFlag F Text ; No longer in text mode
14: BSR SaveScreen ; Save screen in buffer now
15: MOVEM.L (SP)+,DO-D7/A0-A6; ; Restore registers
16: RTS ; Done

Listing 6.37 – The DrawCurs routine

1: DrawCurs: ;
2: MOVE.L Point2(A5),-(SP); ; Reset
3: MoveTo ; pen location
4: MOVE.W #CursChar,-(SP) ; Delete
5: _DrawChar ; cursor
6: RTS ; Return to caller

Listing 6.38 – The UnPack routine

1: UnPack MOVEM.L DO-D3/A2/A6,-(SP); ; Stack registers
2: SUBQ.W #1,DO ; Adjust # rows for DBRA
3: SUBA.L #Swidth,A6 ; Adjust limit register
4: MOVE.W DO,D3 ; Place in nonvolatile register
5: MOVE.L A0,Addr1(A5) ; Store addresses
6: MOVE.L Al,Addr2(A5) ;
7: @1 CMPA.L Addr2(A5),A6 ; Check limit
8: BLS PMemErr ; Too high, quit
9: PEA Addr1(A5) ; Push source address
10: PEA Addr2(A5) ; and destination
11: MOVE.W #Swidth,-(SP) ; Push byte count
12: UnPackBits ; Do the pack
13: DBRA D3,@1 ; Loop till done
14: MOVE.L Addr1(A5),A0 ; Restore
15: MOVE.L Addr2(A5),Al ; addresses
16: MOVEM.L (SP)+,DO-D3/A2/A6; ; Restore registers
17: RTS ; Back to caller
18: PMemErr StopAlert #MemErr ; Out of memory
19: EXIT ; So quit
### Register | Parameter
--- | ---
D0.W | Number of 72-byte rows to unpack
A6.L | First address beyond the unpacked buffer

On return from either Pack or UnPack, registers A0.L and A1.L are set to the first bytes in the source and destination areas not used in the conversion process.

Line 2 adjusts D0 for the DBRA instruction, and line 3 adjusts A6 down by the number of bytes in an unpacked row. Register D3 contains the actual loop count, because D0 is modified by the _UnPackBits system call. Lines 5 and 6 set up the two pointer variables required by _UnPackBits. Lines 7–8 ensure that no part of the unpacked data will land in memory outside the destination buffer. Lines 9–12 issue the _UnPackBits call for a single row of data (72 bytes). The DBRA instruction at line 13 repeats lines 7–13 until all rows have been processed. Lines 14–15 set up the return values in A0 and A1. Lines 18–19 are the error routine invoked when a memory bounds error occurs.

The routine to pack screen data is very similar; it appears in Listing 6.39. The Pack and UnPack routines differ only in the system call used and the fact that the limit value subtracted from A6 in line 3 is one greater in the Pack routine. The maximum number of bytes that can be generated by the _PackBits system call at line 12 is 73. The UnPack bits limit is 72.

```
1: Pack MOVEM.L D0-D3/A2/A6,-(SP); Stack registers
2: SUBQ.W #1,D0 Adjust # rows for DBRA
3: SUBA.L #$Width+1,A6 Adjust limit
4: MOVE.W D0,D3 Place in nonvolatile register
5: MOVE.L A0,Addr1(A5) Store addresses
6: MOVE.L A1,Addr2(A5)
7: CMPA.L Addr2(A5),A6 Check limit
8: BLS MemErr Too high, quit
9: PEA Addr1(A5) Push source address
10: PEA Addr2(A5) and destination
11: MOVE.W #$Width,-(SP) Push byte count
12: _PackBits Do the pack
13: DBRA D3,01 Loop till done
14: MOVE.L Addr1(A5),A0 Restore addresses
15: MOVE.L Addr2(A5),A1
16: MOVEM.L (SP)+,D0-D3/A2/A6; Restore registers
17: RTS Back to caller
18: Addr1 DS.L 1 Temp address
19: Addr2 DS.L 1 Another
```

**Listing 6.39 – The Pack routine**
PackU

The PackU routine shown in Listing 6.40 packs the screen buffer contents into the undo buffer. This routine is normally called just before modifying the screen.

Lines 2–4 lock the undo buffer in memory. Lines 5–6 place the address of the undo buffer in A1 and A4. Lines 7–10 lock the screen buffer and place its address in A0. The vertical coordinate of the screen size is the number of rows to pack. This is placed in D0 to call the Pack routine in Listing 6.39. Lines 12–13 calculate the limit value for Pack and place it in A6. Line 14 contains the call to Pack. Lines 15–16 place the number of bytes packed in the top longword on the stack. When the registers are popped off the stack just before returning, this quantity is placed in D0.L. Lines 17–20 unlock the two buffers. Lines 21–22 restore the registers and return to the calling routine.

RePack

The RePack routine concentrates the entire document into the high end of the file buffer. This operation is required when the document is to be written to a file and when the display is scrolled.

The routine consists of three steps:

1. Pack the screen buffer to the undo buffer.
2. Move this buffer to the right place in the file buffer.
3. Move the starting part of the file buffer down to be contiguous with the rest of the data.

Figure 6.30 illustrates these steps.

The RePack routine appears in Listing 6.41. Line 2 accomplishes step 1. Lines 3–6 place the undo buffer address in A0 and the file buffer address in A1. Lines 8–13 calculate the address in the file buffer for the data in the undo buffer. Line 15 adjusts D0 (returned by PackU) for a DBRA loop count. Lines 16–19 check for an overlap between the data in the undo buffer and the beginning part of the file buffer.

Lines 20–21 move the undo buffer into the file buffer. This completes step 2 of the procedure.

Lines 22–26 compute the new buffer length. This is the total number of bytes in the buffer after consolidation. Lines 26–33 move the top section of the buffer down, completing the procedure. Note that the top section must be moved starting with the highest address. If the free area between the top and bottom areas of the buffer is smaller than the data to
be moved, moving from the top down will destroy data in the top part of the buffer.

**UnBuf**

The UnBuf routine performs the inverse of a RePack. This code splits a single data area into the three buffer areas: the top of the file buffer, the screen buffer, and the bottom of the file buffer. UnBuf is shown in Listing 6.42.

Lines 2–3 lock the file buffer. Lines 4–10 compute the address of the first byte of data in the buffer. The global variable SRow indicates the row number of the first row to appear in the screen buffer. Lines 12–13 calculate the number of unpacked bytes in the top area of the screen buffer. Calculating the number of packed bytes requires a knowledge of the packed format.

Lines 15–29 move the packed data to the top of the file buffer. The Macintosh packing algorithm compresses adjacent bytes with the same value. The data is divided into groups that are less than 128 bytes long. The first byte in each group is a count byte. Count bytes are one less than the actual number of bytes represented by the group. A negative count byte indicates that the next byte is to be replicated. The number of replicated bytes is the absolute value of the count byte plus 1. Count bytes with the value $-128$ (80 hex) are ignored. A positive count byte indicates a run of unequal bytes. For a count

---

**Listing 6.40 – The PackU routine**

```
1: PackU    PUSHALL ;       Save caller's registers
2: MOVE.L  UnDoBuf(A5),A0 ;  A0 -> Undo handle
3: MOVE.L  A0,A3 ;           Save handle
4:   _HLock ;                Lock it down, too
5: MOVE.L  (A0),A1 ;         A1 -> Undo buffer
6: MOVE.L  A1,A4 ;           Save this
7: MOVE.L  ScrBuf(A5),A0 ;   A0 -> Handle
8: MOVE.L  A0,A2 ;           Save handle
9:   _HLock ;                Lock it down
10: MOVE.L  (A0),A0 ;        A0 -> Unpacked data
11: MOVE.W  SSizelA5),D0 ;   D0 = Count
12: MOVE.L  A1,A6 ;          Calculate
13: ADDA.L  UBufSiz(A5),A6 ; Pack it
14:   BSR  Pack ;            Compute byte count
15:   SUB.L  A4,A1 ;         Put it in D0 (via POPALL)
16: MOVE.L  A1,(SP) ;       Unlock all
17: MOVE.L  A2,A0 ;          locked buffers
18:   _HUnLock ;             buffers
19: MOVE.L  A3,A0 ;          Restore registers
20:   _HUnLock ;             Return to caller
21: POPALL ;                 Return to caller
22: RTS
```
byte of \( n \), there are \( n + 1 \) data bytes that follow. Figure 6.31 illustrates the relationship between packed and unpacked data.

Lines 16–17 fetch the next count byte from the buffer and store it in the destination. Lines 19–22 handle a positive count byte, moving the data bytes that follow into the buffer. Lines 23–25 handle repeated bytes, moving the repeated data byte and negating the count byte. Lines 26–28 subtract the number of unpacked bytes moved from the total number required. The loop should terminate after moving exactly the number of bytes required (that is, D2 should be zero) at line 29. The BNE instruction branches to an alert routine if this is not the case. Lines 33–34 compute the byte count in the first part of the file buffer.

Lines 35–42 set up a call to UnPack at line 43. This converts the data to be displayed into unpacked format in the screen buffer. Line 44 computes the address of the first byte in the last part of the file buffer. Lines 44–45 correct the count in FBEnd to the proper number of bytes left in the end of the file buffer.

Lines 48–50 unlock the locked buffers. Line 51 packs the screen buffer into the undo buffer. This is necessary because the undo buffer may have data in it that reflect a part of the document which is no longer in the window. Lines 52–53 restore the registers and branch to the ReDraw routine. This causes the correct part of the document to appear in the window.

![Figure 6.30 - File buffer consolidation](image-url)
**Draw Data Area**

Listing 6.43 contains data definitions for variables used only by the draw routines. The data items have been explained in the text accompanying previous listings.

**MacDoodle Resource File Definitions**

To build a Macintosh application, you need both source code and resource definitions. This section describes the different resource types required for MacDoodle. These definitions are contained in the file MacDoodle.R.

```
1: RePack PUSHALL ; Save all registers
   BSR PackU ; Pack screen to undo buffer
2: MOVE.L UnDoBuf(A5),AO ; AO -> Undo buffer
   MOV.E L (AO),AO ; Al -> File buffer
   MOV.E L (AI),AI ; Save this
3: CLR.L D1 ; Clear D1 to convert
4: MOVE.W FBEnd(A5),D1 ; D1 = # bytes in bottom area
5: NEG.L D1 ; Subtract buffer size
6: SUB.W D1,A1 ; D1 = Buffer offset
7: NEG.L #1,DO ; Compute new buffer offset
8: SUB.W DBFStart(A5) ,01 ; Al -> New buffer offset
9: LEA A4,DO ; Save this
10: LEA 0(AS),DO ; Clear Do for DBRA now
11: LEA 1,A2 ; Overlap?
12: CMP.W DBFStart(A5),01 ; No, it's OK
13: BGE @1 ; Out of memory, all is lost
14: SUB.W D1,FBFStart(A5) ; Move in undo buffer
15: ANDI.L #$FFFF,01 ; until done
16: SUB.L FBufSiz(A5),01 ; Subtract start length
17: NEG.L D1 ; Mask off upper part
18: MOVE.W D1,FBEnd(A5) ; Compute
19: MOVE.W DBFStart(A5),D1 ; end length
20: SUB.W DBFStart(A5) ,01 ; Store new count
21: ANDI.L #FFFF,01 ; DO = # bytes to move
22: LEA 0(A2,D0.W),A2 ; EQ => Top region empty
23: SUBQ.W #1,DO ; A2 -> End of start region
24: CLR.W DBFStart(A5) ; DBRA-Adjusted
25: MOV.E B -(A2),-(A4) ; No bytes here now
26: MOV.E B -(A2),-(A4) ; Move in
27: DBRA D0,D2 ; start of buffer
28: POPALL ; Restore registers
29: RTS ; Back to caller
```

*Listing 6.41 – The RePack routine*
Listing 6.42 – The UnBuf routine

1: UnBuf PUSHALL ; Save the registers
2: MOVE.L FileBuf(A5),AO ; AO -> File buffer handle
3: _HLock ; Lock it
4: MOVE.L (AO),A1 ; A1 -> File buffer
5: MOVE.L A1,A2 ; Save for later
6: _CLR.D D1 ; Load
7: MOVE.W FBEnd(A5),D1 ; Compute byte count
8: SUB.L FBufSz(A5),D1 ; new
9: NEG.L D1 ; offset
10: LEA 0(A1,D1.W),AO ; Remember this
11: MOVE.L AO,A4 ; D2 =
12: MOVE.W SRow(A5),D2 ; # bytes
13: MULS.W #SWidth,02 #
14: BEQ @5 If EQ, do unpack
15: CLR.L 03 ; D3 = temp
16: @1 MOVE.B (AO)+,D3 ; Fetch store top
17: MOVE.B D3,(Al)+ ;_byte count
18: BMI @l < 0 means repeated byte
19: MOVE.W D3,D4 ; Copy count byte
20: @2 MOVE.B (AO)+,(Al)+ Move to buffer top
21: DBRA D4,@2 ; Branch to end of loop
22: BRA @4 ; Correct count
23: NEG.B D3 ; Ignore hex 80 bytes
24: BMI @1 Move data byte
25: MOVE.B (AO)+,(Al)+
26: @4 ADDQ.W #1,D3 Bump count (Un-DBRA adjust)
27: SUB.L D3,D2 ; Subtract item count
28: BGT @1 > 0 means go get next
29: BNE Void A terrible error!
30: ;
31: ; Now unpack file buffer to screen
32: ;
33: @5 SUBA.L A2,A1 ; Compute top byte count
34: MOVE.W Al,FBStart(A5) ; Save AO for a bit
35: MOVE.L AO,-(SP) ; AO -> Screen buffer handle
36: MOVE.L ScrBuf(A5),AO ; Lock it
37: _HLock ;
38: MOVE.L (AO),A1 ; AI -> Screen buffer
39: MOVE.L (SP)+,AO ; Restore AO
40: MOVE.W SSize(A5),D0 ; DO = # rows to unpack
41: MOVE.L Al,A6 ; Calculate
42: ADDA.L SBufSz(A5),A6 ; limit
43: BSR UnPack ; Unpack to screen buffer
44: SUB.L A4,A0 ; Size of start + unpacked area
45: MOVE.L AO,DO ; Move to data register
46: SUB.W DO,FBEnd(A5) ; Result is new size
47: MOVE.L ScrBuf(A5),AO ; Unlock all
48: HUnlock ;
49: MOVE.L FileBuf(A5),AO ; locked
50: HUnlock handles
51: BSR PackU ; Make undo buffer correct now
52: POPALL ; Pop the registers
53: BRA ReDraw ; Redraw the screen

Programming the Macintosh in Assembly Language
Output File

The first nonblank and noncomment line in a resource definition file defines the output file for RMAKER. Listing 6.44 shows this definition for MacDoodle.

The notation !MacDoodle means that the resources are to be appended to the file named MacDoodle. To build MacDoodle, you normally run the linker to produce this file, and then you run RMAKER to append the resources.

MacDoodle Icons

Macintosh applications can specify icons to be used for the application file and for document files with the application's signature. Figure 6.32 shows the icons for MacDoodle.

Listing 6.45 contains the definitions necessary to define the MacDoodle icons. The Finder looks at each application on the disk to see if it has a bundle resource. The bundle bit in the Finder flags word for the file must be set for the Finder to recognize the bundle resource. The bundle resource is a data area that specifies other resources in the application file which define the icons. Lines 6-12 define the bundle resource for MacDoodle. This bundle resource links together the other resources in Listing 6.45. Line 8 defines the resource type and ID of a version number resource. The version number resource must have the application's signature as its resource type. This is DOOD for MacDoodle. The resource ID is 0.

Two other resource types are required to complete the bundling process. A file reference resource (FREF) maps a file type onto a number called a local ID. An icon list resource (ICN#) maps the local ID onto an icon to be displayed. There are normally two FREF and two ICN# resources: one for the application file and one for documents processed by the application. The local IDs are the Finder's method of relating the

Figure 6.31 – Packed and unpacked data format
two resources. All resources in Listing 6.45 associated with the application file type have the same local ID, as do all resources associated with the document file type.

Lines 9–10 give the resource ID of the icon list. Line 10 maps local ID 0 to resource ID 128 and local ID 1 to resource ID 129. Lines 11–12 give the resource IDs of file references for the application and document icons. Local ID 0 maps onto FREF ID 128, and local ID 1 onto FREF ID 129.

The FREF resources map a file type onto a local ID. There are two such resources used in MacDoodle: one for the application file and one for document files. These have local IDs 0 and 1 (resource IDs 128 and 129), respectively. The file type for an application is APPL. This is mapped onto local ID 0 in line 16. The file type for a document processed by MacDoodle is PNTG. Line 18 maps this file type onto local ID 1.

The version data is defined in lines 23–26. The type statement in line 23 uses a GNRL (general) construction. The GNRL mechanism allows you to define resources with arbitrary format. The .P specification at line 25 specifies that the next line is to be placed in the file as a Pascal string.

The icon lists referenced in lines 9–10 are defined in lines 32–81. Line 10 maps local ID 0 to resource ID 128 and local ID 1 to resource ID 129. Resource ID 128 defines the icon for use with the application file.

Each icon definition consists of a 32 x 32-bit image for the icon itself plus another 32 x 32-bit image for the icon mask. The icon mask determines which parts of the background will show through when the icon is placed on top of another object. Also, an icon is highlighted by XORing the icon with the mask. Normally, the mask is the same shape as the icon and completely black.

```
1: Point1: DS.L 1 ; Temp point
2: Point2: DS.L 1 ; Second temp point
3: TmpRect DS.L 2 ; Temporary rectangle
4: OldRect DS.L 2 ; Old rectangle for boxes, ovals
5: NewRect DS.L 2 ; New rectangle for boxes, ovals
6: OldPen: DS.W 9 ; Pen state structure
7: SBitMap DS.L 1 ; Bitmap structure for screen buffer
8: SRBytes DS.W 1 ; RowBytes word
9: SBounds DS.W 4 ; Bounds rectangle
10: SrcRect DS.W 4 ; Source rectangle
11: PortAdr DS.L 1 ; GrafPort address
12: ScrType DS.W 1 ; Remember original type here
13: BuffCnt DS.W 1 ; # characters in buffer
14:BuffPtr DS.L 1 ; -> Next free slot in buffer
15: TBufCnt DS.B 1 ; Count byte for draw string
16: TBuffer DS.B TBuffSize ; Buffer itself
```

Listing 6.43 – The Draw data area
The .H directive at lines 34 and 62 specifies that the resource data that follows is in hex. Lines 35–42 define the MacDoodle application icon, and lines 46–53 define the mask. Lines 63–70 define the document icon, and lines 74–81 define the mask.

Apple supplies a program called the Icon Editor with a package called the Software Supplement. This program has a 32 × 32-bit version of MacPaint FatBits for drawing icons. It can also output the data in hexadecimal. Using this program can save a lot of time in defining icons.

**Menus**

Listing 6.46 contains the resource definitions for the MacDoodle menus. Menus used by the run-time library described in Chapter 8 must have resource IDs numbered consecutively from 1.

The first line after the resource ID for each menu gives the menu title. Subsequent lines contain the text for menu choices. The “(-” construct indicates a line drawn across the menu. This line occupies a menu choice, but it cannot be selected.

Lines 6–9 define the Apple menu, which contains the About dialog choice and the desk accessories. The “\14” at line 7 is the name of the menu. Using a backslash (\) character in any string takes the next two characters as hexadecimal digits, and inserts a character with that hexadecimal value. A value of 14 hex generates the Apple symbol on the screen.

```
1: *
2: * This is the resource file for the MacDoodle Program
3: *
4:
5: !MacDoodle
```

*Listing 6.44 – Output file definition*

*Figure 6.32 – The MacDoodle icons*
1: *
2: * Bundle resource definition. Specifies use of the
3: * MacDoodle private icon to the Finder.
4: *
5: *
6: Type BNDL
7: ,128
8: DOOD 0
9: ICN#
10: 0 128 1 129
11: FREF
12: 0 128 1 129
13:
14: Type FREF
15: ,128
16: APPL 0 ;; Application maps to Icon #0
17: ,129
18: PNTG 1 ;; Document maps to Icon #1
19:
20: *
21: * Version number resource
22: *
23: Type DOOD = GNRL
24: ,0
25: P
26: MacDoodle Program Version 1.0
27:
28: *
29: * MacDoodle icon definition
30: *
31:
32: Type ICN# = GNRL
33: ,128
34: H
35: 00018000 00018000 00018000 7FFFFFFE
36: 40000002 40000002 40200002 40500002
37: 40500002 40500002 40508002 40500002
38: 40500002 40708002 40C88002 41488402
39: 42494802 444E3002 40000002 7FFFFFFE
40: 00C18300 01818180 030180C0 06018060
41: 00C18030 18018018 3001800C 60018006
42: 00C18003 80018001 00000000 00000000
43: *
44: * Icon mask
45: *
46: 00018000 00018000 00018000 7FFFFFFE
47: 7FFFFFFE 7FFFFFFE 7FFFFFFE 7FFFFFFE
48: 7FFFFFFE 7FFFFFFE 7FFFFFFE 7FFFFFFE
49: 7FFFFFFE 7FFFFFFE 7FFFFFFE 7FFFFFFE
50: 7FFFFFFE 7FFFFFFE 7FFFFFFE 7FFFFFFE
51: 00FFFF00 01FFFF00 03FFFF00 07FFFF00
52: 00FFFF00 01FFFF00 03FFFF00 07FFFF00
53: 7FFFFFFE 7FFFFFFE 7FFFFFFE 7FFFFFFE
54:

Listing 6.45 – Icon definition
55:  
56: *  
57: * Document icon definition  
58: *  
59:  
60: Type ICN# = GNRL  
61: 1,129  
62: .H  
63: 1FFFF800 10000C00 10000A00 10000900  
64: 10000880 10000840 10000820 10000FF0  
65: 10000010 10018010 10018010 17FFFFD0  
66: 14000050 14100050 14280050 14280050  
67: 14280050 14284050 14280050 143C4050  
68: 14644050 14A4A450 15271850 14000050  
69: 17FFFFD0 10318C10 10618610 10C18310  
70: 11818190 13018000 10000010 1FFFFFFD0  
71: *  
72: * Document icon mask  
73: *  
74: 1FFFF800 1FFFFC00 1FFFFE00 1FFFFFF0  
75: 1FFFF800 1FFFFC00 1FFFFE00 1FFFFFF0  
76: 1FFFFF0 1FFFFFF0 1FFFFFF0 1FFFFFF0  
77: 1FFFFFF0 1FFFFFF0 1FFFFFF0 1FFFFFF0  
78: 1FFFFFF0 1FFFFFF0 1FFFFFF0 1FFFFFF0  
79: 1FFFFFF0 1FFFFFF0 1FFFFFF0 1FFFFFF0  
80: 1FFFFFF0 1FFFFFF0 1FFFFFF0 1FFFFFF0  
81: 1FFFFFF0 1FFFFFF0 1FFFFFF0 1FFFFFF0  

Listing 6.45 – Icon definition (continued)

1: *  
2: * Menu definitions  
3: *  
4:  
5: Type MENU  
6: 1,1  
7: \14  
8: About MacDoodle ...  
9: (-  
10:  
11: 1,2  
12: File  
13: New/N  
14: Open/R  
15: Save/W  
16: Save As ...  
17: (-  
18: Print  

Listing 6.46 – MacDoodle menu definitions
Listing 6.46 – MacDoodle menu definitions (continued)

19: (-
20: Quit
21:
22: ,3
23: Edit
24: Undo
25: (-
26: Cut/X
27: Copy/C
28: Paste/V
29:
30: ,4
31: Draw
32: Lines
33: Freehand
34: Boxes
35: Ovals
36: Text
37: (-
38: Eraser
39: (-
40: Erase Screen
41:
42: ,5
43: PenSize
44: 1 x 1
45: 2 x 2
46: 3 x 3
47: 4 x 4
48: 5 x 5
49: 6 x 6
50: 7 x 7
51: 8 x 8
52: 9 x 9
53: 10 x 10
54: 11 x 11
55: 12 x 12
56: 13 x 13
57: 14 x 14
58: 15 x 15
59: 16 x 16
60:
61: ,6
62: Font
63: Chicago
64: New York
65: Geneva
66: Monaco
67: Venice
68: London
69: Athens
70: San Francisco
71: Toronto
72: Cairo
73: Los Angeles
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74: Seattle
75: ,7
76: Style
78: Plain/P
79: <BBold/B
80: <IItalic/I
81: <IUnderline/U
82: <OOutline/O
83: <SShadow/S
84: Compressed
85: Expanded
86: (¬
87: 9 Point
88: 10 Point
89: 12 Point
90: 14 Point
91: 18 Point
92: 20 Point
93: 24 Point
94: 36 Point
95: 72 Point

Listing 6.46 – MacDoodle menu definitions (continued)

This is the MacDoodle Program
By Steve Williams

About MacDoodle Dialog (ID = 1)

Save changes before closing?

Save Changes Dialog (ID = 2)

Figure 6.33 – MacDoodle dialog boxes
1: Type DLOG
2: ,1
3:
4: 100 100 190 450
5: Visible NoGoAway
6: 1
7: 0
8: 1
9:
10: Type DITL
11: ,1
12: 3
13:
14: StaticText
15: 15 20 36 350
16: This is the MacDoodle program
17:
18: StaticText
19: 35 20 56 350
20: By Steve Williams
21:
22: Button
23: 60 260 80 320
24: OK
25:
26: Type DLOG
27: ,2
28:
29: 100 100 190 400
30: Visible NoGoAway
31: 1
32: 0
33: 2
34:
35:
36: Type DITL
37: ,2
38: 3
39:
40: Button
41: 60 175 80 225
42: Yes
43:
44: Button
45: 60 235 80 285
46: No
47:
48: StaticText
49: 15 20 36 325
50: Save changes before closing?

Listing 6.47 - MacDoodle dialog definitions
The resource file defines two items in this menu: the About dialog and a line at the second menu choice. The run-time library adds the desk accessory names to this menu during program initialization. The code that does this appears in Listing 8.4 (Chapter 8).

Command key equivalents to menu selection are defined by placing a slash (/) character and the desired key character at the end of the selection name. For instance, the New file selection in line 13 can also be invoked by the Command-N key sequence.

You may also specify text attributes for the menu selection items. Lines 79–83 illustrate how to do this. Using a less-than symbol (<), you can assign a single attribute to the text string. These are the allowable attribute sequences:

- `<B>` Bold
- `<I>` Italic
- `<U>` Underline
- `<O>` Outline
- `<S>` Shadow

There is no sequence for Compressed or Expanded text attributes. You cannot set more than one attribute using this technique.

**Dialogs**

MacDoodle has two dialog boxes, one for the About dialog and one to prompt the user to save changes to the document. These are shown in Figure 6.33. Listing 6.47 contains the resource definitions for these two items.

Defining a dialog box requires two resources: a DLOG resource, which defines the box, and a DITL (Dialog Item List) resource, which defines what goes in the box. Lines 1–8 define the DLOG resource for the About dialog, and lines 10–24 define the associated DITL resource.

A DLOG resource definition consists of five lines (blank lines are not significant). The first line (line 4 in Listing 6.47) gives the rectangle on the screen where the box is to appear. This rectangle is represented by global coordinates. The next line (5) gives the attributes of the box. The three lines that follow (6–8) give the definition procedure ID, the reference value, and the resource ID of the associated DITL definition.

Two of four possible attributes can be specified for a dialog box. The box can be either visible or invisible, which determines whether the box is drawn initially. The dialog box can have a box similar to a window's box. Specify GoAway if you want the dialog box to have a close box, or NoGoAway.
The definition procedure ID is 1 for a standard dialog box, like the ones in Figure 6.33. The reference constant is normally unused, but it still must be specified. The DITL resource associated with the first dialog has resource ID 1.

Lines 10–24 define the DITL resource for the About dialog. Line 11 indicates the resource ID. Line 12 specifies the number of items in the item list. Lines 14–16 define the first item. StaticText means a message that cannot be edited by the user. Line 15 gives a rectangle in which the message is to appear. This rectangle is in the local coordinates of the dialog box. Line 16 contains the actual text. Lines 18–19 define the second line of text in the dialog. Lines 22–24 define the OK button. Line 23 gives the rectangle containing the button, again in local coordinates. Line 24 contains the text to appear inside the button.

Lines 26–50 define the second dialog box. This is very similar to the About box, except that there are two buttons. The order of the items in the DITL resource determines the value that will be returned by the DIALOG macro when the user makes a selection. In this case, the Yes button returns a value of 1 and the No button returns a value of 2. Static text items occupy a position in determining this value. A DIALOG macro that specifies the About box would return a value of 3.

Alerts

Listing 6.48 shows a sample alert resource definition. Line 2 gives the resource ID for this alert. Line 3 gives the rectangle for the alert box in screen coordinates. Line 4 contains the resource ID of the associated DITL resource. Line 5 contains the stages word (in hexadecimal). Alert stages are illustrated in Figure 6.17.

The DITL resource appears in Lines 7–21. Note that the button is the first entry. Since the default button can be only the first or second item, you must be careful when ordering items in a DITL resource associated with an alert.

Main Window

Listing 6.49 contains the definition for the main document window. The run-time library requires that the window have resource ID 1.

Lines 8–9 define the window boundaries (in global coordinates) and attributes. Window attribute specifications are the same as the dialog attributes discussed previously. Line 10 gives the definition procedure ID. This is 0 for a standard document window. Line 11 contains the reference constant. This is not used by MacDoodle.

The scroll bars are defined next. Lines 17–24 define the vertical scroll bar, and lines 26–33 define the horizontal scroll bar. Lines 19 and 28 define a
control title. This is a field required by RMAKER that is unused by scroll bars. Any string can be used. Lines 20 and 29 define the coordinates for the scroll bar in the window's local coordinate scheme. Lines 21 and 30 define the control attributes. Control attributes can be either visible or invisible. Lines 22 and 31 give the procedure definition ID, which is 16 for scroll bars. Lines 23 and 32 contain the reference constant. Lines 24 and 33 contain the minimum, maximum, and initial values for each scroll bar.

**Sample Cursor**

Listing 6.50 contains a definition of a sample cursor. A cursor resource consists of two 16 × 16-bit images and a point. The first bit image defines the cursor and the second defines the cursor mask. The point defines the mouse coordinates within the cursor.

The cursor is defined with the GNRL type, using hexadecimal data. Lines 10–25 define the cursor outline, and lines 27–42 define the mask. Lines 45–46 define the mouse point within the cursor.

This cursor is the 8 × 8 eraser cursor. The resource ID is 23 (decimal) or 17 hex. The code in Listing 6.17 selects this cursor when Eraser is selected on the Draw menu and 8 × 8 is selected on the PenSize menu. The remaining cursor definitions are left as an exercise.

```
1: Type ALRT
2: ,129
3: 50 50 160 325
4: 3
5: 5555
6:
7: Type DITL
8: ,3
9: 3
10:
11: Button
12: 85 205 105 265
13: QUIT
14:
15: StaticText
16: 20 60 40 225
17: MAJOR PROGRAM BUG
18:
19: StaticText
20: 50 20 70 225
21: This should "Never Happen"
```

*Listing 6.48 – Sample alert definition*
Run-Time Library Configuration

MacDoodle requires a version of the run-time library that is different from the one used by the programs we wrote earlier. Listing 6.51 shows the technique used to configure the RTL.

Line 4 disables the use of the Text Edit package, so that the document window can contain graphics. Line 5 enables the use of scroll bars on the window, and line 6 specifies that the application does not have a separate resource file. These options are explained in Chapter 8.

The Linker Command File

Listing 6.52 shows the MacDoodle linker command file. MacDoodle requires the use of a few additional linker features. Lines 1–6 list the files

```
1: * Main window definition
2: *
3: *
4: 
5: Type WIND
6: ,1
7: 
8: 40 5 300 500
9: Visible GoAway
10: 0
11: 0
12: 
13: *
14: * Scroll bar controls for main window
15: *
16: 
17: Type CNTL
18: ,256(4)
19: x
20: 0 480 245 495
21: Visible
22: 16
23: 0
24: 0 720 0
25: 
26: Type CNTL
27: ,257(4)
28: x
29: 245 0 260 480
30: Visible
31: 16
32: 0
33: 0 576 0
```

Listing 6.49 – MacDoodle window definition
to be included in the link, including the PrLink file from the Macintosh Development System. Line 7 specifies the entry point for the program. The XXSTART label is generated by the PROGRAM macro in Listing 6.1. Line 8 sets the bundle bit in the Finder file flags word for the file. Line 9 sets the Finder file type and application signature words. A file type of

```
1:                     8 x 8 Eraser cursor
2: *
3: *                   
4: *
5:                      
6: Type CURS = GNRL
7: *                    
8: .H                   
9: *    16 words of cursor pattern
10: FFOO
11: 8100
12: 8100
13: 8100
14: 8100
15: 8100
16: 8100
17: FFOO
18: 0000
19: 0000
20: 0000
21: 0000
22: 0000
23: 0000
24: 0000
25: 0000
26: *    16 words of cursor mask
27: FEOO
28: FEOO
29: FEOO
30: FEOO
31: FEOO
32: FEOO
33: FEOO
34: 0000
35: 0000
36: 0000
37: 0000
38: 0000
39: 0000
40: 0000
41: 0000
42: 0000
43: *    Hot spot point
44: 0000
45: 0000
```

Listing 6.50 – Sample cursor definition
APPL denotes an application file. DOOD is the application signature for MacDoodle.

**SUMMARY**

This chapter contains a brief overview of the techniques used to write Macintosh applications. We have covered a number of important topics:

- The use of the QuickDraw graphics package
- Memory layout and memory management
- Resources
- Windows, dialogs, and alerts
- Menu operations
- Events

```
1: ;
2: ; MacDoodle RTL. Configures the RTL code for use with MacDoodle.
3: ;
4: TEXTRTL EQU -1 ; Not text RTL
5: CONTROL EQU 0 ; Does have window controls
6: RESFILE EQU -1 ; No separate resource file
7: Include RTLcode.Asm ; Include RTL
8: END
```

**Listing 6.51 – MacDoodle RTL configuration file**

```
1: MacDoodle
2: MacDoodleDraw
3: MacDoodleMenu
4: MacDoodleData
5: MacDoodleRTL
6: PrLink
7: !XXSTART
8: /Bundle
9: /Type 'APPL' 'DOOD'
10: $
```

**Listing 6.52 – The MacDoodle linker command file**
The most important part of the chapter is the example program. This is a piece of working code that performs most of the commonplace operations in the Macintosh environment.

The Macintosh system has many more facilities than we have used here. Most of the system services have several options that give the application a good deal more flexibility than we have presented. However, you can write fairly sophisticated programs using just the material in this chapter.

**EXERCISES**

1. The MacDoodle application uses a complicated buffering scheme to avoid the need for a 56K buffer to store the entire unpacked document. Using such a buffer would mean that the program would not run on a 128K Macintosh. What changes would you make if you could restrict the program to running on a 512K Macintosh?

2. Replace the UnPack and Pack routines in Listings 6.38 and 6.39 with routines that make no system calls. What simplifications can you make to other parts of the program?

3. Modify the code in Listing 6.5 to support printing multiple files specified by the Finder.

4. Write resource definitions for all of the cursors and alerts in the MacDoodle program.

5. Which resources in the MacDoodle resource file should be pre-loaded to quicken program startup?
Chapter 7

Exception Processing

Consider nothing as impossible before it has come to pass.
—Confucius

INTRODUCTION

This chapter will teach you what a machine exception is and the programming techniques you can use to process exceptions. We will discuss the types of exceptions possible on the 68000 chip and how each is handled by the Macintosh.

WHAT IS AN EXCEPTION?

An exception is the machine's ability to interrupt what it is doing, do something else, and (if necessary) return to the interrupted task. There are two types of exceptions on the 68000:

1. Exceptions caused by I/O devices, called interrupts
2. Exceptions caused by internal operations, such as program errors or the TRAP instructions

The exception mechanism is commonly used to interweave I/O processing with computation. Because I/O devices are typically much slower
than the CPU, the CPU can spend most of its time waiting for the I/O device. The use of exceptions allows programs to make use of that idle CPU time to perform computations, without in any way delaying or interrupting the I/O task at hand. This effectively means that programs can perform both I/O and computations simultaneously, reducing the time required to perform a task.

**General Exception Processing**

There are four steps in using the external exception mechanism:

1. The program starts an I/O operation and begins doing computations.
2. When the I/O is complete, an exception occurs, causing the computational work to be suspended.
3. If there is more I/O to be done, the program starts another I/O operation.
4. Computation can then resume until another exception occurs.

This type of I/O is commonly called *interrupt-driven I/O*. The Macintosh uses interrupt-driven I/O for the keyboard, mouse, disks, and serial ports.

Exceptions that result from internal operations act like subroutine calls. The TRAP instructions are used to call the operating system in many 68000 computers; the Macintosh uses the illegal instructions with op codes A000 hex and greater instead, as described in Chapter 5. From the standpoint of the application, the instruction that causes the exception resembles a BSR or JSR instruction. Execution resumes at the location following the TRAP or illegal instruction.

In many cases, it is not desirable to resume execution following an internal exception. Most internal exceptions result from programming errors, such as accessing nonexistent memory, division by zero, or a privilege violation. Continuing the program after such an error is almost certain to produce more errors. The Macintosh displays a “System Error” message after this type of error, and you must reboot the Macintosh to recover from such an error.

**Vectors**

Each possible exception is associated with a unique longword in memory called a vector. There are 256 possible vectors, numbered from 0
to 255. Each vector contains the address of the routine that processes the exception. Vectors are organized contiguously in memory, starting at absolute address 0. The address of a vector is the vector number times 4. Internally generated exceptions use dedicated, or preassigned, vector numbers. There are also seven dedicated vector numbers for I/O, called the autovector interrupts. In addition, a mechanism exists for I/O devices to specify vectors to be used for I/O interrupts.

Table 7.1 lists the vector numbers that are preassigned by the 68000. Locations 0 and 4 are used for the initial stack and program counter when the processor is first powered up or when the RESET signal is applied. The forward button on the Macintosh Programmer's Switch panel (described in the Macintosh owner's manual) causes a RESET exception.

<table>
<thead>
<tr>
<th>Vector (decimal)</th>
<th>Address (hex)</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>RESET initial SSP (supervisor stack pointer)</td>
</tr>
<tr>
<td>1</td>
<td>4</td>
<td>RESET initial PC (program counter)</td>
</tr>
<tr>
<td>2</td>
<td>8</td>
<td>BUSERR (nonexistent memory)</td>
</tr>
<tr>
<td>3</td>
<td>C</td>
<td>Address (boundary) error</td>
</tr>
<tr>
<td>4</td>
<td>10</td>
<td>Illegal instruction</td>
</tr>
<tr>
<td>5</td>
<td>14</td>
<td>Zero divide</td>
</tr>
<tr>
<td>6</td>
<td>18</td>
<td>CHK instruction</td>
</tr>
<tr>
<td>7</td>
<td>1C</td>
<td>TRAPV instruction</td>
</tr>
<tr>
<td>8</td>
<td>20</td>
<td>Privilege violation</td>
</tr>
<tr>
<td>9</td>
<td>24</td>
<td>TRACE</td>
</tr>
<tr>
<td>10</td>
<td>28</td>
<td>Line 1010 emulator</td>
</tr>
<tr>
<td>11</td>
<td>2C</td>
<td>Line 1111 emulator</td>
</tr>
<tr>
<td>12–14</td>
<td>30–38</td>
<td>Unassigned (reserved)</td>
</tr>
<tr>
<td>15</td>
<td>3C</td>
<td>Uninitialized interrupt vector</td>
</tr>
<tr>
<td>16–23</td>
<td>40–5C</td>
<td>Unassigned (reserved)</td>
</tr>
<tr>
<td>24</td>
<td>60</td>
<td>Spurious interrupt</td>
</tr>
<tr>
<td>25–31</td>
<td>64–7C</td>
<td>Level 0–7 autovector interrupts</td>
</tr>
<tr>
<td>32–47</td>
<td>80–BF</td>
<td>TRAP 0–15 instruction vectors</td>
</tr>
<tr>
<td>48–63</td>
<td>C0–FC</td>
<td>Unassigned (reserved)</td>
</tr>
<tr>
<td>64–255</td>
<td>100–3FF</td>
<td>User interrupt vectors</td>
</tr>
</tbody>
</table>

Table 7.1 - Preassigned Vectors
A BUSERR (bus error) indicates a program reference to a memory location that does not exist. (This is colloquially known as "missing the bus."\) A reference to a word or longword at an odd-numbered address causes an addressing-error exception. Illegal instructions cause exceptions through vector numbers 4, 10, or 11. The op codes Axxx and Fxxx cause exceptions that trap through the line 1010 and line 1111 vectors (10 and 11, respectively). All other illegal instructions (for example, an op code of 4AFC) use vector 4.

Division by zero causes an exception through vector 5. The CHK and TRAPV exceptions are caused by the CHK and TRAPV instructions (see Chapter 3). These instructions trap through vectors 6 and 7.

A privilege-violation exception results from executing a privileged instruction while the processor is in user mode. If bit 13 of the status register is not set before executing a privileged instruction, the 68000 takes an exception through vector 8. All Macintosh software runs in supervisor mode, so this exception should not occur on a Macintosh.

Macintosh debugger programs use the TRACE exception vector (9) for executing single instructions in a program to be debugged. These are the steps usually used in single-stepping:

1. Push the program counter of the instruction to be debugged onto the stack.

2. Push the status register with the trace bit (bit 15) set.

3. Execute an RTE instruction.

The processor will execute one instruction with the trace bit set and then trap through the TRACE vector. Any instruction that affects all bits of the status register can set the trace bit.

Whenever a memory violation (BUSERR) occurs during an external interrupt, the spurious interrupt (vector 24) is used. This indicates a hardware malfunction on the Macintosh.

Vector 15 is used by Motorola support chips for the 68000. The Macintosh does not use these chips. An interrupt through this vector also indicates a hardware malfunction.

Vectors 12–14, 16–23, and 48–63 are reserved for use by Motorola on future 68000-family chips. Vectors 64–255 are reserved for use by Motorola customers (like Apple) for devices connected to the 68000. None of these vectors is used by the Macintosh.
WHAT HAPPENS DURING AN EXCEPTION?

When the 68000 recognizes an exception condition, several things occur:

1. The current values of the program counter (which normally points to the next instruction to be executed) and status register are pushed onto the supervisor-mode stack.

2. The trace bit in the status register is turned off, and the supervisor bit is turned on. This prevents a TRACE exception and forces the 68000 into supervisor state. For external interrupts, the interrupt mask in the status register is also updated.

3. For a BUSERR or addressing-error exception, extra information is pushed onto the stack.

4. The program counter is loaded from the appropriate vector, and execution begins at this address.

The routine whose address is contained in the vector is called an exception handler. This routine normally saves the registers on the stack, performs some action, restores the registers, and executes an RTE instruction. Thus, the 68000 provides the ability to interrupt a program and later resume executing the program with no noticeable effect, other than increased processing time. This ability is normally used with interrupt-driven I/O.

RESET

There is one exception that does not behave this way. A special pin on the 68000 chip called RESET causes a special exception to take place. A signal placed on the RESET pin causes the processor to load the supervisor stack pointer from location 0 and the program counter from location 4. This provides a mechanism for starting the 68000 in a known state. RESET is normally used for the bootstrap button on 68000 microcomputers; that is, it provides both a mechanism for starting the 68000 when power is applied and the ability to recover from catastrophic software failures. The button labeled RESET on the Macintosh Programmer's Switch panel activates the 68000 RESET signal.
**BUSERR and Addressing-Error Exceptions**

Vectors 2 and 3 are used for errors detected in references to memory. The BUSERR exception (vector 2) indicates that the program has referenced memory that does not exist.

An addressing-error exception means that the program has referenced a memory word or longword at an odd address. If a program references a memory word or longword at an odd address that is also nonexistent (i.e., both bus and addressing-error conditions), the processor will detect the addressing error first, and only the addressing-error exception will take place.

These two exceptions differ from all other exceptions in that the processor puts extra information on the stack. When the exception handler is entered, the stack appears as shown in Figure 7.1.

The first word on the stack contains information about the type of memory access that caused the fault. Bits 5 through 15 of this word are undefined. If the access error occurred during a memory read, the R/W bit is 1.

```
<table>
<thead>
<tr>
<th>Bits</th>
<th>15</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>A7</td>
<td>/////</td>
<td>R/W</td>
<td>I/N</td>
<td>Access</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>+2</td>
<td>High word of erroneous address</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>+4</td>
<td>Low word of erroneous address</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>+6</td>
<td>First word of instruction</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>+8</td>
<td>Status register</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>+10</td>
<td>Program counter high word</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>+12</td>
<td>Program counter low word</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
```

*Figure 7.1 - The stack after bus or addressing error*
If the access error occurred during a memory write, the R/W bit is 0.

The I/N bit is 0 if the processor was processing an instruction and 1 if the error was detected by an external device. (Most of these errors result from instruction processing.) The access code contained in the lower three bits describes the type of memory access being performed. Table 7.2 shows the type of memory access indicated by each access code.

These bits tell you two things: whether the processor was referencing data or program instructions and whether the processor was in supervisor mode or user mode. Data references include all accesses to memory that use all addressing modes except the two PC-relative modes. Program references include instruction accesses to memory that use the PC-relative addressing modes as well as accesses to memory that fetch instruction words.

The next two words on the stack give the address where the fault occurred. The processor saves a copy of the op code of the instruction that caused the fault in the next word on the stack. As with all other exceptions, the status register and program counter are present. The value stored as the program counter is advanced from the beginning of the instruction by two to ten bytes. (The smallest 68000 instruction is two bytes long; the largest is ten bytes.)

If the error occurred while an instruction was being fetched, the stored program counter will be in the vicinity of the previous instruction. Normally, this error is caused by taking a wild branch. In this case, the program counter and op code word on the stack indicate the branch instruction rather than the erroneous address of the attempted transfer.

<table>
<thead>
<tr>
<th>Code</th>
<th>Type of Access</th>
</tr>
</thead>
<tbody>
<tr>
<td>000</td>
<td>Unassigned</td>
</tr>
<tr>
<td>001</td>
<td>User mode data reference</td>
</tr>
<tr>
<td>010</td>
<td>User mode program reference</td>
</tr>
<tr>
<td>011</td>
<td>Unassigned</td>
</tr>
<tr>
<td>100</td>
<td>Unassigned</td>
</tr>
<tr>
<td>101</td>
<td>Supervisor mode data reference</td>
</tr>
<tr>
<td>110</td>
<td>Supervisor mode program reference</td>
</tr>
<tr>
<td>111</td>
<td>Interrupt acknowledge</td>
</tr>
</tbody>
</table>

Table 7.2 - Memory Access Codes
The erroneous address words on the stack will contain the erroneous instruction address (see Figure 7.1).

If the processor encounters a second BUSERR or addressing error during the processing of one of these errors, a situation called a double bus fault occurs. This occurs if the supervisor stack pointer is corrupt and the processor is unable to save any information on the stack. The processor halts and can be restarted only by using the RESET input on the chip.

**Illegal Instruction Exceptions**

Whenever the 68000 fetches an op code that cannot be interpreted as a legal 68000 instruction, an exception through vectors 4, 10, or 11 occurs. Vectors 10 and 11 are used for op codes that have 1010 or 1111 in the high-order four bits. These are called the A-line and F-line traps, respectively. Vector 4 is used for all other illegal instructions:

- Illegal op codes other than Axxx or Fxxx
- Illegal addressing modes, such as a PC-relative operand specified as an instruction destination
- Illegal addressing mode or instruction combinations, such as byte operations on address registers

Illegal instructions can be used to simulate extended 68000 instructions. The Macintosh uses the op code Axxx (the A-line trap) in this fashion. (Fxxx is also often used for this purpose on 68000 machines.) To simulate an extended instruction, first define an illegal op code pattern for this instruction. Then write an exception handler for the appropriate illegal instruction vector that simulates the action of the instruction. A program can then make use of the instruction without knowing that the instruction is simulated. There is, of course, a significant cost in terms of processing speed.

This technique is often used to simulate optional hardware extensions to a processor's instruction set, such as floating point. In this way you can write a program that uses floating-point operations and run that program on any machine, whether or not it has the floating-point hardware. The only difference is that the program will run much faster on a machine with the optional hardware.

The Macintosh uses the A-line trap for all Toolbox and operating system calls. The application views the trap as a subroutine call into the operating
TRAP Exceptions

The notion of an operating-system call instruction is similar to software simulation of illegal instructions. The TRAP instructions are frequently used for operating system calls. The Macintosh does not use TRAP instructions, however. The program first issues an operating-system call instruction; then the operating system performs some function and returns an indication of its success or failure to the program.

The program can treat these operating system calls as if they were single instructions. The operating system can provide a set of functions, sometimes called the extended instruction set, which is the same on machines that have substantially different hardware. This is the appeal of standard operating systems, which allow the same applications software to run unchanged on many different machines.

The 68000 has 16 operating-system call instructions, TRAP 0 through TRAP 15. Illegal instructions can be used to extend this set almost infinitely. The TRAP instructions use vectors 32 through 47. The advantage of having a large number of such instructions is that the operating system can dedicate a TRAP instruction to a frequently used operating system service and reduce the number of instructions required to perform this service. Less frequently called services can be invoked by requiring the application to load a function code into a register before performing the TRAP instructions. This function code specifies which operating system routine is desired.

The TRAP instruction allows a convenient transition between user mode and supervisor mode. On 68000 systems other than the Macintosh, applications normally run in user mode, while the operating system normally runs in supervisor mode. To enter the operating system, the TRAP instruction automatically places the processor into supervisor mode.

When the RTE instruction is used to return to the user program, the user program’s status register is loaded from the stack, causing the processor to go back to user mode. This mechanism also makes it possible for both supervisor-mode and user-mode programs to call the operating system, or even for the operating system to call itself.

Another advantage of the TRAP instruction is that the application program need not know the location of the operating system. Many systems require that the application program jump to some fixed address to call the operating system. The TRAP instruction allows the location of the operating system to change without affecting the application program.
Exceptions Used for Debuggers

Macintosh debuggers provide two mechanisms for controlling program execution: breakpoints and single-instruction execution. These mechanisms make use of two 68000 exceptions: the illegal-instruction and TRACE exceptions.

To set a breakpoint in a program being debugged, the most common technique is to save the instruction at the breakpoint location and place an illegal instruction at that location. The debugger then allows the program to execute until an illegal-instruction exception occurs. This technique will fail if a breakpoint is set in the middle of a multiword instruction, if the breakpoint is never executed, or if the program uses the instruction as data. Also, continuing from a breakpoint requires that the instruction at the breakpoint be single-stepped before program execution resumes.

Single-stepping an instruction involves setting the trace bit in the status register. The most common method is to stack the program counter and status register, set the trace bit in the stacked status register, and execute an RTE instruction. A TRACE exception will occur immediately following the execution of the target instruction. There are some side effects of this technique, however:

- Because an exception clears the trace bit, an exception caused by the instruction being traced causes the debugger to lose control unless the debugger receives control when exceptions occur.

- A-line instructions that call an operating-system or Toolbox function appear as a single instruction.

- Tracing an RTE instruction causes the debugger to lose control because the RTE instruction reloads the status register. Tracing an instruction that reloads the status register has the same effect. These instructions include MOVE to SR, ANDI to SR, and EORI to SR.

- Tracing a MOVE from SR instruction can cause the program to malfunction, because the trace bit will be set in the copy of the status register that the program receives. If the program compares this copy without masking the trace bit, it could execute incorrectly.

Because all Macintosh software executes in supervisor mode, you must exercise care in tracing the instructions that reload the status register.
Other Error Exceptions

The TRAPV, CHK, and zero-divide exceptions are also mechanisms that detect malfunction. These exceptions are used to assist the application in detecting problems with overflow, array subscript range, and division by zero.

The application program may need to regain control after one of these exceptions in order to print out a message that identifies the error and its cause. High-level language programs may have a way of identifying the routine and its line number in the source program. Operating systems usually have some mechanism that allows the application program to regain control following an error exception.

Privilege-Violation Exceptions

A user-mode program that attempts to execute a privileged instruction causes a privilege-violation exception through vector 8. This usually indicates an error condition. With some computer systems, however, you can use the privilege-violation exception to execute multiple supervisor-mode programs. The multiple supervisor-mode programs run in user state and a supervisor-mode monitor simulates the action of all the privileged-mode instructions. This technique is sometimes known as the virtual machine technique.

Virtual machines are used to run multiple operating systems on a single computer. A hardware device called a memory management unit (MMU) simulates different memory spaces for each operating system. This allows each system to have its own vector area as well as other dedicated memory locations. Because the operating systems run in user mode, they do not interfere with each other.

The 68000 chip is capable of running a virtual machine system with a single exception—the MOVE from SR instruction is not privileged. If software that needs to run in supervisor state uses the MOVE from SR instruction and looks at the supervisor bit, it may malfunction. On the 68010 chip, MOVE from SR is privileged.

Because all Macintosh software runs in supervisor mode, a privilege-violation exception is an indication of a software error. The normal cause for this type of exception is an RTE instruction executed with the wrong data on the stack. This loads an incorrect value into the status register, possibly putting the processor into user mode. The next privileged instruction causes a privilege-violation exception.
Interrupts

Exceptions that come from external sources are often called interrupts. The 68000 provides two techniques for external devices to interrupt the CPU: vectored interrupts and autovectored interrupts.

An external device can use three pins on the 68000 chip to cause an interrupt. These pins are called IPL0, IPL1, and IPL2. IPL stands for interrupt priority level. These three inputs to the 68000 comprise a three-bit code used to request interrupts. The special code 000 means no interrupt. Combinations 1 through 7 request an interrupt with priorities 1-7. The 68000 chip recognizes an interrupt if the interrupt mask (contained in status register bits 8-10) is less than the priority presented on the IPL0-2 pins. Thus, an interrupt mask of 0 allows all interrupts, and an interrupt mask of 7 allows no interrupts (except level 7).

When an interrupt occurs, the interrupt mask in the status register is set to the priority level of the interrupt. This prevents that interrupt, or any interrupt with the same priority, from recurring until the interrupt mask is set to a lower value by the exception handling routine.

Interrupt level 7 is a special case because it cannot be masked off. This interrupt level is normally reserved for extremely high-priority devices or for a "panic button" that can be used to recover from a runaway program. A level-7 interrupt is sometimes called a nonmaskable interrupt or NMI.

An interrupt requested at a lower level than the current processor priority remains pending until the operating system lowers the processor priority. The maximum amount of time an interrupt can remain pending is called interrupt latency. This time is determined by the maximum number of instructions a program can execute with interrupts masked off. Several applications, including instrumentation, industrial automation, and communications, require rapid interrupt response. In programming interrupt-driven software, there are usually restrictions on the amount of time interrupts can be disabled.

When the 68000 recognizes an interrupt, an additional control pin can be used to request an autovectored interrupt. Autovectored interrupts use vectors 25 through 31 for interrupt levels 1-7. If an autovectored interrupt is not requested, the 68000 reads a vector number from the device requesting the interrupt. Deciding which type of interrupt to use is the prerogative of the engineer who designs the 68000 computer system. Autovectored interrupts have the advantage of requiring less hardware (you don't need the extra control pin), but they are slower and require more sophisticated software. Vectored interrupts provide better interrupt response time at the cost of extra hardware. The Macintosh designer chose to use autovectored interrupts.
The relationship between a device's interrupt vector and its interrupt priority level is dependent on the physical connection between the 68000 and the hardware device. This relationship differs for each type (and possibly model) of computer. Interrupt programming usually requires different coding for each machine on which the program runs. (It is possible to write a fixed program that processes software exceptions, such as BUSERR, addressing error, and so on, because these are characteristics of the 68000 chip and do not change from machine to machine.)

The Macintosh hardware uses the autovectored interrupts for all external devices. The devices are connected as follows:

**IPL Devices**

1. Clock, vertical retrace, keyboard, mouse, timer, disk, sound
2. Serial ports
3. Both 1 and 2
4. INTERRUPT button
5. Both 4 and 1
6. Both 4 and 2
7. All three devices: 4, 2, and 1

There are three IPL lines into the 68000 chip. A chip called the VIA (Versatile Interface Adapter) handles the clock, vertical retrace, keyboard, mouse, timer, disk, and sound devices. The VIA interrupt is connected to the low-order IPL line (IPL0). The serial ports are controlled by a single chip, the SCC (Serial Communications Controller). The interrupt from this chip is connected to the middle IPL line (IPL1). The INTERRUPT button on the Macintosh Programmer's Switch panel is connected to the high-order IPL line (IPL2).

Thus, the Macintosh normally has only three possible interrupts: level 1, level 2, and level 4. However, if two or more of the devices interrupt, an interrupt on one of the other levels occurs.

**SUMMARY**

In this chapter we have presented the exception mechanism of the 68000 and learned how it relates to the Macintosh. This information is important for writing device drivers or for debugging programs that cause exceptions.
INTRODUCTION

This chapter describes the source code for the run-time library used in all of the previous programs in this book. There are two sections of this code. The first section, found in file MACLIB.ASM in Appendix E, is a set of macros that are called by the user program. The second section, found in files RTLcode.asm and RTLdata.asm in Appendix E, consists of the subroutines called by these macros.

The Macintosh program-level interface is often criticized as being too "low level." The Macintosh system designers, in their desire to give the application writer total flexibility, have created a system that requires a large number of system calls to do anything. The run-time library offers a collection of simpler calls that perform the most common combinations of the low-level calls.

There is also a large amount of code that is required as overhead in Macintosh applications. The run-time library attempts to isolate and standardize this software so that it need not be recoded for each new application.

The benefits to the application writer are twofold. First, there are large areas of the Macintosh system software with which the application writer need not be concerned. This saves time in learning how to write applications. Second, the macro calls to the run-time library are easier to code than direct calls to the Macintosh system routines. The resulting smaller programs are easier to write and modify.
The costs are also twofold. First, the application writer loses a certain amount of flexibility in writing an application. Many of the optional features available through direct calls are not available with the run-time macros. Second, there is a small memory overhead for programs that do not use all of the available features. You can eliminate these problems by modifying the source to the run-time library. By creating a custom version of the run-time code for a given application, you can change certain features to match the requirements of your application. You can also reduce memory overhead by taking out unused routines.

The run-time library is a set of reusable software components. It reduces the time required to write an application by cutting both learning time and coding time. This is accomplished through standardization. Each run-time call gives you the most common way of performing that particular function. You invoke run-time functions with a single-line macro call. You can easily rewrite run-time functions to work differently should your application require it.

**PROGRAM INITIALIZATION**

Programs using the run-time library begin execution with the PROGRAM macro. This macro defines the label XXSTART, which you used in linker command files. Listing 8.1 contains the PROGRAM macro.

This macro has three parameters: the name of the program, a debug flag, and the number of menus present in the program's resource file. The first instruction executed by the program is the JSR to a routine called XXINIT. This is a run-time routine that performs one-time initialization for the program. Following the JSR instruction is a Pascal-format string (lines 23–28) that gives the name of the program. If the name is not specified in the macro call, the string "No Name" is used instead. At the next even address following the name string, there is a word that contains the number of menus in the program menu bar. This word is set to zero if the macro parameter is omitted on the macro call. Following this word is another word that contains the first instruction to be executed by the program. This word contains either hex 4E71 or FF01, depending on the setting of the debug parameter. A value of FF01 invokes the debugger when the program starts. The 4E71 value (a no-operation instruction) causes the program to begin normally.

The code invoked by the PROGRAM macro resides in the run-time library. The PROGRAM macro calls the routine at label XXINIT. This routine performs the following functions:

1. It initializes the Macintosh Toolbox routines.
2. It opens the resource file.
3. It builds and displays the menu bar.
4. It creates a window on the screen.
5. It adds scroll bars to the window.
6. It creates a text record for the window.

---

Listing 8.1 - The PROGRAM macro

```
1: ;
2: ; PROGRAM macro. This macro is used to define an application.
3: ; It must be the first code-generating statement in the program.
4: ;
5: ; Usage:
6: ; PROGRAM name,debug,menus
7: ;
8: ; Where "name" is the application's name (used to find the
9: ; resource file, for instance).
10: ;
11: ; "Debug" is either "DEBUGON" or "DEBUGOFF", to make the program's
12: ; first instruction an illegal instruction ($FF01) or a NOP.
13: ; This may later be patched.
14: ;
15: ; "Menus" is the number of menus in the main menu bar, or the
16: ; "DEFAULT" token.
17: ;
18: STRING_FORMAT 3          ; Set all strings to Pascal standard
19: .MACRO PROGRAM           ; name,menus,debug =
20: XDEF XXSTART             ; Entry point name
21: XREF XXINIT              ; Initializer
22: XXSTART JSR XXINIT       ; Call init routine
23: IF  '%1' <> ' '          ; Name specified
24:  DC.B  '%1'              ; Yes
25: ELSE
26:  DC.B  'No Name'         ; Default
27: ENDIF
28: .ALIGN 2                 ; Force word alignment
29: IF  '%3' <> ' '          ; Menus?
30:  DC.W  %3                ; Do specified number
31: ELSE
32:  DC.W  0                 ; Not specified
33: ENDIF
34: IF  '%2' <> ' '          ; Debug specified?
35:  DC.W  %2                ; Yes
36: ELSE
37:  DC.W  $4E71             ; Not specified
38: ENDIF
39: .ENDM
40: DEFAULT EQU 0           ; Default parameter
41: DEBUGON EQU $FF01        ; Debug option
42: DEBUGOFF EQU $4E71      ; No debug option
```

Run-Time Library Source
**Initializing the Toolbox Routines**

Listing 8.2 shows the code required to initialize the Macintosh Toolbox routines. The debug instruction at line 2 is used for debugging changes to the XXINIT routine. Note that the semicolon at the beginning of the line deletes this instruction. A breakpoint in the PROGRAM macro is executed only after the initialization code is run. Removing the semicolon at the beginning of line 2 allows use of the debugger before any initialization code runs.

Lines 3–4 initialize the QuickDraw graphics package. QuickDraw requires a scratch area in memory. The linker reserves the first 256 bytes of the uninitialized data area for this purpose. The PEA instruction specifies the address to be used. QuickDraw uses offsets –205 to +3 from the address you specify. This call was not documented correctly in early versions of *Inside Macintosh*.

Lines 5–7 initialize the sections of the Macintosh ROM that handle fonts, windows, and menus, respectively. Lines 8–9 initialize the dialog manager, which handles alerts and dialogs. The longword parameter to this routine is the address of a restart procedure. If the program causes a system error and the user selects Restart from the dialog box, this procedure will be called. Using a zero for this parameter means that the Restart selection will be disabled, and the user must reboot after a system error.

Line 10 initializes the Text Edit routines in ROM. Text Edit is used by the PRINT and INPUT macros, as well as by the dialog manager.

**Opening the Resource File**

The run-time library supports either a combined executable file, containing both code and other resources, or separate files, one for code and

```
1: XXINIT:                      ; Called by PROGRAM macro
2: ; DC.W $FF01               ; For debugging only!!
3: ; PEA -4(A5)               ; QuickDraw scratch area
4: InitGraf                   ; Init QuickDraw
5: InitFonts                  ; Init font package
6: InitWindows                ; Init windows package
7: InitMenus                  ; Init menu package
8: CLR.L -(SP)                ; No restart procedure
9: InitDialogs                ; Init dialog package
10: _TEInit                   ; Init text edit package
```

*Listing 8.2 – Toolbox initialization*
the other for all the other resources. You will normally use separate files to save time while a program is being developed, combining them when the program is completed.

For combined resource files, the run-time library does not try to open a separate resource file. You can remove the code that opens the resource file with conditional assembly in applications that don't use a separate resource file. The symbol RESFILE should be equated to zero if the code is to be included and nonzero if the code is to be excluded.

For separate code and resource files, the code in Listing 8.3 opens the appropriate resource file. This code tries opening two files: Program.RSRC and RTL.RSRC. Program is the name specified in the PROGRAM macro call.

Lines 1–8 build a file name string consisting of the program name and the ending .RSRC. An area called Scratch is used to build the name. Lines 9–15 move register A2 to point to the word containing the number of program menus. This is outside of any conditional assembly, as it must be done in all cases. Lines 16–21 attempt to open the constructed file name. The routine called to open the resource file scans all mounted volumes.

```
1:   IF         RESFILE = 0   : Only if resource file separate
2:   MOVE.L   (SP),A2        : A2 -> Name string
3:   LEA       Scratch(A5),A0 : A0 -> Target count byte
4:   LEA       1(A0),A1      : A1 -> Destination
5:   BSR       MoveCnt       : Move in count-delimited string
6:   LEA       RSRC,A2       : A2 -> "RSRC" string
7:   BSR       MoveCnt       : Move in this field
8:   ENDFD     : Part 1 of resource conditional
9:   MOVE.L   (SP),A2        : Fetch string address again
10:  CLR.L     D7            : Load long
11:  MOVE.B   (A2),D7        : unsigned byte
12:  MOVE.L   D7,D6          : Save this value
13:  ADDQ.L   #2,D7          : Adjust to word boundary
14:  BCLR.L   #0,D7          : A2 -> Menu word
15:  ADD.L    D7,A2          : Start part 2 of resource conditional
16:  IF         RESFILE = 0   : Add in "RSRC" length
17:  ADD.W    #RSRCLEN,D6    : Try to open file
18:  MOVE.B   D6,(A0)        : Save it for later
19:  BSR       OpenRsrc      : If > 0, then file opened OK
20:  MOVE.W   DO,ResPD(A5)   : Try default name
21:  BPL       ResOK         : Attempt open
22:  LEA       Canned,A0     : Couldn't open, quit
23:  BSR       OpenRsrc      : Resource file open
24:  MOVE.W   DO,ResPD(A5)   : RESFILE = 0
25:  BMI       ResNFG
26:  ResOK:
27:  ENDFD
```

Listing 8.3 – Opening an external resource file
for the file. Should this open fail, the code in lines 22–27 will attempt to open the file RTL.RSRC. This feature allows you to write programs that use a single standard resource file, like the programs in Chapter 4.

Setting Up the Menu Bar

The next step in the initialization process is setting up and displaying the menu bar. Menus are numbered from 1 on the menu bar. The RTL code forces each menu description in the resource file to have a resource ID equal to the position of the menu in the menu bar. The standard Macintosh menu scheme applies. Menu number 1 has the “About” description and the desk accessories. Menu number 2 is the File menu, which must contain a Quit choice. Menu number 3 is the Edit menu, which must contain Undo, Cut, Copy, and Paste choices. All other menus are application specific. The menu initialization code is shown in Listing 8.4.

Lines 1–5 load the number of menus in D6 and the starting menu resource ID in D7. By default, there are three menus, the Apple, File, and Edit menus. As explained above, the first menu has a resource ID of 1.

```
1:  MOVE.W (A2)+,D6         ;   Fetch # of menus in resource file
2:  BNE GotMenus            ;   NE => Default not chosen
3:  MOVE.W #DEFMENU,D6     ;   Select default
4:  GotMenus:               ;
5:  MOVE.W #MENURS,D7      ;   Menu resource number
6:  MenuLoop:               ;   Loop on menus
7:  CLR.L -(SP)             ;   Clear space for menu handle
8:  MOVE.W D7,-(SP)         ;   Push resource number
9:  _GetMenu               ;   Get menu handle
10: CLR.W -(SP)             ;   Insert after flag
11: _InsertMenu            ;   Insert current menu
12: ADDQ.L #1,D7            ;   Bump resource number
13: CMP.W D6,D7             ;   Done?
14: BLE MenuLoop            ;   Not yet, repeat until all inserted
15: ;
16: ;  Add desk accessories into first menu (Apple)
17: ;
18: CLR.L -(SP)             ;   Room for menu handle result
19: MOVE.L '#MENU',-(SP)    ;   Indicate resource type
20: MOVE.W #MENURS,-(SP)   ;   Menu #1
21: _GetResource            ;   Fetch menu handle
22: MOVE.L '#DRVR',-(SP)    ;   Accessory type
23: _AddResMenu            ;   Add to menu
24: _DrawMenuBar           ;   Paint bar on screen
```

**Listing 8.4** – Menu initialization code
The loop from lines 6-14 is executed once per menu in the resource file. The _GetRMenu reads a menu from the resource file into memory, returning a handle on the stack. The _InsertMenu call takes a menu handle and a menu number. Note that the handle returned by _GetRMenu is passed directly to _InsertMenu without popping it off the stack. This coding technique saves a few bytes of memory. The second parameter to _InsertMenu is a menu resource ID of a menu already in the menu bar. The menu being inserted will appear before the menu that is already present. Specifying a zero menu ID means that the menu being inserted will be inserted following all other menus in the menu bar. The RTL code uses this feature to build the menu bar in menu resource ID order.

Lines 18-23 add the desk accessories to the first menu. The _GetResource call returns a handle to this menu, and the _AddResMenu appends the names of all resources with the ID DRVR to this menu. This resource type is normally found only in the System resource file. Note that a _GetResource call is used to find the menu handle, instead of a _GetRMenu call. Inside Macintosh recommends that _GetRMenu be called only once per menu.

At line 24, the menu initialization is complete. The _DrawMenuBar call draws the menu bar on the screen.

Creating a Window

Following menu bar initialization, the next step is to create a document window. The RTL procedure for doing this is shown in Listing 8.5.

Listing 8.5 - Creating a new window

```
1:  CLR.L  -(SP) ; Room for window pointer
2:  MOVE.W #WINDOWR,-(SP) ; Window resource number
3:  PEA  WArea(A5) ; -> Window space
4:  MOVE.L #ONTOP,-(SP) ; Code for on top of others
5:  _GetNewWindow ; Create the window
6:  MOVE.L (SP),A3 ; A3 -> window record
7:  MOVE.L  A3,WindowPtr(A5); ; Save window record address
8:  _SetPort ; Make window the Q/D current port
9:  MOVE.W #monaco,-(SP) ; Set font to Monaco
10:  _TextFont ;
11:  MOVE.W #9,-(SP) ; Use 9 point (80 cols on MAC)
12:  _TextSize ;
13:  MOVE.L (SP)+,AO ; Get string address from stack
14:  BSR  XXWTITLE ; Set the window title
```
The window description is contained in the resource file. The _Get-NewWindow call takes a window resource ID, a memory area address, and a variable that indicates whether the window is to be in front of or behind existing windows on the screen. This call draws the window on the screen and returns a pointer to be used in other calls that reference the window.

The memory area must be word-aligned and 292 bytes long. If you pass a null (zero) pointer for the storage area, the window manager will allocate the storage dynamically. The window storage area will then be locked in memory, however. This can cause memory to become fragmented. Fragmented memory can cause your program to run out of memory prematurely. You should therefore avoid letting the window manager allocate the window storage dynamically by allocating space for the window in your program. Use a DS directive to allocate this space in the global area, so it will not be stored in the application file.

The positioning parameter is the window behind which the new window will appear. To place the new window in front of all others, use a value of −1. A value of 0 places the window behind all other windows. A value of 1 places the new window behind the top-most window on the screen. A value of 2 places the new window behind two other windows, and so on.

Lines 6–8 of Listing 8.5 copy the window pointer to a location in the RTL data area and set the QuickDraw port to the new window. Note that the return parameter from the _GetNewWindow call is left on the stack to serve as an input parameter for the _SetPort call.

Lines 9–12 set the text font and size to 9-point Monaco. Monaco is a fixed-width font, and the 9-point size gives approximately 80 screen columns. This simplifies screen output for small programs. The application can change these values at any time, so subsequent routines in the runtime library do not rely on them.

Lines 13–14 cause the name given in the PROGRAM macro to appear as the window title. The address on the stack is the return address from the JSR XXINIT instruction in the PROGRAM macro. The XXWTITLE routine will be described later.

**Attaching Controls to a Window**

A normal document window has four controls: a vertical scroll bar, a horizontal scroll bar, a grow box, and a close box. The close box is drawn by the _GetNewWindow call. The other controls must be installed by the application. Listing 8.6 shows the RTL code for installing controls on an existing window.
Lines 2–6 create the vertical scroll bar. The _GetNewControl call adds a new control to an existing window. This routine takes the control resource ID and the window address as input. It returns a handle to the new control. Lines 7–11 create the horizontal scroll bar in a similar fashion.

The grow box is a square in the lower-right corner of the window. Lines 12–13 draw the box. The _DrawGrowlcon call takes only the window address as a parameter.

Line 15 calls a routine to determine the size of the window. The application needs to know the original size to correctly display any initial information. Listing 8.7 shows the SizeW routine.

A window data structure has a handle to a region that describes the content area of the window. Within the region data structure there is a rectangle that gives the size of the window's content region (including the scroll bars and grow box). Lines 2–5 isolate this rectangle into registers D0 and D1. If the window has controls, lines 7–10 correct the rectangle to exclude the controls.

Lines 12–17 convert the rectangle from global coordinates (bitmap data structure) to local coordinates (GrafPort data structure). The converted rectangle is stored in a local area. Lines 18–20 set the GrafPort's clipping rectangle to the area inside the controls. This prevents the application from drawing over the control area.

As you will see later, the clipping region must be set to include the controls when you are altering them. However, normal drawing requires that the clipping region exclude the controls.

**Text Edit Initialization**

A program that uses the PRINT and INPUT macros must create a Macintosh Text Edit record. Use of the Text Edit routines simplifies the PRINT and INPUT support code. The Text Edit record is a data structure required by the Text Edit routines. The code that creates and activates the Text Edit record is shown in Listing 8.8. A Text Edit record is created using the _TENew call, which requires a destination rectangle and a view rectangle. For our purposes, these rectangles are the local variables DestRect and ViewRect created in Listing 8.7. Lines 6–8 set a special field in the new Text Edit record, which disables wrapping long lines. The scrolling code in the PRINT macro depends on this. Lines 9–10 activate the Text Edit record.

**Final Initialization**

Listing 8.9 shows the code that executes prior to starting the user program. The first two lines get rid of all events in the event queue in order to make behavior during startup more predictable.
When the Finder launches an application, the cursor is set to the watch symbol. The _InitCursor call at line 3 changes the cursor to the standard arrow symbol. The location xCursor contains the ID of the present cursor. A zero indicates the arrow. The location Cursor indicates the cursor to be

```
1: IF CONTROL = 0 ; If window controls
2: CLR.L -(SP) ; Space for result
3: MOVE.W #$VscrID, -(SP) ; Push resource ID
4: MOVE.L A3, -(SP) ; Push window pointer
5: _GetNewControl ; Add control to window
6: MOVE.L (SP)+,Vscroll(A5); Save VScroll handle
7: CLR.L -(SP) ; Space for result
8: MOVE.W #$HscrID, -(SP) ; Push resource ID
9: MOVE.L A3, -(SP) ; Push window pointer
10: _GetNewControl ; Add control to window
11: MOVE.L (SP)+,Hscroll(A5); Save HScroll handle
12: MOVE.L A3, -(SP) ; Push window pointer
13: _DrawGrowIcon ; Draw grow box
14: ENDIF ; CONTROL = 0
15: BSR SizeW ; Size the window
```

**Listing 8.6 – Adding controls to a window**

```
1: SizeW MOVEM.L DO-D2/A0-A3, -(SP); Save registers we use
2: MOVE.L WindowPtr(A5),A3; A3 -> window structure
3: MOVE.L contrRgn(A3),AO ; AO -> content region (handle)
4: MOVE.L (AO),AO ; AO -> content region (pointer)
5: MOVEM.L RgnBBox(AO),DO/D1; DO,DL = GrafPort rectangle
6: IF CONTROL = 0 ; If doing control stuff
7: SUB.W #$ScrollW,D1 ; Subtract
8: SWAP D1 ;
9: SUB.W #$ScrollW,D1 ; scroll region
10: SWAP D1 ;
11: ENDIF ;
12: MOVEM.L DO/D1,DestRect(A5); Set dest rect
13: PEA DestRect(A5); Convert
14: _GlobalToLocal ; to local coords
15: PEA DestRect+4(A5); Both points
16: _GlobalToLocal ; in rectangle
17: MOVEM.L DestRect(A5),DO/D1; Get normalized rectangle
18: MOVEM.L DO/D1,ViewRect(A5); Store as view rectangle
19: PEA ViewRect(A5); Set
20: ClipRect ; clip region
21: MOVEM.L (SP)+,DO-D2/A0-A3; Restore the registers
22: RTS ; Back to caller
```

**Listing 8.7 – Computing the size of a window**
used inside the window on the screen. This is initialized to the I-beam symbol at line 7.

When the user program starts, the window pointer is in register A0 and the window size is in register D0. Lines 8–9 set up these values. The JMP instruction at line 10 returns to the debug word in the PROGRAM macro. Following the execution of that word, the application begins.

**RUN-TIME LIBRARY CONVENTIONS**

The rest of the run-time library, after the initialization code, is called by macros in the user program. These macros follow certain conventions:

1. There are at most two return values: in D0 and D1.
2. All registers that don’t return values are preserved.
3. Errors are indicated by a negative value in D0.

```
1: IF TEXTRTL = 0 ;     If no text, don't create TE
2: CLR.L -(SP) ;        Space for text handle result
3: PEA DestRect(A5) ;   -> Destination rectangle area
4: PEA ViewRect(A5) ;   -> View rectangle area
5: TENew ;              New text record
6: MOVE.L (SP),A3 ;     A3 -> -> text record
7: MOVE.L (A3),A3 ;     Dereference
8: MOVE.B #-1,teCROnly(A3); Specify no wrap mode
9: MOVE.L (SP),THandle(A5) ; Store text handle
10: TIEActivate ;       Activate text record
11: ENDFP
```

**Listing 8.8 – Creating a Text Edit record**

```
1: MOVE.L #$0000FFFF,D0 ; Mask for all events
2: _FlushEvents ;        Get rid of all events
3: _InitCursor ;         Make cursor the arrow
4: CLR.W xCursor(A5) ;   Indicate last cursor set
5: MOVE.L (SP)+,EXITAddr(A5); Save Finder's return address
6: MOVE.L SP,ORGSP(AS) ; and stack pointer contents
7: MOVE.W #IBeam,Cursor(A5) ; Set I-beam cursor
8: MOVE.L WindowPtr(A5),AO; Set return register
9: MOVE.L ViewRect+4(A5),D0; Return window size, also
10: JMP (A2) ;           return to application
```

**Listing 8.9 – Final initialization code**
Values are passed to the run-time routines in registers. This means that the macro used to invoke a routine must save and restore the registers used to pass parameters.

The external names for the run-time routines begin with XX and end with the macro name. Thus, the routine for the OPEN macro is named XXOPEN. This avoids conflict with user-selected names.

User-callable routines inside the run-time library usually begin with a SAVE macro, which stores all the registers in a global memory area. To return to the user, one of three macros is used: the RETURN macro (return value in D0), the RETURNP macro (return values in D0 and D1), or the RETURNALL macro (no return value). Listings for these macros can be found in Appendix E.

The run-time services can be grouped into the following four categories:

1. Interaction routines, such as PRINT and INPUT
2. Event routines, such as GETEVENT and CHKABORT
3. File routines, such as OPEN and READ
4. Menu routines, such as CHECK and STYLE

The remainder of this chapter will be devoted to explaining the macros and run-time code that implement these services.

**INTERACTION ROUTINES**

The interaction routines consist of all the run-time services that can alter the appearance of the screen:

1. ALERT, STOPALERT, NOTEALERT, CAUTIONALERT
2. DIALOG
3. INPUT
4. PRINT
5. SETVMIN, SETVMAX, SETVVAL, SETHMIN, SETHMAX, SETHVAL
6. SCURSOR

**ALERT**

All the ALERT macros have nearly identical coding. Listing 8.10 shows the ALERT macro. This macro invokes a Macintosh trap routine directly.
There is no supporting routine in the run-time library. The parameters to the macro are the resource ID of the alert template and an optional procedure address that is called for every event received while the alert is in progress.

The STOPALERT, NOTEALERT, and CAUTIONALERT macros are identical, except for the trap number. Trap numbers are given in Table 8.1.

The value returned by the trap (on the stack) is the item number in the alert template that was selected by the user. This number is placed in D0 to be compatible with the other run-time macros.

**DIALOG**

The DIALOG macro is similar to the ALERT macros in that it creates a display on the screen and returns an item number in D0. The DIALOG macro does not permit an event-filter procedure, however. Listing 8.11 shows the DIALOG macro.

The macro puts the resource ID of the DIALOG template into D0.W and calls the run-time routine XXDIALOG. Listing 8.12 shows the code for XXDIALOG.

Lines 3–7 create a new dialog record. The _GetNewDialog call takes a dialog template resource ID, a memory area for the dialog record, and a positioning parameter. This call is very similar to the _GetNewWindow call described earlier. Note that a zero is used for the memory area, indicating that it is to be allocated dynamically. This will not cause problems because the storage will be deallocated almost immediately. The _GetNewDialog call returns the address of the dialog record.

Line 9 sets the QuickDraw active port to the newly allocated dialog record. Note that again we save an instruction by leaving the return value

```
1: .MACRO Alert
2: MOVEM.L D1-D2/A0-A1,-(SP) ; Save registers
3: CLR.W -(SP) ; Room for result
4: MOVE.W %1,-(SP) ; Push resource ID
5: IF '%2' <> ', ' ; If procedure specified
6: PEA %2 ; Load pointer
7: ELSE ; No procedure
8: CLR.L -(SP) ; Push 0 long
9: ENDIP ;
10: DC.W $A985 ; Alert trap
11: MOVE.W (SP)+,DO ; Result to DO
12: MOVEM.L (SP)+,D1-D2/A0-A1 ; Unsaveregisters
13: .ENDM
```

*Listing 8.10 – The ALERT macro*
from one call on the stack to serve as a parameter to the next call.
If the Text Edit routines are in use, they must be deactivated before the
dialog can take place. This is done in lines 11–12.
The actual dialog takes place in lines 14–16. The _ModalDialog call
takes a filter procedure and the address of a word as parameters. The
word is filled in with the item number selected by the user. The dialog
record must represent the top-most window on the screen.
Lines 17–18 free up the dialog storage. Line 19 places the return value
in register D0. Lines 20–21 reset the active QuickDraw port to the stan-
dard window. Activate and update events for the window will be gener-
ated automatically. This causes the application to redraw the area of the
screen covered by the dialog box.

**INPUT**

The INPUT macro (Listing 8.13) reads a line of text from the keyboard.
The requesting program receives this text in the form of a Pascal string.
The macro loads the input area address into A0 and the length of the
area into D0. If no length is specified, 80 (decimal) is assumed.
The macro calls the run-time routine XXINPUT to read the line from
the keyboard. Listing 8.14 contains the code for the XXINPUT routine.

<table>
<thead>
<tr>
<th>Macro</th>
<th>Trap Name</th>
<th>Trap Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALERT</td>
<td>_Alert</td>
<td>$A985</td>
</tr>
<tr>
<td>STOPALERT</td>
<td>_StopAlert</td>
<td>$A986</td>
</tr>
<tr>
<td>NOTEALERT</td>
<td>_NoteAlert</td>
<td>$A987</td>
</tr>
<tr>
<td>CAUTIONALERT</td>
<td>_CautionAlert</td>
<td>$A988</td>
</tr>
</tbody>
</table>

**Table 8.1** – Alert Trap Numbers

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1:</td>
<td>.MACRO DIALOG</td>
<td></td>
</tr>
<tr>
<td>2:</td>
<td>MOVE.W %1,D0</td>
<td>; Load ID</td>
</tr>
<tr>
<td>3:</td>
<td>XREP XXDIALOG</td>
<td>; For the linker</td>
</tr>
<tr>
<td>4:</td>
<td>JSR XXDIALOG</td>
<td>; Call RTL routine</td>
</tr>
<tr>
<td>5:</td>
<td>.ENDM</td>
<td></td>
</tr>
</tbody>
</table>

**Listing 8.11** – The DIALOG macro
Lines 4–6 ensure that the byte count parameter is a legal value. The character count for a Pascal string cannot exceed one byte (0–255). This code simply replaces a value greater than 255 with 255.

Lines 8–12 place the buffer address in A2 and the count in D4. These registers are not modified across system calls. They are called nonvolatile registers. Register A3 is used as a pointer to the next byte that will receive a character. Register D3 is used to count the number of characters placed in the buffer.

Line 14 gets a keyboard event from the event queue. The operation of the NEXTEVT macro will be described in “The Event System” section of this chapter. Line 15 rejects null events. A null event is an indication that no character is present. Lines 16–17 reject characters typed with the Command key down. Note that all other events (such as menu selection) are ignored by this code.

Lines 19–26 handle backspacing. The Backspace key on the Macintosh generates a character with the value 8. Characters less than backspace are rejected by lines 19–20. Lines 22–23 reject a backspace character when there are no characters in the buffer (that is, the user tried to back up past the beginning). Lines 24–26 handle a valid backspace character by deleting the last character typed.

Lines 28–29 check the character to see if it is a carriage-return (decimal 15) character. If the character is not a carriage return and there is room in

---

Listing 8.12 – The XXDIALOG routine

```assembly
1: XXDIALOG
2: MOVEM.L DL/D6/A0-Al,-(SP);
3: CLR.L -(SP) ; Push volatile registers
4: MOVE.W DO,-(SP) ; Dialog pointer return area
5: CLR.L -(SP) ; Dialog box resource ID
6: MOVE.L #ONTOP,-(SP) ; No dialog storage
7: GetNewDialog ; Create a new dialog box
8: MOVE.L (SP),D6 ; On top of all
9: _SetPort ; Handle to D6
10: IF TEXTRTL = 0 ; Make it QuickDraw port
11: MOVE.L THandle(A5),-(SP) ; If text style RTL
12: TDeActivate ; Deactivate text window
13: _ENDIF ;
14: CLR.L -(SP) ;
15: PEA ItemHit(A5) ; No filter procedure
16: ModalDialog ; -> Item hit data
17: MOVE.L D6,-(SP) ; Wait for "OK" button
18: DisposeDialog ; Push dialog box handle
19: MOVE.W ItemHit(A5),DO ; And close it
20: MOVE.L WindowPtr(A5),-(SP) ; Load return register
21: _SetPort ; Reset port address
22: MOVEM.L (SP)+,DL/D6/A0-Al; Restore registers
23: RTS ; Back to caller
```

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the buffer, lines 34–49 put the character in the user's buffer and on the screen. The _TEKey system call takes a Text Edit handle (returned from _TENew) and a character. This call adds the character into the Text Edit display so that PRINT and INPUT statements can be used together.

Lines 40–46 store the character count in the first byte of the user's buffer. The unused part of the buffer is filled with binary zeros. Lines 47–48 print a carriage return on the screen, using the code for the PRINT macro.

PRINT

The PRINT macro displays a string (in Pascal format) on the screen. This macro is shown in Listing 8.15. The address of the string to be printed is loaded into register A4. The macro then calls the routine XXPRINT to output the string to the screen using the Text Edit routines. If the second parameter is omitted, the macro again calls XXPRINT with A4 pointing to a string containing only a carriage return.

The XXPRINT routine is shown in Listing 8.16. This routine uses the Text Edit routines to print an entire string. It is surprising how much of this code is required to support scrolling. Note that the code is included in the run-time library only if the Text Edit package is in use. Applications that do not use Text Edit (such as MacDoodle) cannot use the PRINT macro.

Lines 4–14 count the number of carriage returns in the string. If there is none, the code at lines 15–16 causes the scrolling code to be skipped. Lines 17–22 compute in D5 the height of the window in pixels. Line 23 determines how many lines will fit in the window by dividing the height in pixels (from the window record) by the number of pixels per line (from the Text Edit record). Lines 24–28 determine whether the string will fit on the screen without scrolling. If the string will not fit, lines 29–34 scroll the screen an appropriate number of pixels. The _TEScroll call takes three

```
1: .MACRO INPUT ;Address,length =
2: XREF XXINPUT ;Define for linker
3: MOVEM.L A0/DO,-(SP) ;Save parameter registers
4: LEA %1,A0 ;-> Return buffer
5: IF 1%21 = 11 ;Not specified?
6: MOVEQ.L #80,DO ;Default to 80
7: ELSE ;Use specified
8: MOVE.L %2,DO ;
9: ENDIF ;
10: JSR XXINPUT ;Call RTL routine
11: MOVEM.L (SP)+,A0/DO ;Restore registers
12: .ENDM
```

Listing 8.13 – The INPUT macro
Listing 8.14 – The XXINPUT routine

1: IF TEXTRTL = 0 ; If text style RTL
2: XDEF XXINPUT
3: XXINPUT SAVE ; Save user's registers
4: CMP.W #255,DO ; DO > 1 byte?
5: BLE CountOK ; No, count is OK
6: MOVE.W #255,DO ; Use only 255
7: CountOK ;
8: MOVE.W DO,d4 ; Preserve in nonvolatile reg
9: MOVE.L A0,a2 ; Save buffer pointer
10: MOVE.L A2,a3 ; in nonvolatile registers
11: TST.B (A3)+ ; → First character position
12: CLR.W D3 ; = Character count so far...
13: InputLoop ; Here to get next character
14: NEXTEVN #KeyMask ; Get next keyboard event
15: BNE InputLoop ; No, just ignore
16: BTST #ComKey,Modify(A5); Command key down?
17: BBQ InputLoop ; Yes, ignore
18: MOVE.W Message+2(A5),DO; Character to DO
19: CMP.B #BS,DO ; Backspace?
20: BLT InputLoop ; Invalid character
21: BNE NotBS ; Check for control chars
22: TST.W D3 ; Any characters?
23: BBQ InputLoop ; No, invalid character
24: SUBQ.W #1,d3 ; Decrement count
25: TST.B -(A3) ; Remove from buffer
26: BRA DoKey ; Do TEKey for screen update
27: NotBS: ; Here to see if control character
28: CMP.B #CR,d0 ; Was it carriage return?
29: BBQ IsCR ; Yes, store count and return
30: CMP.B #BL,d0 ; Less than space?
31: BLT InputLoop ; Yes, error
32: CMP.W D3,d4 ; Room in buffer?
33: BLE InputLoop ; No, don't do anything
34: MOVE.B DO,(A3)+ ; Store in buffer
35: ADDQ.L #1,d3 ; Increment count
36: DoKey: MOVE.W DO,-(SP) ; Now put on screen
37: MOVE.L THandle(A5),-(SP); and in TE buffer
38: TKEy ; Get next character
39: BRA InputLoop ; Here when CR typed
40: IsCR: ;
41: MOVE.B D3,(A2) ; Store the count byte
42: SUB.W D3,d4 ; How many bytes remain?
43: BLE PrintCR ; None, bail out
44: SUB.W #1,d4 ; Adjust for DBRA
45: ADDQ.L CLR.B (A3)+ ; Clean out
46: DBRA D4,ZapBuf ; rest of buffer
47: PrintCR LEA XXCR,A4 ; A4 → CR sequence
48: JMP DoPrint ; Print CR, then return
49: ENDF ; TEXTRTL

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parameters: the number of horizontal pixels to scroll, the number of vertical pixels to scroll, and the Text Edit record handle returned by _TENew. Positive values for the number of pixels to scroll move the text right or down. Negative values move the text left or up. In the XXPRINT code, the value in D5 at line 27 will be negative, causing the text on the screen to scroll upwards.

After the TEScroll call, the screen has the correct appearance. However, the text that was scrolled off the top of the screen is still in memory. There is no support in the Text Edit package for deleting lines that scroll off the top of the screen. This means that a program that does a lot of PRINT calls will eventually run out of memory. The code at lines 35-57 deletes the lines that were scrolled off the top of the screen. The Text Edit package has two rectangles associated with a given Text Edit record: a destination rectangle, which encloses all the text in the record, and a view rectangle, which encloses only the text visible on the screen. Lines 35-38 reset the destination rectangle to the view rectangle.

The Text Edit record stores the character offset of the beginning of each line in successive words, starting at offset TELines. The text itself is stored separately. Lines 39–53 delete the text scrolled off the top of the screen from the text buffer. Lines 54–57 call the _TESetText routine to replace the old text with the shortened text.

After the scrolling is complete, lines 59–62 output the text. The _TEInsert call inserts a string of characters into a Text Edit record and onto the screen. This call has three parameters: the string address, the number of characters, and the Text Edit record handle.

**SCURSOR**

The SCURSOR macro is used to change the shape of the mouse cursor on the screen. This macro takes a single parameter: the resource ID of the

```plaintext
1: .MACRO PRINT ;String,crflag =
2: XREF XXPRINT ;Define for linker
3: MOVE.L A4,-(SP) ;Save A4
4: LEA %1,A4 ;A4 -> output string
5: JSR XXPRINT ;Call output string
6: IF 1%21 = II
7: XREF XXCR ;If carriage return desired
8: LEA XXCR,A4 ;A4 -> carriage-return sequence
9: JSR XXPRINT ;Output it
10: ENDIF
11: MOVE.L (SP)+,A4 ;Restore A4
12: .ENDM
```

*Listing 8.15 – The PRINT macro*
1: IF TEXTRTL = 0 ; Junk whole routine if graphics
2: XDEF XXPRINT ; Define for linker
3: XXPRINT SAVE ; Save registers
4: DoPrint CLR.L D6 ; Clear a temporary
5: MOVE.B (A4)+,D6 ; Fetch count byte
6: MOVE.L A4,A1 ; Al -> Text
7: MOVE.L D6,DO ; DO = Count
8: SUBQ.L #1,DO ; Adjust for DBRA count
9: BLT TYPEDone ; Done if < 0
10: CLR.L D7 ; Initialize counter
11: LookCR: CMP.B #CR,(A1)+ ; Is it a <CR>?
12: BNE TYPEDBR No, don't bump count
13: ADDQ.L #1,D7 ; Bump count
14: TYPEDBR DBRA DO,LookCR ; Repeat till count exhausted
15: TST.W D7 ; Any line control chars?
16: BBQ DoType ; No, skip next
17: MOVE.L THandle(A5),A1 ; Al -> Text handle
18: MOVE.L (A1),Al ; Al -> Actual text record
19: CLR.L D5 ; Clear out D5 long
20: MOVE.L WindowPtr(A5),AO ; AO -> Window record
21: MOVE.W PortRect+4(AO),D5; D5 = Rectangle
22: SUB.W PortRect+0(AO),D5 ; size (vertical)
23: DIVS teLineHite(A1),D5 ; D5 = # lines in dest rectangle
24: SUB.W teNLines(A1),D5 ; How many already?
25: BGT Gotsome ; Still some left at bottom
26: CLR.L D5 ; Correct for none left
27: Gotsome SUB.W D7,D5 ; How many lines do we need?
28: BBQ DoType ; None
29: MOVE.W D5,DO ; Copy to scratch register
30: MULS.W teLineHite(A1),DO; Multiply to convert to pixels
31: CLR.W -(SP) ; No horizontal scroll
32: MOVE.W DO,-(SP) ; Push vertical scroll
33: MOVE.L THandle(A5),-(SP); Push text handle
34: _Tscroll ; Scroll it
35: MOVE.L THandle(A5),A1 ; Al -> Text handle
36: MOVE.L (A1),Al ; Al -> Actual text record
37: MOVE.L teViewRect(A1),teDestRect(A1); Adjust vertical view for deletion
38: MOVE.L teViewRect+4(A1),teDestRect+4(A1); "
39: NEG.W D5 ; D5 = # lines to delete
40: SUB.W D5,teNlines(A1); Mark as deleted
41: ADD.W D5,D5 ; Convert to index
42: MOVE.W teLines(A1,D5,W),DO; First character to remain
43: MOVE.L teTextH(A1),A2 ; A2 = Text handle
44: MOVE.L (A2),A2 ; A2 -> Text start (destination)
45: LEA (A2,DO,W),A3 ; A3 -> Source
46: MOVE.W teLength(A1),D1 ; Count of characters to move
47: SUB.W D0,D1 ; Fix for deletion
48: EXT.L D1 ; Out to long
49: MOVE.W D1,DO ; Adjust
50: SUBQ.W #1,DO ; for DBRA
51: MOVE.L A2,A0 ; Save address in AO
52: TypeDel MOVE.B (A3)+(,AO)+ ; Move a byte
53: DBRA DO,TypeDel ; Until done

Listing 8.16 – The XXPRINT routine
Listing 8.16 – The XXPRINT routine (continued)

cursor desired. As explained in Chapter 6, it is possible to use this macro for the standard cursors as well as any cursor you define in a resource file. Listing 8.17 contains the SCURSOR macro definition.

The macro loads the cursor resource ID into D0.W and calls the run-time routine XXCURSOR. The code for this routine is shown in Listing 8.18.

Lines 2-4 check the last cursor displayed against the requested cursor. The routine returns immediately if the desired cursor is already being displayed. Lines 6-10 display the arrow cursor using the _InitCursor call. Other cursors are displayed by the code in lines 12-17. The _GetCursor call fetches a cursor from the resource file and returns a handle to the memory copy. The _SetCursor call displays a cursor, given its address. Note the conversion from handle to address at line 16.

**SETVMIN, SETVMAX, SETVVAL, SETHMIN, SETHMAX, and SETHVAL**

These routines set the values associated with a scroll bar. They are all essentially the same; only the system trap changes. Listing 8.19 shows the SETVMIN macro.

This macro puts the desired value in D0.W and calls the appropriate run-time routine. The run-time routine is shown in Listing 8.20.

Note that much of this code is shared between the XXSETVMIN and XXSETHMIN routines. They differ only in the control ID passed to the _SetMinCtl trap. The other routines are similar, differing only in trap name. The trap names appear in Table 8.2.
**TRACK**

The TRACK macro is used when a user program receives a page or line scroll event from the run-time library GETEVENT macro. This macro causes a procedure to be called repetitively, as long as the user holds down the mouse button in the control that causes the scrolling event. The TRACK macro code is shown in Listing 8.21.

The macro loads the control handle into register D0 and the procedure address into A0. It then calls the run-time routine XXTRACK (Listing 8.22). The XXTRACK routine calls an internal procedure, IncControls, which resets the window's clipping region to include the scroll bars. If you

```assembly
1: .MACRO SCURSOR
2:   MOVE.L DO,-(SP) ; Save register
3:   MOVE.W &1,DO ; Set ID
4:   XREF XXCURSOR ; RTE routine
5:   JSR XXCURSOR ; Call RTL
6:   MOVE.L (SP)+,DO ; Restore register
7: .ENDM
```

**Listing 8.17 – The SCURSOR macro**

```assembly
1: XXCURSOR:
2:   CMP.W xCursor(A5),DO ; Need to do this?
3:   BNE @1 ; Yes
4:   RTS ; No
5: @1: MOVEM.L DO-D2/A0-A2,-(SP); ; Save registers
6:   MOVE.W DO,xCursor(A5) ; Remember for next time
7:   TST.W DO ; Arrow?
8:   BNE @2 ; No, do it differently
9:   InitCursor ; Arrow done thusly
10:  BRA CDone ; Finished
11: @2: CLR.L -(SP) ; Must get from resource file
12:   MOVE.W DO,-(SP) ; Space for cursor handle
13:   MOVEM.L (SP)+,AO ; Push cursor ID
14:   GetCursor ; Fetch cursor handle
15:   MOVE.L (SP)+,AO ; AO -> cursor pointer
16:   MOVE.L (AO),-(SP) ; Push actual address
17:   _SetCursor ; Do the set
18: CDone: _ ; Here with correct cursor
19:   MOVEM.L (SP)+,DO-D2/A0-A2; ; Restore registers
20:   RTS ; Return to caller
```

**Listing 8.18 – The XXCURSOR routine**
invoke a system call that affects the controls before doing this, the screen appearance will not change.

The system call _TrackControl takes three parameters: the control ID (from the macro), the original mouse point (from the event that caused the scroll), and the user's procedure address (from the macro). When _TrackControl finishes, the ExcControls routine resets the window's clip region to exclude the control area. This prevents the applications from drawing on top of the scroll bars.

### Listing 8.19 - The SETVMIN macro

1: .MACRO SETVMIN               ;
2: MOVEM.L DO,-(SP)            ;  Push registers
3: MOVE.W %1,DO              ;  DO = Value
4: XREF XXSETVMIN            ;  For the linker
5: JSR XXSETVMIN             ;  Call RTL routine
6: MOVEM.L (SP)+,DO         ;  Pop registers
7: .ENDM

### Listing 8.20 - The XXSETVMIN and XXSETHMIN routines

1: XXSETVMIN                ;  Set upper limit
2: SAVE                    ;  Save registers
3: MOVE.L VScroll(A5),-(SP) ;  Push control handle
4: BRA                     ;  Do the SetMin
5: XXSETHMIN               ;  Set left limit
6: SAVE                    ;  Save registers
7: MOVE.L HScroll(A5),-(SP) ;  Push control handle
8: SetMin MOVE.W DO,-(SP)  ;  and value
9: _SetMinCtl               ;  Set it
10: RETURNALL              ;  Back to caller

### Listing 8.21 - The TRACK macro

1: .MACRO TRACK             ;  Save the registers
2: MOVEM.L DO/A0,-(SP)      ;  DO gets handle
3: MOVE.L %1,A0            ;  A0 gets procedure
4: LEA %2,A0               ;  For the linker
5: XREF XXTRACK            ;  Call RTL routine
6: JSR XXTRACK             ;  Restore the registers
7: MOVEM.L (SP)+,DO/A0     ;
8: .ENDM
THE EVENT SYSTEM

The run-time library event-handling code handles a large number of things that a Macintosh application is expected to perform. This code handles many events, such as opening desk accessories, directly. The run-time library also partially processes other events, such as menu selection, scrolling, and window sizing. Still other events, such as disk insertion and network events, are passed back to the application with no processing. Placing this code in the run-time library means that the application writer need not be aware that it is present. The following macros are event related:

1. The GETEVENT macro, which returns the next event
2. The CHKABORT macro, which checks for an ABORT event

The GETEVENT routine is the most complicated of these routines.

<table>
<thead>
<tr>
<th>Macro Name</th>
<th>Run-Time Name</th>
<th>Control ID</th>
<th>Trap Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>SETVMIN</td>
<td>XXSETVMIN</td>
<td>VScroll(A5)</td>
<td>_SetMinCtl</td>
</tr>
<tr>
<td>SETVMAX</td>
<td>XXSETVMAX</td>
<td>VScroll(A5)</td>
<td>_SetMaxCtl</td>
</tr>
<tr>
<td>SETVVAL</td>
<td>XXSETVVAL</td>
<td>VScroll(A5)</td>
<td>_SetCtlValue</td>
</tr>
<tr>
<td>SETHMIN</td>
<td>XXSETHMIN</td>
<td>HScroll(A5)</td>
<td>_SetMinCtl</td>
</tr>
<tr>
<td>SETHMAX</td>
<td>XXSETHMAX</td>
<td>HScroll(A5)</td>
<td>_SetMaxCtl</td>
</tr>
<tr>
<td>SETHVAL</td>
<td>XXSETHVAL</td>
<td>HScroll(A5)</td>
<td>_SetCtlValue</td>
</tr>
</tbody>
</table>

Table 8.2 – Scroll Bar Value Routines

1: XDEF XXTRACK ; For the linker
2: XXTRACK SAVE ; Save the registers
3: BSR IncControls ; Clip to allow drawing controls
4: CLR.W -(SP) ; Room for result
5: MOVE.L D0,-(SP) ; Push control handle
6: MOVE.L Point(A5),-(SP) ; and original mouse point
7: MOVE.L A0,-(SP) ; and user’s procedure
8: _TrackControl ; Do the track
9: ADDQ.L #2,SP ; Pop return
10: BSR ExcControls ; Reclip for no controls
11: RETURN ; and return

Listing 8.22 – The XXTRACK routine
**GETEVENT**

The GETEVENT macro returns the next event number in D0.W. Additional parameters may be returned in D1.L and the high word of D0. The code for this macro is shown in Listing 8.23.

The macro has one parameter: the resource ID of a cursor to be used when the mouse is inside the content region of the active window. D0.W receives the cursor ID, and the macro calls the run-time routine XXEVENT. This routine is shown in Listing 8.24.

Lines 3–16 select the proper cursor, depending on whether the mouse is in the application window. The _GetMouse system call takes the address of a point and returns the mouse location (a point) in that location. The _PtInRect system call takes a point and the address of a rectangle and returns a word that is nonzero if the point is in the rectangle and zero otherwise. The mouse form is set to the specified cursor inside the window and the arrow cursor outside the window, using the XXCURSOR routine described previously.

Line 17 fetches the next event from the Macintosh event queue. The NEXTEVT macro is explained below. The event call fills in a memory area called an event record, which has the structure shown in Figure 8.1.

The event type field is a number between 0 and 15. The event time and mouse position fields give the time of day in binary and the mouse position at the time of the event. The message and modifier fields are dependent on the event type code. The event codes returned by the Macintosh Toolbox routine are shown in Table 8.3.

Lines 19–50 of Listing 8.24 perform a 16-way branch based on the value of the event type field. Before investigating each of these 16 branches, let’s look first at the NEXTEVT macro and supporting code. Listing 8.25 shows the NEXTEVT macro and its supporting run-time routine.

The NEXTEVT macro calls NextEvent. The word parameter is a bitmask indicating the type of event being

```
1: .MACRO GETEVENT
2:   IF   "%1" <> "
3:     MOVE.W %1,DO
4:   ELSE
5:     MOVE.W #1,DO
6:   ENDIF
7:   XREF XXEVENT
8:   JSR XXEVENT
9: .ENDM
```

Listing 8.23 – The GETEVENT macro
1: XXEVENT: ;
2: SAVE ; Save registers
3: MOVE.W D0, Cursor(A5) ; Set default cursor
4: DoEvent PEA Point(A5) ; Push mouse point address
5: _GetMouse ; Fetch mouse coordinates
6: CLR.W -(SP) ; Room for result
7: MOVE.L Point(A5), -(SP) ; Push point
8: PEA DestRect(A5) ; Push rect address
9: _PtInRect ; See if mouse in window
10: TST.W (SP)+ ; Is mouse in window?
11: BNE ChangeCurs ; Yes, change the cursor
12: CLR.L D0 ; Set to arrow (0)
13: BRA DoCurs ; Set the cursor
14: ChangeCurs: ; Here if need to change cursor
15: MOVE.W Cursor(A5), D0 ; Change to requested
16: DoCurs BSR XXCURSOR ; Change the cursor
17: NEXTEVT #AllMask ; Get new event
18: BEQ NoEvent ; None there, try again
19: MOVE.W What(A5), D0 ; D0 = Event type
20: ADD.W D0, D0 ; Multiply by 2
21: MOVE.W Eventtab(D0), D0 ; D0 = Offset
22: JMP Event(D0) ; Jump to event routine
23: Event: ; Base point for offset table
24: ;
25: ; Define a macro for event table entries
26: ;
27: MACRO ETAB addr = ; Entry macro
28: DC.W {addr}-XXBASE ; Generate an offset word
29: |
30: ;
31: ; Define the event table itself
32: ;
33: EventTab ; Offset table
34: XXBASE SET * ; Here is the base value
35: ETAB NullEvent ; 0 => Null event, ignore
36: ETAB MouseDown ; 1 => Mouse-down event
37: ETAB MouseUp ; 2 => Mouse-up event
38: ETAB KeyDown ; 3 => Key press (down)
39: ETAB KeyUp ; 4 => Key release (up)
40: ETAB AutoKey ; 5 => Autokey
41: ETAB Update ; 6 => Update event
42: ETAB Disk ; 7 => Disk
43: ETAB Activate ; 8 => Activate
44: ETAB Abort ; 9 => Abort
45: ETAB Network ; A => Network
46: ETAB Driver ; B => Driver
47: ETAB Appl1 ; C => Application #1
48: ETAB Appl2 ; D => Application #2
49: ETAB Appl3 ; E => Application #3
50: ETAB Appl4 ; F => Application #4

Listing 8.24 – The XXEVENT routine
sought. This can be used to eliminate undesirable events, as in the XXINPUT routine where only key-down events are useful.

The NextEvent routine does more than simply return the next event. Since this routine is called very often, it performs the normal chores

<table>
<thead>
<tr>
<th>Offset</th>
<th>Contents</th>
<th>Label</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Event Type</td>
<td>What</td>
</tr>
<tr>
<td>2</td>
<td>Event Message</td>
<td>Message</td>
</tr>
<tr>
<td>6</td>
<td>Event Time</td>
<td>When</td>
</tr>
<tr>
<td>10</td>
<td>Mouse Position</td>
<td>Point</td>
</tr>
<tr>
<td>14</td>
<td>Modifier Bits</td>
<td>Modify</td>
</tr>
</tbody>
</table>

*Figure 8.1 – Macintosh event record*

<table>
<thead>
<tr>
<th>Code</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No event is present</td>
</tr>
<tr>
<td>1</td>
<td>Mouse button was pressed (mouse down)</td>
</tr>
<tr>
<td>2</td>
<td>Mouse button was released (mouse up)</td>
</tr>
<tr>
<td>3</td>
<td>A key was pressed (key down)</td>
</tr>
<tr>
<td>4</td>
<td>A key was released (key up)</td>
</tr>
<tr>
<td>5</td>
<td>Repeat keypress (autokey)</td>
</tr>
<tr>
<td>6</td>
<td>Window update</td>
</tr>
<tr>
<td>7</td>
<td>Disk insertion</td>
</tr>
<tr>
<td>8</td>
<td>Activate window</td>
</tr>
<tr>
<td>9</td>
<td>Abort</td>
</tr>
<tr>
<td>10</td>
<td>Network event</td>
</tr>
<tr>
<td>11</td>
<td>Driver event</td>
</tr>
<tr>
<td>12</td>
<td>Application event #1</td>
</tr>
<tr>
<td>13</td>
<td>Application event #2</td>
</tr>
<tr>
<td>14</td>
<td>Application event #3</td>
</tr>
<tr>
<td>15</td>
<td>Application event #4</td>
</tr>
</tbody>
</table>

*Table 8.3 – Macintosh Event Types*
expected of an idling Macintosh application. Lines 9–10 call the TEIdle procedure, which causes the cursor to flash. Line 12 calls the _SystemTask function, which gives CPU time to any desk accessories that may be active.

Lines 14–18 actually fetch the next event from the queue. The _GetNextEvent system call takes the event mask and event record address as parameters and returns an event ID. The ID is zero if no event is available. The event record is filled in if the ID is nonzero.

We will now discuss the remaining code for the GETEVENT macro. Listing 8.24 contains a 16-way branch that is based on the return value from the NEXTEVT macro. Routines invoked by this branch handle the following events:

- Events passed back to the application and not processed by the application
- Mouse-down events, including menu selection, opening a desk accessory, scrolling, dragging the window, changing the window size, and closing the window
- Update events
- Activate events

We will also discuss the CHKABORT macro, which uses the NEXTEVT macro.

**Events Passed to the Application**

Many events are passed directly to the application without further processing. Listing 8.26 shows the values returned to the application program. The events in lines 1–11 all return the event code in the low word of D0, the message longword in D1.L, and the modifier word in the high word of D0.

Other events are screened before they are passed to the application. For instance, a key-down event is checked to see if the key pressed is actually a menu selection.

**Mouse-Down Events**

By far, the most difficult device to support is the Macintosh mouse. The mouse-down event is tricky to handle. Depending on the position of the mouse, this event can signal one of seven different activities:

1. If the mouse is in the desk area, the mouse-down event is meaningless and should be ignored.
2. If the mouse is in the menu area, the user wants to select a menu item.

3. If the mouse is in a desk accessory window, the event must be passed on to the accessory.

4. If the mouse is in the content area of the window, the event must be passed on to the application.

```
1: MACRO NEXTEVT Evmask =
2:     MOVE.W {Evmask},DO ; Load mask register
3:     JSR NextEvent ; Get next event
4: |
5: |
6: NextEvent:
7:     MOVE.L DO,-(SP) ; Called internally only
8:     IF TEXTRTL = 0 ; Save DO for a bit....
9:     MOVE.L THandle(A5),-(SP); If text type RTL
10: _TEIdle ; Push text record handle
11:     ENDF ; Call text edit idle proc
12:     _SystemTask ; TEXTRTL
13:     MOVE.L (SP)+,DO ; Let system tasks run
14:     CLR.W -(SP) ; Recover mask
15:     MOVE.W DO,-(SP) ; Make room for event ID
16:     PEA EventRecord(A5); Push event mask
17:     GetNextEvent ; Push event record address
18:     MOVE.W (SP)+,DO ; Fetch next Mac event
19:     RTS ; Event ID to DO
```

**Listing 8.25 - The NEXTEVT macro and the NextEvent routine**

```
1: NullEvent
2: Disk
3: Abort
4: MouseUp
5: KeyUp
6: Network
7: Driver
8: Appl1
9: Appl2
10: Appl3
11: Appl4
12: UserEvt MOVE.W Modify(A5),DO ; Modify word
13: SWAP DO ; To high word of DO
14: MOVE.W What(A5),DO ; Set return code
15: MOVE.L Message(A5),D1 ; Message to D1.L
16: RETURNP ; Restore and return
```

**Listing 8.26 - Passing events to the application**
5. If the mouse is in the title bar of the window, the user wants to move the window.

6. If the mouse is in the grow box of the window, the user wants to change the size of the window.

7. If the mouse is in the close box of the window, the user wants to close the window.

The code that evaluates a mouse-down event is shown in Listing 8.27. The _FindWindow call determines which window, and which part of that window, contains a given point. The integer returned by _FindWindow indicates the area of the window, as shown in lines 13–19 of Listing 8.27. Values of 0 and 7 are discarded. Values 1–6 are processed by the run-time library.

**Menu Selection** A mouse-down event in the menu bar means that a menu selection must be performed. The run-time library classifies menu selections into one of four groups:

1. A menu selection that is passed back to the application
2. An About... dialog selection from the Apple menu, which is processed by the run-time library

```
1: MouseDown
2:    CLR   -(SP)                        ; Clear a space for result
3:    MOVE.L Point(A5),-(SP)            ; Mouse at time of event
4:    PEA   Window(A5)                  ; Event window
5:    _FindWindow                      ; Find the window
6:    MOVE.W (SP)+,DO                  ; Fetch index
7:    AND.W  #7,DO                     ; Force to range 0–7
8:    ADD.W  DO,DO                     ; Multiply by 2
9:    MOVE.W WTable(DO),DO            ; Fetch offset
10:   JMP   WTable(DO)                  ; Jump to appropriate routine
11:   WTable:                           ; Start dispatch table
12:   XBASE   SET  *                    ; Define macro base here
13:   ETAB   Doevent                   ; 0 Mouse in desk area someplace
14:   ETAB   InMenu                    ; 1 Mouse in menu area
15:   ETAB   SystemEvent               ; 2 Mouse in system window
16:   ETAB   Content                   ; 3 Window content area
17:   ETAB   Drag                      ; 4 In drag area
18:   ETAB   Grow                      ; 5 In grow area
19:   ETAB   GoAway                    ; 6 In close box
20:   ETAB   Doevent                   ; 7 (Undefined)
```

**Listing 8.27 – Mouse-down events**
3. Starting a desk accessory, which is handled by the run-time library

4. The Copy, Cut, and Paste selections in the Edit menu (if the run-time library is configured to use the Text Edit package), which are also handled by the run-time library

Most menu selections fall into the first group. The first part of the menu code is shown in Listing 8.28.

Lines 1–9 illustrate how keyboard equivalents to menu selections work. The _MenuKey system call takes a key value and returns a longword. The high-order word of the return value is the menu number, and the low-order word is the item number in that menu.

Using the mouse to select a menu item involves the _MenuSelect call. This call takes the mouse point from the event as input and returns the

```
1: KeyDown
2: AutoKey
3: MOV.E.W Message+2(A5),D1;      Key to D1.W
4: BTST #ComKey,Modify(A5);        Is Command key down?
5: BBRQ UserEvt ;                 No, give key to user
6: CLR.L -(SP) ;                 Room for result
7: MOV.E.W D1,-(SP) ;           Push character
8: MenuKey ;                        See if a command
9: BRA DoMenu ;                   Go do the menu
10: InMenu:
11: CLR.L -(SP) ;               Clear space for return value
12: MOV.E.L Point(A5),-(SP) ;      Push mouse point
13: _MenuSelect ;             Perform menu selection
14: DoMenu CLR.W -(SP) ;            Unhighlight menus
15: HiLiteMenu ;                This does all
16: MOV.E.L (SP),D1 ;       Both to D1
17: MOV.E.W (SP)+,,D6 ;    Menu number (from _MenuSelect)
18: MOV.E.W (SP)+,,D7 ;    Menu selection (from _MenuSelect)
19: TST.L D1 ;              Really a choice?
20: BBRQ DoEvent ;         No, just kidding
21: MOV.E.L #MenuChoice,D0 ;   DO = menu choice return code
22: CMP.W #APPLE,D6 ;       Apple menu?
23: BBRQ Inapple ;       Yes, do this one ourselves
24: CMP.W #EDIT,D6 ;       No, how about the Edit menu?
25: BBRQ InEdit ;        Yes, handle this one too
26: RETURNP ;              Restore registers; return
27: Inapple:
28: CMP.W #ABOUT,D7 ;       Here if it's a choice we handle ....
29: BNE DeskAcc ;           Was it the "About" choice?
30: MOV.E.W D7,D0 ;        No, must be a desk accessory
31: BSR XXDIALOG ;            Set parameter register
32: BRA DoEvent ;         Do the dialog

Listeing 8.28 – Menu selection code
```
same longword as _MenuKey. After line 13, the code is the same, regardless of the method used to select the entry.

Both the _MenuKey and _MenuSelect calls leave the menu highlighted in the menu bar. Lines 14–15 unhighlight the menu. This is a deviation from standard Macintosh practice. Normally, you don’t unhighlight the menu until you have finished performing the action associated with the menu selection. Since the run-time library will not regain control when the application finishes processing the selection, the unhighlighting must be done in advance.

Lines 16–26 determine whether the menu selection is to be returned directly to the user, or whether the run-time library will process the selection. The run-time library handles all events in the Apple menu and some events in the Edit menu.

Lines 28–32 handle the About... choice in the Apple menu. This is a dialog, identical to the one invoked by the DIALOG macro. The dialog template in the resource file must have a resource ID of 1.

The other selections in the Apple menu are desk accessories. The code to open a desk accessory appears in Listing 8.29. Lines 1–4 get a handle to the Apple menu on the stack. Lines 5–8 fetch the name associated with the menu selection into a scratch area. The return value of the _GetResource call is used as the first parameter to the _GetItem call. The returned string is in Pascal format.

The desk accessory is opened with the _OpenDeskAcc call at line 13. This call takes the name as input and returns a handle to the open accessory. Note that the current GrafPort is saved and restored around the _OpenDeskAcc call. This is advisable since the accessory may not restore the GrafPort before returning.

Desk accessories are parasites. They rely on the menu bar and the event code of the current application. The application must issue a _SystemTask request frequently to allow the accessory to run. The application must support an Edit menu selection in an accessory window via the _SysEdit call. The accessory receives mouse-down event notification via the _SystemClick call.

The code for the _SysEdit and _SystemClick support is shown in Listing 8.30. Lines 1–8 invoke _SysEdit. Note that the parameter to _SysEdit is zero-relative instead of one-relative like all other menu-related calls. The return value is either zero or nonzero, indicating whether the active window belongs to a desk accessory. This value is ignored by the run-time library.

Lines 9–13 illustrate how to call _SystemClick. You supply the event record address and the window pointer as parameters. The desk accessory receives an appropriate event call.

The code for handling the Edit menu appears in Listing 8.31. Lines 2–6 decide whether the Edit choice is destined for the application or a desk
accessory. If the Text Edit package is in use, the _TECut, _TECopy, and _TEPaste system calls handle the Cut, Copy, and Paste selections. Lines 8–10 return a choice larger (lower on the menu) than Paste directly to the application. Lines 11–18 handle the Cut selection. Lines 21–23 handle the Copy selection. Lines 25–27 handle the Paste selection.

If the run-time library is not configured to use the Text Edit package, the code at lines 29–33 returns the Edit menu selection directly to the application.

**Content Area or Scroll Bar Click** A mouse-down event in the content area of a window invokes the code in Listing 8.32. Lines 2–4 reject windows

```assembly
1: DeskAcc:
2:   CLR.L -(SP) ; Clear return space
3:   MOVE.L #"MENU",-(SP) ; Indicate menu resource
4:   MOVE.W #APPLE,-(SP) ; Push menu ID
5:   GetResource ; Get menu handle
6:   MOVE.W D7,-(SP) ; Push menu selection
7:   PEA Deskname(A5) ; → Acc name area
8:   GetItem ; Fetch desk accessory name
9:   PEA GPort(A5) ; Push longword address
10:  GetPort
11:  CLR.W -(SP) ; Space for handle
12:  PEA DeskName(A5) ; → Filled-in name area
13:  OpenDeskAcc ; Open the accessory
14:  TST.W (SP)+ ; Discard handle
15:  MOVE.L GPort(A5),-(SP) ; Push old GrafPort address
16:  _SetPort
17:  BRA Doevent ; and back for another event
```

**Listing 8.29 – Opening a desk accessory**

---

```assembly
1: SystemEdit:
2:   MOVE.W D7,DO ; DO = menu choice
3:   SUBQ.L $1,DO ; Decrement
4:   CLR.W -(SP) ; Space for result
5:   MOVE.W DO,-(SP) ; Choice word
6:   _SysEdit ; Do it
7:   MOVE.W (SP)+,DO ; Result to DO
8:   BRA Doevent ; Back for next event
9:   SystemEvent:
10:  PEA EventRecord(A5) ; → Event not ours
11:  MOVE.L WWindow(A5),-(SP) ; Window handle
12:  _SystemClick ; Call O/S
13:  BRA Doevent ; Back for another event
```

**Listing 8.30 – Calling _SysEdit and _SystemClick**
other than the application window. Note that desk accessory windows are handled by the SystemEvent routine, which is selected by the code in Listing 8.27. This code will not cause a desk accessory event to be lost. Lines 5–6 select the window (make it active) if it is behind another window. Lines 7–8 convert the mouse point in the event record from global (screen) coordinates to local (window) coordinates. If the Text Edit package is in use, lines 10–13 invoke the _TEClick routine, which handles mouse-down events. This routine has three parameters: the mouse point in local coordinates, an extend flag, and the Text Edit record handle. The extend flag indicates that the current selection is to be expanded. The runtime library always sets this flag to FALSE (zero).
When the window has controls, a click in the content area could be in the scroll bars. The code for this situation is shown in Listing 8.33.

The call to routine IncControls sets the window’s clipping region to include the scroll bars. You must do this before you attempt any operations on the controls. The _FindControl call in lines 3–9 determines whether the mouse point (now in local coordinates) is in one of the controls. This system call takes the mouse point, the window address, and the address of a control handle as parameters. If the mouse point is inside a control, the control handle is set to indicate which control. The return value (a word) indicates which part of the control contains the mouse point, as shown in the following list:

<table>
<thead>
<tr>
<th>Value</th>
<th>Control Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Not in any control, or in an inactive control</td>
</tr>
<tr>
<td>10</td>
<td>In a simple button</td>
</tr>
<tr>
<td>11</td>
<td>In a check box or other button</td>
</tr>
<tr>
<td>20</td>
<td>In up (left) arrow of a scroll bar</td>
</tr>
<tr>
<td>21</td>
<td>In down (right) arrow of a scroll bar</td>
</tr>
<tr>
<td>22</td>
<td>In page up (left) region of a scroll bar</td>
</tr>
<tr>
<td>23</td>
<td>In page down (right) region of a scroll bar</td>
</tr>
<tr>
<td>129</td>
<td>In thumb area of a scroll bar</td>
</tr>
</tbody>
</table>

If the mouse point is not in any control area, the point is returned to the user as a mouse-down event. If the point is in a scroll bar region (codes 20–23), the event is returned as a scroll event. The event code is 19 (decimal),
IF CONTROL = 0 ; Only if we have controls
BSR IncControls ; Include controls first
CLR.W -(SP) ; Room for result
MOVE.L Point(A5),-(SP) ; Push point
MOVE.L WindowPtr(A5),-(SP); Push window address
PEA Chandle(A5) ; Push control handle
_FindControl ; Fetch the control
MOVE.W (SP)+,DO ; Get part code
BBQ NoControl ; None, give point to user
MOVE.L Chandle(A5),Dl ; Fetch control handle
CMP.W #inThumb,DO ; Special case?
BBQ @2 ; Yes, go handle
SUB.W #inUpButton,DO ; Force to range 0-3
CMP.L VScroll(A5),Dl ; Was it?
BBQ @1 ; Yes, give to user
ORI.W #4,DO ; Or in horizontal bit
SWAP DO ; Set return
MOVE.W #ScrollWin,DO ; register
BRA @4 ; Back to user

If in thumb, we can do the tracking for the user program.

MOVE.L Dl,D4 ; Preserve control ID
CLR.W -(SP) ; Room for result
MOVE.L Dl,-(SP) ; Push control ID
MOVE.L Point(A5),-(SP); Push original point
CLR.L -(SP) ; No action procedure
TrackControl ; Track it
TST.W (SP)+ ; For real?
BNE @3 ; Yes, process
BSR ExcControls ; Reset clip region
BRA DoEvent ; Get an event

User changed the value. Fetch new setting.
CLR.W -(SP) ; Room for result
MOVE.L D4,-(SP) ; Push control handle
GetCtlValue ; Fetch the value
MOVE.W (SP)+,DO ; to
SWAP DO ; return register
MOVE.L D4,D1 ; Reset parameter register
MOVE.W #TScrollV,DO ; Assume vertical
CMP.L VScroll(A5),D1 ; Good assumption?
BBQ @4 ; Yes
MOVE.W #TScrollH,DO ; No, fix it
@4 BSR ExcControls ; Exclude controls
RETURNP ; Done, return to caller
NoControl ; Here if user point
BSR ExcControls ; Exclude controls
ENDIF ; CONTROL = 0

*Listing 8.33 – Mouse down in window content area (graphics mode)*
Listing 8.33 – Mouse down in window content area (graphics mode) (continued)

with the high word of D0 containing a value from 0–7 indicating the type of scrolling to be performed:

<table>
<thead>
<tr>
<th>Value</th>
<th>Scroll Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Line scroll up</td>
</tr>
<tr>
<td>1</td>
<td>Line scroll down</td>
</tr>
<tr>
<td>2</td>
<td>Page scroll up</td>
</tr>
<tr>
<td>3</td>
<td>Page scroll down</td>
</tr>
<tr>
<td>4</td>
<td>Line scroll left</td>
</tr>
<tr>
<td>5</td>
<td>Line scroll right</td>
</tr>
<tr>
<td>6</td>
<td>Page scroll left</td>
</tr>
<tr>
<td>7</td>
<td>Page scroll right</td>
</tr>
</tbody>
</table>

Note that bit 0 of this value determines scrolling direction. An even scrolling value indicates a scroll up (left), and an odd scrolling value indicates a scroll down (right). Similarly, bit 1 distinguishes between a line scroll and a page scroll, and bit 2 distinguishes between a vertical scroll and a horizontal scroll. Lines 10–19 compute this value. The user program should issue a call to the TRACK macro to continue scrolling until the mouse button is released.

If the mouse is down in the thumb area, the run-time library returns a thumb scroll event (D0.W = 20 for a vertical scroll, 21 for a horizontal scroll). The final value of the thumb is returned in the high word of D0. D1 contains the control handle on return to the application.

Lines 23–29 perform the _TrackControl call necessary to allow the user to change the thumb position on the screen. This system call returns the part code (described previously) of the control if the mouse remains in the control. A zero is returned otherwise, indicating that the user moved the mouse outside the control area. Lines 30–32 handle this case, resetting the window’s clipping region to exclude the controls, and ignoring the event.
Lines 37–48 handle the other case, where the user actually moves the thumb box on the screen. The _GetCtlValue call takes a control handle and returns the value of the control. This value is placed in the high word of D0 at lines 40–41. The application sets the minimum and maximum values for the controls using the SETVMIN, SETVMAX, SETHMIN, and SETHMAX macros. Lines 42–46 set the low word of D0 to the appropriate event code, depending on which scroll bar was affected. Lines 47–48 reset the window clipping region and return the new control value to the user.

Lines 49–59 return a mouse-down event to the application. If the mouse was not pressed in a control, or if there are no controls, the run-time library passes the event directly back to the application.

**Dragging the Window** A mouse-down event in the window title bar means the user is trying to drag the entire window. The code required to support this is shown in Listing 8.34.

The _DragWindow system call does all the required work. This system call takes as parameters the window pointer, the mouse point from the event record, and a bounds rectangle. The bounds rectangle specifies limits within which the window can be moved.

**Changing the Window Size** Listing 8.35 contains the code for altering window size. This code is activated when the mouse is pressed in the window's grow box, as determined by the _FindWindow call in Listing 8.27.

Lines 3–9 issue a _GrowWindow system call. This call requires a window pointer, the mouse point from the event record, and a bounds rectangle. The bounds rectangle establishes limits on the minimum and maximum size of the window. The first point in the rectangle gives the minimum size, and the second point gives the maximum size. _GrowWindow returns a point containing the new size of the window. If this return value is zero, the window did not change size.

```
1: Drag:                ;
2:   MOVE.L  Window(A5),-(SP);  Push window handle
3:   MOVE.L  Point(A5),-(SP);  Push mouse point
4:   PEA    DWBounds;          and bounds rectangle
5:   _DragWindow;            Do the drag
6:   BRA    Doevent;          and get a new event
```

**Listing 8.34** – Window dragging code
1: Grow:
2:   IF CONTROL = 0 ; Only if controls in place
3:     CLR.L -(SP) ; Room for result
4:     MOVE.L WWindow(A5),-(SP); Push window handle
5:     MOVE.L Point(A5),-(SP); and mouse point
6:     PEA GWBounds ; and bounds rectangle
7:     GrowWindow ; Do the grow
8:     MOVE.L (SP)+,D5 ; D5 = New size
9:     BEQ DoEvent ; If EQ, didn’t change
10:   First, generate an update for the old scroll bar region.
11:   PEA ViewRect(A5) ; Convert ViewRect to
12:     LocalToGlobal ; global coordinates
13:     MOVEM.L ViewRect(A5),D3/D4; Fetch rectangle twice
14:     MOVEM.L ViewRect(A5),D0/D1;
15:   ; Invalidate VScroll bar
16:   ;
17:     MOVE.W D1,D0 ; Copy right to left
18:     ADD.W #ScrollW,D1 ; Adjust right for scroll bar width
19:     SWAP D1 ; Adjust
20:     SUB.W #ScrollW,D1 ; bottom
21:     SWAP D1 ; for grow box
22:     MOVEM.L D0/D1,ViewRect(A5); Now
23:     PEA ViewRect(A5); make
24:     _InvalidRect ; invalid
25:   ; Now, invalidate HScroll bar
26:   ;
27:     SWAP D3 ; Invert rectangle
28:     SWAP D4 ;
29:     MOVE.W D4,D3 ; Copy bottom to top
30:     ADD.W #ScrollW,D4 ; Adjust bottom for scroll width
31:     SWAP D3 ; Re-
32:     SWAP D4 ; swap
33:     ADD.W #ScrollW,D4 ; Adjust right for grow box
34:     MOVEM.L D3/D4,ViewRect(A5); Now
35:     PEA ViewRect(A5); make
36:     _InvalidRect ; invalid
37:   ; Next, actually resize the window on the screen
38:   ;
39:     MOVE.L WWindow(A5),-(SP); Push window handle
40:     MOVE.L D5,-(SP); Push size
41:     MOVE.W #-1,-(SP); Push TRUE value
42:     SizeWindow ; Update screen to new size
43:     BSR SizeW ; Size the window
44:   ; Erase the new window content area
45:   ;
46:     PEA ViewRect(A5) ; Push view rectangle address
47:     _EraseRect ; Erase it

Listing 8.35 – Changing the size of a window
Here we move the scroll bars to their new location. First, hide both controls.

MOVE.L  VScroll(A5),-(SP); Hide VScroll bar
_HIDEControl

MOVE.L  HScroll(A5),-(SP); Hide HScroll bar
_HIDEControl

Next move and resize VScroll bar

MOVE.L  VScroll(A5),-(SP); Move VScroll
MOVE.W  ViewRect+6(A5),-(SP); "Right" - scroll width
MOVE.W  ViewRect+0(A5),-(SP); "Top"
MOVE.L  VScroll(A5),-(SP); Move the scroll bar
MOVE.L  ViewRect+4(A5),-(SP); Length
MOVE.L  #ScrollW,-(SP); SizeControl

Now move and resize HScroll bar

MOVE.L  HScroll(A5),-(SP); Move HScroll
MOVE.W  ViewRect+2(A5),-(SP); "Left"
MOVE.W  ViewRect+4(A5),-(SP); "Bottom" - scroll width
MOVE.L  HScroll(A5),-(SP); Do the move
MOVE.L  ViewRect+6(A5),-(SP); Push control handle
MOVE.W  ViewRect+4(A5),-(SP); Length
MOVE.W  #ScrollW,-(SP); SizeControl

Now show both controls

MOVE.L  VScroll(A5),-(SP); Show VScroll bar
_SHOWControl

MOVE.L  HScroll(A5),-(SP); Show HScroll bar
_SHOWControl

Now pass the size information to the application.

MOVE.L  ViewRect+4(A5),D1; Pick up new size (clipped)
MOVE.L  #GrowWin,D0 ; Set return code
RETURNP ; Give back to user
ELSE ; CONTROLS = 0
BRA  DoEvent ; No grows allowed
ENDIF ; CONTROLS = 0

Listing 8.35 – Changing the size of a window (continued)
_GrowWindow drags an outline of the window around on the screen, as shown in Figure 8.2. When the mouse button is released, the outline disappears and _GrowWindow returns the new size to the application.

Lines 13–40 mark the region occupied by the scroll bars and the grow box as invalid. This is necessary for proper operation of overlapped windows. (When the top window shrinks, any underlying window must be redisplayed.) The view rectangle for the window gives the bounds of the content area of the window (exclusive of scroll bars) in local coordinates. Lines 13–16 convert this rectangle to global (screen) coordinates and make copies in D0/D1 and D3/D4.

Lines 20–24 calculate the rectangle occupied by the old vertical scroll bar on the screen. Lines 25–27 mark the rectangle as invalid. Lines 31–37 calculate the rectangle occupied by the combination of the old horizontal scroll bar and grow box. Lines 38–40 mark this area on the screen as invalid.

Figure 8.2 – Enlarging a window
Lines 44–47 actually change the size of the window. The _SizeWindow call redraws the window on the screen. The scroll bars and grow box are not drawn, however. _SizeWindow requires a window address, the size returned by _GrowWindow, and a word that indicates whether the update region should automatically be updated. This word is nonzero for updating. The area between the old and new window sizes is added to the update region. The call to SizeW at line 48 updates the internal variables in the run-time library to reflect the change in window size. The SizeW routine appears in Listing 8.7.

Lines 52–53 erase the content region (not including the scroll bars) of the resized window. You must at least erase the area occupied by the old grow box when enlarging a window. The run-time code requires that the application redraw the window contents.

Lines 58–61 issue the _HideControl call for both scroll bars. Lines 65–68 move the vertical scroll bar to its new location. The _MoveControl call takes the control handle and the coordinates of the new location as parameters. Note that the coordinates are specified in reverse order (horizontal first) for this call. Lines 69–72 specify the size of the scroll bar. The _SizeControl call takes the control handle, width, and length as parameters. Lines 76–83 repeat the move and size operations for the horizontal scroll bar.

Lines 87–90 issue _ShowControl calls for both scroll bars. This causes the scroll bars to reappear in their new locations on the screen.

Lines 94–96 return the size window event to the application. D1.L contains the new window size (not including the scroll bars). Lines 97–99 ignore the event if the window has no controls.

Listing 8.36 contains the code for the IncControls and ExcControls routines, which include and exclude the controls in the window clipping area. Lines 5–6 add the width of the scroll bar to the bottom and right words of the rectangle. Lines 7–8 set the clip rectangle to this rectangle. Lines 12–19 reset the clip rectangle to the saved rectangle.

Closing the Window A mouse click in the window's close box is handled by the code in Listing 8.37. The _TrackGoAway call highlights the close box as shown in Figure 8.3. If the user moves the mouse outside the close box before releasing the button, _TrackGoAway unhighlights the box. Moving the mouse back into the box highlights it again.

Lines 2–6 perform the _TrackGoAway call. The parameters are the window address and the mouse point from the event record. A word is returned. If this word is nonzero, the user released the button inside the close box, and a close-window event is returned to the application at lines 8–9. A zero value indicates that the user released the button outside the close box. The event is ignored in this case.
Listing 8.36 – IncControls and ExCtrlIons routines

Update Events

The result of the _InvalRect calls in Listing 8.36 is to generate a Macintosh update event. When an area of the screen is marked as invalid, an update event is generated for all windows in the invalid area. In many cases, only a part of each window is affected. However, most applications update all of the window in response to any update event. This is the case for all programs in this book.

Listing 8.38 shows the code executed by the run-time library in response to an update event. Lines 2–10 handle the update completely if the run-time code is using the Text Edit package. The actual update must be bracketed with _BeginUpdate and _EndUpdate calls, as with the MacDoodle program in Chapter 6. For a Text Edit window, you need call only the _TEUpdate routine. This call requires a rectangle and the Text Edit handle for the affected window. The rectangle is in the local coordinates of the window, and it can be used to update only a part of the window if desired. The ViewRect structure specified in line 5 causes the entire window to be updated.

For applications using graphics, the update event is handled by the application. If the window has controls, however, the run-time library draws the controls before giving the event to the application. Lines 12–17 redraw all the window’s controls. Note that the clipping region must be
set to include the controls during this operation, as evidenced by the calls to
IncControls and ExcControls before and after drawing the controls.

**Activate Events**

A window becomes the active window by means of a Macintosh activate event. An activate event can also deactivate a window. Listing 8.39 shows the code executed in response to an activate event.

Lines 2–3 reject activate events for windows other than the application window. Bit 0 of the event record "modify" word determines whether the event is an activate or deactivate request. If the bit is clear, the event is a deactivate request. Lines 12–14 make this determination.

Lines 15–31 process activate requests. If the window is a text window, the _TEActivate system call is required, as shown in lines 11–14. You must then issue a _SelectWindow call to highlight the window and a _SetPort call to make the window the active QuickDraw port. Finally, if the window has scroll bars, you must issue a _ShowControl call for each scroll bar.

Listing 8.37 – The close-window routine
Listing 8.38 – Update event handler

1: Update: ; Just update text part
2: IF TEXTRTL = 0 ; If text only
3: MOVE.L WindowPtr(A5),-(SP) ; Warn
4: BeginUpdate ; everyone first
5: PEA ViewRect ; Now repaint
6: MOVE.L THandle(A5),-(SP) ; text window
7: _TEUpdate ; thusly
8: MOVE.L WindowPtr(A5),-(SP) ; Now signal end of update
9: _EndUpdate ;
10: BRA Doevent ; Done
11: ELSE ; Graphics mode
12: BSR IncControls ; Include controls in window
13: MOVE.L WindowPtr(A5),-(SP) ; Push window pointer
14: _DrawControls ; Draw the controls
15: MOVE.L WindowPtr(A5),-(SP) ; Push window pointer
16: _DrawGrowIcon ; Draw grow box
17: BSR ExeControls ; Take controls back out
18: BRA UserEvt ; Let user handle
19: ENDD IF

Lines 35–47 handle deactivate requests. If the window is a Text Edit window, you must call _TEDeactivate to deactivate the Text Edit Record. If the window has controls, you must call _HideControl for each scroll bar. Note that there is no counterpart to the _SelectWindow or _SetPort calls in the Activate code.

CHKABORT

The CHKABORT routine used in the Dump program in Chapter 4 tests to see if the next event is an abort event. This routine is also part of the event system. This code consists of the CHKABORT macro and a run-time support routine called XXABORT. The CHKABORT macro is shown in Listing 8.40. It is simply a JSR to routine XXABORT. The code for this routine appears in Listing 8.41.

XXABORT gets the next event from the event queue. Only three types of events are allowed by the bit mask AbtEvt: key down, autokey, and abort. If the event returned is an abort event or if the key pressed is Command-Period, a value of −1 is returned to the user program at line 13. Otherwise, a value of zero is returned at line 15.
1: Activate
2:  MOVE.L Message(A5),AO       ; Activate window request
3:  A0 = window pointer
4:  CMP.L WindowPtr(A5),AO       ; Is it ours?
5:  BNE DoEvent                   ; No, get next event
6:  IF CONTROL = 0                ; Controls?
7:  BSR IncControl                ; Yes, include them
8:  ENDIF                         ; CONTROL
9:  ;
10: (De)activate the text window
11: ;
12:  MOVE.W Modify(A5),DO         ; Activate or deactivate?
13:  BTST.L #0,DO                  ; Bit 0 tells us
14:  BEQ Deactivate                ; Clear => Deactivate
15:  IF TEXTRTL = 0                ; Don't activate TE if not needed
16:  MOVE.L THandle(A5),-(SP)      ; Push text handle
17:  TEActivate                    ; Activate text window
18:  ENDIF                         ;
19:  MOVE.L Message(A5),-(SP)      ; Push window pointer
20:  _SelectWindow                 ; Select this window as active
21:  MOVE.L Message(A5),-(SP)      ; Push window pointer
22:  _SetPort                      ; Make the Q/D active port
23:  IF CONTROL = 0                ; If window has controls
24:  MOVE.L VScroll(A5),-(SP);    ; Show scroll
25:  _ShowControl                  ; bars
26:  MOVE.L HScroll(A5),-(SP);    ;
27:  ShowControl                   ;
28: / BRA EndAct                   ; Do end stuff
29: ELSE                           ; CONTROL = 0
30:   BRA DoEvent                  ; Fetch next event
31:   ENDIF                        ; CONTROL
32: ;
33: ; Here if deactivate specified
34: ;
35: Deactivate:
36: IF TEXTRTL = 0                ; Don't deactivate TE if no text
37:   MOVE.L THandle(A5),-(SP)     ; Push text handle
38:   _DeActivate                   ; and deactivate it
39:   ENDIF                         ;
40: IF CONTROL = 0                ; If scroll bars
41:   MOVE.L VScroll(A5),-(SP);    ; Hide scroll
42:   _HideControl                  ; bars
43:   MOVE.L HScroll(A5),-(SP);    ;
44:   _HideControl                   ;
45: EndAct: BSR ExcControls        ; Exclude controls
46:   ENDIF                        ; CONTROL = 0
47:   BRA Doevent                  ; Get next event

Listing 8.39 - Activate event handler
The run-time library supports several calls relating to the Macintosh file system:

1. The OPEN, OPENR, and POPEN calls open an existing file.
2. The CREATE and PCREATE calls create a new file.
3. The CLOSE call closes an open file.
4. The READ and READLN calls read data from a file.
5. The WRITE call writes data to a file.
6. The SEEK call allows random access to a file.
7. The DELETE call removes an existing file.
8. The GETFINFO and SETFINFO calls get and set the file information.
Macintosh I/O Parameter Block

Most of these routines use a Macintosh data structure known as an I/O parameter block, or IOPB. This structure was partially described in Chapter 4. Figure 8.4 shows the structure of an I/O parameter block.

<table>
<thead>
<tr>
<th>Offset</th>
<th>Contents</th>
<th>MDS Label</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>I/O Link Address</td>
<td>ioLink</td>
</tr>
<tr>
<td>4</td>
<td>I/O Type</td>
<td>ioType</td>
</tr>
<tr>
<td>6</td>
<td>I/O Trap</td>
<td>ioTrap</td>
</tr>
<tr>
<td>8</td>
<td>I/O Command Address</td>
<td>ioCmdAddr</td>
</tr>
<tr>
<td>12</td>
<td>Application Completion Routine Address</td>
<td>ioCompletion</td>
</tr>
<tr>
<td>16</td>
<td>I/O Result Code</td>
<td>ioResult</td>
</tr>
<tr>
<td>18</td>
<td>File Name Address</td>
<td>ioFilename</td>
</tr>
<tr>
<td>22</td>
<td>Volume Reference Number</td>
<td>ioVRefNum</td>
</tr>
<tr>
<td>24</td>
<td>I/O Reference Number</td>
<td>ioRefNum</td>
</tr>
<tr>
<td>26</td>
<td>I/O File Type</td>
<td>ioFileType</td>
</tr>
<tr>
<td>27</td>
<td>I/O Permission</td>
<td>ioPermssn</td>
</tr>
<tr>
<td>28</td>
<td>File Private 522-byte Buffer Address</td>
<td>ioOwnBuf</td>
</tr>
<tr>
<td>32</td>
<td>Read/Write Buffer Address</td>
<td>ioBuffer</td>
</tr>
<tr>
<td>36</td>
<td>Read/Write Byte Count Requested</td>
<td>ioByteCount</td>
</tr>
<tr>
<td>40</td>
<td>Read/Write Byte Count Completed</td>
<td>ioNumDone</td>
</tr>
<tr>
<td>44</td>
<td>File Positioning Mode/End-of-Line Character</td>
<td>ioPosMode</td>
</tr>
<tr>
<td>46</td>
<td>File Position Offset</td>
<td>ioPosOffset</td>
</tr>
</tbody>
</table>

Figure 8.4 – The I/O parameter block
The column labeled MDS Label contains the standard name for each field using the MDS equate files. The IOPB names are found in the file SysEqux.D. The first four fields of the IOPB are used internally by the operating system. The application need only reserve the space for these fields.

The ioCompletion field is used for asynchronous I/O. You can specify a routine to be called when the operation is complete. To specify that no routine is to be called, zero this field. The run-time library does not use this feature.

The ioResult field is returned by the system. This word contains either an error code or a positive result. Macintosh error codes are always less than zero.

The ioFileName field is specified by the application on an open, create, delete, or file information request. This field should contain the address of a Pascal-format (leading count byte) string. You can specify a volume name before the file name, separating the two by a colon if desired.

The volume reference number (ioVRefNum) is set by the application before an open, create, delete, or file information request. This is an alternate way of specifying a drive on which to find the file. If this field is zero, the default drive is used. This field is set by the operating system on a successful operation. Specifying a drive name as part of the file name overrides the volume reference number.

The I/O reference number (ioRefNum) contains a reference number on a file open or create operation. This number is set by the application on a read, seek, or write request.

The I/O file type (ioFileType) and I/O permission (ioPermssn) bytes are additional parameters for open requests. The file type is set to zero by most applications on create and open requests. The I/O permission byte is an indication of what requests will be attempted after the file is open. This byte can have the following values:

<table>
<thead>
<tr>
<th>Value</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Request type is unknown</td>
</tr>
<tr>
<td>1</td>
<td>Only read requests will be attempted</td>
</tr>
<tr>
<td>2</td>
<td>Only write requests will be attempted</td>
</tr>
<tr>
<td>3</td>
<td>Both read and write requests will be attempted</td>
</tr>
</tbody>
</table>

This byte provides the means to detect whether you can perform the operations you desire on the file at open time. For instance, writing on a locked file or disk could be detected at open time rather than at the first write call. The run-time library, however, always sets this byte to zero.

The private buffer address, ioOwnBuf, provides a means of speeding up file access. If this buffer is not specified, a buffer shared by the entire disk
will be used. If you have many files open at once, you can achieve a significant performance improvement by using private file buffers.

Read and write requests use the buffer address (ioBuffer) as the address of the first byte to be transferred. The byte count requested (ioByteCount) is the number of bytes to be transferred. The operating system will set the byte count completed (ioNumDone) to the number of bytes actually transferred. If the number of bytes requested is not equal to the number transferred, an error occurred if the request was a write request. This situation may not indicate an error with read requests, however, if you are reading the last bytes in the file (that is, you ask for 100 bytes but there are only 50 left).

The ioPosMode field indicates the meaning of the file position offset field (ioPosOffset) in requests that require a file offset. The SEEK macro uses this field. You can specify an offset relative to the beginning of the file, the current file position, or the end of the file. In addition, if bit 7 of this word is set on a read request, the upper byte is taken to be an end-of-line character. The READLN macro uses this feature.

**Opening a File**

To access the data within a file, you must open the file. A file open operation establishes a link between an I/O reference number and a file name on the disk. The run-time library offers three open macros: OPEN, OPENR, and POPEN.

**OPEN and OPENR**

Listing 8.42 contains the source to the OPEN macro. The OPENR macro is identical, except for the name of the run-time support routine.

The run-time routine for the OPEN macro is called XXOPEND. For the OPENR macro, the run-time routine is XXOPENR. These macros have three parameters: the file name address, a buffer area, and a volume reference number. The file name is passed in A0, the buffer address in A1, and the volume reference in D1. A zero is passed for missing parameters. The file name must always be specified, however. The I/O reference number is returned in the low-order word of D0. The volume reference number is returned in the low-order word of D1.

Listing 8.43 shows the run-time support routine. The Gopen function starting at line 11 is common to the OPEN, OPENR, and GETFINFO routines. It is also called internally by the OpenRsrc routine, which is called from the run-time initialization. The Gopen routine receives the file name address in A0 and the address of an open function in A6. Gopen tries to open the named file on every mounted drive in the system.
Listing 8.42 – The OPEN macro

Lines 2–3 set up the Gopen parameters to open the data fork of a file. Lines 11–16 attempt to open the file on the default drive (or the drive whose volume reference is contained in D1). If this open fails and the volume reference number was not specified, a volume scan is attempted.

The volume scan begins at line 17. D6 is used to hold the byte count of the specified file name, and A3 is used to point to an operating system data structure called a volume control block, or VCB. Lines 20–21 test the drive number in the VCB. If this number is zero, the disk is not in any drive. No open is attempted for such a disk. Lines 22–28 move the volume name from the VCB into a run-time library scratch area called FScratch. Line 29 appends a colon character to the volume name. Lines 30–33 append the file name to this string, so that the complete string is

vol:filename

where “vol” is the volume name and “filename” is the name supplied by the application. Lines 34–38 attempt to open the file name thus constructed. If successful, the BGT at line 38 succeeds, and Gopen exits back to the application. Otherwise, the code at lines 39–42 attempt the next volume. If there is no next volume, the link word in the VCB is zero, and a −1 is returned to the application at line 43.

You could use the volume reference number instead of constructing the file name string, except that the _OpenResFile trap used to open a resource file does not allow specification of a volume reference number.

Listing 8.44 contains the code for the TryDopen routine, which is called by Gopen to open the data fork of a file. The _Open trap at line 9 is a register-based call to the operating system. Register A0 contains the address of an I/O parameter block (IOPB) on entry. For the _Open trap,
Listing 8.43 - The XXOPEN and Gopen routines

you must fill in the file name, volume reference number, file type, permission, and private buffer fields. After the _Open, any error code will be in the ioResult field of the IOPB. If this field is zero, the I/O reference number for the file will be in the ioRefNum field.
Listing 8.44 – The TryDopen routine

As mentioned before, the code for the OPENR macro is nearly identical. The run-time routine is named XXOPENR, and the trap name for the open is _OpenRF. The routine passed to Gopen is called TryRopen. This function opens the resource fork of a file for I/O.

OpenRsrc

Opening an application resource file is a completely different operation. This function requires the _OpenResFile trap. The code that performs this operation is shown in Listing 8.45.

Lines 2-6 are called from the initialization code in Listing 8.3. The routine called from Gopen issues the _OpenResFile trap at line 10. The word returned from this function is an I/O reference number. The run-time library uses it simply as an indication of whether the open attempt was successful.

POPEN

The POPEN macro uses a feature of the Macintosh system called the standard file package. A Macintosh package is loaded on demand as an overlay from the System file. It is not in the ROM. The code for the POPEN macro is shown in Listing 8.46.

The POPEN macro has four parameters: the address of a type array, the address of a file extension string, the address of a buffer to receive the file name, and the address of a file buffer. These parameters are loaded into address registers in lines 3–6. The run-time support routine is called XXPOPEN. This routine is shown in Listing 8.47.
1: OpenRsrc: ; Entry point
2:     SAVE ; Save registers
3:     LEA TRYRESOP,A6 ; → Open function
4:     CLR.L Filebuf(A5) ; No special file buffer
5:     CLR.W D1 ; Default volume search
6:     BRA Gopen ; Go do it
7: TRYRESOP: ; A0 → File name
8:     CLR.W -(SP) ; Clear out room
9:     MOVE.L AO,-(SP) ; Push file name
10:     OpenResFile ; Open
11:     MOVE.W (SP)+,A0 ; Fetch file handle/error code
12:     RTS ; Return to caller

Listing 8.45 - The OpenRsrc routine

1: .MACRO POPEN ; types,ext,namebuf,buffer =
2: MOVEM.L A1-A3,-(SP) ; Save registers
3: LEA %1,A3 ; A3 → Type array
4: LEA %2,A0 ; A0 → Extension string
5: LEA %3,A2 ; A2 → Buffer for name
6: LEA %4,A1 ; A1 → buffer
7: XREF XXPOPEN ; For the linker
8: JSR XXPOPEN ; Call RTL routine
9: MOVEM.L (SP)+,A1-A3 ; Restore registers
10: .ENDM
11: Cancelled EQU -1 ; Code for cancelled by user

Listing 8.46 - The POPEN macro

Registers A0 and A1 are saved in global storage by lines 2–3. The call to the standard file package starts at line 5. The first parameter is the point at which the upper-left corner of the window will appear. The run-time library uses an arbitrary value of (100,100). The second parameter is the address of a function that examines each file for placement in the window. The third parameter is the number of types in the type array (−1 if there is no array). The fourth parameter is the actual type array address. Lines 8–13 load these two parameters from the single address given by the macro. The fifth parameter is the address of a dialog hook procedure to capture and filter events during the package operation. This parameter is always set to zero, to indicate no procedure. The sixth parameter is the address of a standard file reply record, as shown in Figure 8.5. The last parameter is the number of the routine desired. For the POPEN macro, it is the SFGet routine (value of 2).
The _Pack3 call at line 17 invokes the standard file package. Line 18 tests the return value. If it is nonzero, a file was selected. Otherwise, a value of -1 is returned to the application at line 20.

After selecting the file, we must open it. Lines 23–27 call the TryDOpen routine, which opens the data fork of the file. On a successful open, lines 28–31 place the file name in the application buffer. Line 32 places the volume reference number in D1 for return to the application.

The extension filter routine specified in line 7 is shown in Listing 8.48. This routine is called by the routine invoked by the _Pack3 trap using standard Pascal parameter conventions. There is one input parameter, the address of an I/O parameter block containing the file information.
**Figure 8.5 – Standard file reply record**

The routine returns a single word, which is zero if the file is to be displayed and nonzero otherwise.

Lines 2–3 return zero for every file if no extension was specified in the POPEN macro call. Lines 5–15 compute the address of the first byte of the file name to compare. The specified extension string is compared with the last bytes in the file name at lines 16–26. Lines 18–22 convert lowercase characters in the file name to uppercase for comparison. Lines 27–30 return an indication that the file should be displayed, while lines 31–34 return the opposite indication.

**Creating a File**

The run-time library supports two methods of creating a file. When the name of the file is specified by the application, the CREATE macro places a new file on the disk and opens the data fork. When the user specifies the file name, the PCREATE macro performs the user dialog, creates the file, and opens the data fork.

**CREATE**

Listing 8.49 shows the code for the CREATE macro. The macro has three parameters: a file name address, a file buffer address, and a volume reference number. The string DEFAULT can be used for either the buffer address or the volume reference number, or these parameters can be omitted.
Listing 8.48 – The ExtFilter routine

The file name parameter is mandatory. Line 3 loads the file name address into A0. Lines 4–8 place the buffer address (or zero if none was specified) into A1. Lines 9–17 set D1 to the volume reference number. Note the nested conditional assembly. The third parameter can be blank, or it can be the string DEFAULT, both of which are special cases. If some other string is specified, line 15 loads the value into D1.W.

The run-time routine called by the CREATE macro is XXCREATE. This code is shown in Listing 8.50. The routine TryCreate, which is shared by the CREATE and PCREATE code, actually does the work. Lines 7–14 set up the IOPB fields. Line 15 deletes any existing file of the same name, and line 16 creates a new file. This is done so that the application need not call the DELETE macro before calling CREATE. The PCREATE macro prompts the user before destroying an existing file.
Listing 8.49 – The CREATE macro

Line 17 gets the file information. Note that A0 is preserved by these calls, so it is not necessary to reload it every time. Lines 18–19 set the Finder file type and application signature, and line 20 writes the corrected file information out to disk. Applications that use a different file type (like MacDoodle) are required to do a SETFINFO call to change the file information from this default. Lines 21–27 open the file and return the I/O reference number in D0.W and the volume reference number in D1.W.

**PCREATE**

The PCREATE macro code is shown in Listing 8.51. This macro has four address parameters: a prompt, a default file name, a buffer for the actual file name, and a file buffer. These are loaded into address registers A0–A3 in lines 3–6.

The run-time routine for the PCREATE macro is called XXPCREATE. The XXPCREATE code is shown in Listing 8.52. The XXPCREATE routine calls the same _Pack3 trap that the POPEN routine uses. It takes six parameters:

1. The point at which the dialog box is to be displayed
2. The address of the prompt string
3. The address of the default name
1: XXCREATE:       ; Save callers registers
2:       ; Save callers registers
3: JSR TryCreate  ; Call internal routine
4: RETURNP       ; Restore all but D0/D1
5: 
6: TryCreate:       ; Here if locally called
7: MOVE.L A0,ioFileName+IOPB(A5); Set file name
8: MOVE.L A1,A3 ; Save A1
9: LEA IOPB(A5),A0 ; A0 → IOPB
10: CLR.L ioCompletion(A0); No completion routine
11: MOVE.W D1,ioVRefNum(A0); Specified volume
12: CLR.W ioFileType(A0); Default version
13: CLR.B ioPermssn(A0); Whatever we can get
14: CLR.L ioOwnBuf(A0); No special access buffer
15: _Delete ; Get rid of existing version
16: _Create ; Do it
17: _GetFileInfo ; Get file information
18: MOVE.L #'TEXT',ioFlUsrWds(A0); Set file type
19: MOVE.L #'EDIT',ioFlUsrWds+4(A0); Set application
20: _SetFileInfo ; Set the info
21: MOVE.L A3,ioOwnBuf(A0); Set buffer address
22: _Open ; Get error code
23: MOVE.W ioResult(A0),D0 ; Extend to long
24: BNE CreateNFG ; Failed if nonzero
25: MOVE.W ioRefNum(A0),D0 ; Get reference number
26: MOVE.W ioVRefNum(A1),D1; Return volume reference number
27: CreateNFG: ; Common exit point
28: RTS ; Return to caller

Listing 8.50 – The XXCREATE routine

4. The address of the dialog hook procedure (always set to zero—no procedure—by the run-time library)

5. The address of the reply buffer (see Figure 8.4)

6. The constant 1, indicating the put file procedure of the package

The standard file package takes care of the user dialog, including the prompt for overwriting an existing file. On return, the file name is in the reply area. Lines 16–19 call the TryCreate routine in Listing 8.50 to create the file. Lines 22–25 copy the file name from the standard file buffer to the application-supplied area. Line 26 copies the volume reference to D1.W for return to the application. The XXPFAIL label is contained in Listing 8.47.
Closing a File

The CLOSE macro disconnects an application from a file opened by an OPEN, OPENR, POPEN, CREATE, or PCREATE call. The code for this macro is shown in Listing 8.53.

The macro has a single parameter, the I/O reference number, which is passed to the run-time library in D0.W. The run-time routine is XXCLOSE and appears in Listing 8.54.

Lines 3–4 set up the IOPB (only one field is needed). The _Close trap closes the file. Line 6 calls an internal routine that instructs the operating system to write any data still in memory out to the disk. This internal routine is part of the EXIT code; it is contained in Listing 8.75.

Transferring Data

Data is copied between application memory and the file system via the READ, READLN, and WRITE macros. The file must have been opened by one of the OPEN or CREATE routines discussed previously.

READ and READLN

The READ and READLN macros are shown in Listings 8.55 and 8.56, respectively. Each macro requires an I/O reference number, a buffer address, and a buffer length. These are placed in registers D0.W, A0, and D1.L, respectively. Register D2.W receives a zero in the READ macro and the constant 3456 (decimal) in the READLN macro.

Both of these macros call the run-time support routine XXREAD, which appears in Listing 8.57. Lines 2–7 set up the IOPB for the read, storing the registers (which contain the macro parameters) in the appropriate places

```
1:   MACRO   PCREATE prompt,defname,namebuf,buffer  =
2:   MOVEM.L A0-A3,-(SP) ; Save registers
3:   LEA      {prompt},A0  ; A0 -> Prompt string
4:   LEA      {defname},A3 ; A3 -> Default name
5:   LEA      {namebuf},A2 ; A2 -> Name buffer area
6:   LEA      {buffer},A1  ; A1 -> 522-byte buffer
7:   XREF     XXPCREATE   ; For the linker
8:   JSR      XXPCREATE   ; Call RTL routine
9:   MOVEM.L (SP)+,A0-A3  ; Restore registers

Listing 8.51 – The PCREATE macro
```
in the IOPB. D2.W is stored in the ioPosMode offset of the IOPB. A value of zero in this field indicates that the read is terminated by the byte count. The read may also be terminated by the end of the file, if there are not enough data left in the file to satisfy the request. If bit 7 of the ioPosMode field is set, the high byte of this word is taken as a terminator character.

Listing 8.52 - The XXPCREATE routine

```
1: XXPCREATE:                  ; Entry point
2:         SAVE                ; Save registers
3: MOVE.L Al,Filebuf(A5)      ; Save buffer address
4: MOVE.L SP,(-(SP))          ; Point for dialog box
5: MOVE.L A0,(-(SP))          ; Prompt string
6: MOVE.L A3,(-(SP))          ; Default name
7: CLR.L --(SP)               ; No dialog hook procedure
8: PEA SFReply(A5)            ; Reply area
9: MOVE.W #SPPut,(-(SP))      ; Routine selector
10: Pack3                      ; Invoke package
11: TST.B Good(A5)            ; Test return code
12: BNE NoCancel              ; NE => Not cancelled
13: MOVE.L #Cancel,DO         ; Return
14: BRA XXPFAIL               ; Failed, return
15: NoCancel:                 ; Here if OK
16: MOVE.W VolRef(A5),D1      ; Set volume ID
17: LEA Fname(A5),AO          ; AO -> File name
18: MOVE.L Filebuf(A5),Al     ; Restore Al
19: JSR TryCreate             ; Try to create it
20: TST.W DO                  ; Worked?
21: BMI XXPFAIL               ; No, quit now
22: MOVE.B Fname(A5),(A2)+    ; Move in count byte
23: MOVE.L A2,Al              ; A1 -> Destination
24: LEA Fname(A5),A2          ; A2 -> Source
25: JSR MoveCnt               ; Move in name
26: MOVE.W ioVRefNum(AO),D1;  ; Set volume ref number
27: BRA XXPFAIL               ; Go exit
```

Listing 8.53 - The CLOSE macro

```
1: MACRO CLOSE filament =    ; Define RTL routine name
2: MOVE.L DO,(-(SP))         ; Save DO
3: MOVE.W {filenam},DO      ; DO = File number to close
4: XREF XXCLOSE              ; Define RTL routine name
5: JSR XXCLOSE               ; Call RTL
6: MOVE.L (SP)+,DO           ; Restore DO
7: |                          ;
```
The read may then also be terminated if this character is encountered. A value of 3456 (D80 hex) causes the read to terminate at the next carriage return. This reads one line from a Macintosh textfile.

Lines 11–16 check for an error on the read operation. If an end-of-file error was returned but some bytes were transferred, no error is returned.
A subsequent READ macro will return the end-of-file error. Line 17 loads the actual number of bytes read into D0.L for return to the application.

**WRITE**

A Macintosh file write operation is very similar to a read operation. There is no support for terminator characters, however, so there is no WRITELN macro. Listing 8.58 contains the WRITE macro code.

Registers D0.W, A0, and D1.L are used for the same parameters as the READ macro. Register D2 is not used by the WRITE code. The run-time routine is called XXWRITE and appears in Listing 8.59.

```
1: XXREAD: SAVE ; Save caller's registers
2: LEA IOPB(A5),A1 ; A1 -> Parameter block
3: MOVE.W D0,ioRefNum(A1) ; Store file reference number
4: MOVE.L D1,ioByteCount(A1); Store byte count
5: MOVE.L A0,ioBuffer(A1) ; and buffer address
6: MOVE.W D2,ioPosMode(A1); Specify sequential read
7: MOVE.L A1,A0 ; A0 -> Parameter block
8: Read ; Issue the read
9: LEA IOPB(A5),A0 ; A0 -> Parameter block again
10: MOVE.W ioResult(A0),D0 ; Fetch result code
11: EXT.L D0 ; Extend to long
12: B EQ Noerr ; No error
13: CMPI.L #eofERR,D0 ; End of file error?
14: BNE ReadDone ; No, return error
15: TST.L ioNumDone(A0) ; Any bytes read?
16: B EQ ReadDone ; No, return error
17: Noerr: MOVE.L ioNumDone(A0),D0; Not (really) an error, return byte count
18: ReadDone: ; Here when done
19: RETURN ; Restore the registers
```

**Listing 8.57 – The XXREAD routine**

```
1: MACRO WRITE filenum,buffer,count =
2: MOVEM.L D1-D2/A0,-(SP) ; Save registers
3: MOVE.W (filenum),D0 ; Load file number
4: LEA (buffer),A0 ; A0 -> Buffer address
5: MOVE.L (count),D1 ; D1 = Byte count
6: XREF XXWRITE ; Define RTL routine name
7: JSR XXWRITE ; Call RTL
8: MOVEM.L (SP)+,D1-D2/A0 ; Restore registers
9: |
```

**Listing 8.58 – The WRITE macro**
Lines 2–7 set up the IOPB for the _Write trap. Following the write, lines 9–12 check for errors and line 13 loads the byte count into D0.L if no error occurred. Note that it is not necessary to check for a shortened return on writes.

**SEEK**

The SEEK macro allows applications to access file data in any order. This macro requires the I/O reference number, an offset, and a sense word, which are placed in registers D0.W, D1.L, and D2.W, respectively. This macro is presented in Listing 8.60.

The run-time routine for the SEEK macro is XXSEEK, shown in Listing 8.61. Lines 1–7 set up the IOPB for the _SetFPos (set file position) trap.

```
1: XXWRITE SAVE          ; Save caller's registers
2: LEA IOPB(A5),A1       ; A1 -> Parameter block
3: MOVE.W D0,ioRefNum(A1); Store file reference number
4: MOVE.L D1,ioByteCount(A1); Store byte count
5: MOVE.L A0,ioBuffer(A1); and buffer address
6: CLR.W ioPosMode(A1);  ; Indicate sequential
7: MOVE.L A1,A0          ; A0 -> Parameter Block
8: Write                 ; Issue the write
9: LEA IOPB(A5),A0       ; A0 -> Parameter block again
10: MOVE.W ioResult(A0),D0; Fetch result code
11: EXT.L D0             ; Extend to long
12: BNE WriteDone        ; NE => Error, done
13: MOVE.L ioNumDone(A0),D0; No error, return actual byte count
14: WriteDone:           ; Here when done
15: RETURN               ; Restore the registers
```

**Listing 8.59** – The XXWRITE routine

```
1: MACRO SEEK ioref,offset,sense =
2: MOVEM.L D1-D2,-(SP)   ; Save input registers
3: MOVE.W {ioref},D0     ; Load ioref #
4: MOVE.L {offset},D1    ; Load offset
5: MOVE.W {sense},D2     ; and sense word
6: XREF XXSEEK           ; For the linker
7: JSR XXSEEK            ; Call RTL routine
8: MOVEM.L (SP)+,D1-D2   ; Restore input registers
```

**Listing 8.60** – The SEEK macro
Lines 5–6 translate the sense value from a UNIX-compatible to a Macintosh-compatible value. Lines 9–12 check for errors, and lines 13–15 fetch the resulting absolute seek value. This allows a single macro to both get and set the file position. Seeking 0 bytes from the current position returns the current position.

Deleting a File

The DELETE macro removes an existing file from a disk. This macro appears in Listing 8.62. It has two parameters: a file name address and a volume reference number. Register A0 receives the file name address, and register D1.W receives the volume reference number.

The run-time routine is called XXDELETE and is shown in Listing 8.63. This routine uses the Gopen volume scan routine described earlier. The TryDel routine is called by Gopen to attempt a delete. Lines 9–12 set up the IOPB for the _Delete trap at line 13. Lines 14–15 retrieve the return code and place it in D0.L.

Getting and Setting File Information

The GETFINFO and SETFINFO macros get and set the Macintosh file information. These macros use an 80-byte buffer, as described in Chapter 4.

```
1: XXSEEK: SAVE ; Seek on an open file
2: LEA IOPB(A5),A0 ; A1 -> Parameter block
3: MOVE.W D0,iоRefNum(A0) ; Store file reference number
4: MOVE.L D1,iоPosOffset(A0) ; Store offset
5: ANDI .W #3,D2 ; Insure proper range
6: MOVE.B SeekTab(D2),D2 ; Load seek table equivalent
7: MOVE.W D2,iоPosMode(A0) ; Set proper field
8: _SetFPos ; Do the set
9: LEA IOPB(A5),A0 ; A0 -> Parameter block
10: MOVE.W iоResult(A0),D0 ; Fetch error code
11: EXT.L D0 ; Out to long
12: BMI _GetFPos ; < 0 means error
13: _GetFPos ; Fetch new pointer
14: LEA IOPB(A5),A0 ; A0 -> Parameter block
15: MOVE.L iоPosOffset(A0),D0; Load return value
16: _SeekDone ; Here to return to caller
17: RETURN ; Restore caller's registers
18: SeekTab DC.B 1,3,2 ; Seek translation table
```

Listing 8.61 - The XXSEEK routine
**List 8.62 - The DELETE macro**

**GETFINFO**

The GETFINFO macro returns the file information for an existing file. This macro has three parameters: a file name address, the address of an 80-byte buffer, and a volume reference number. The volume reference number can be omitted. The GETFINFO macro definition appears in Listing 8.64.

Lines 3-4 place the file name address in register A0 and the buffer address in register A1. Lines 5-13 place the volume reference number in D1.W. This parameter can be omitted or set to the string DEFAULT, either

```
Listing 8.62 - The DELETE macro
```

```
Listing 8.63 - The XXDELETE routine
```

Listing 8.62 - The DELETE macro

Listing 8.63 - The XXDELETE routine
of which will place a zero in D1.W. The run-time routine is called XXGETF and is shown in Listing 8.65.

The XXGETF routine uses the Gopen code described in Listing 8.43. Gopen calls the label TryGetF at line 9 to attempt to get the information for a file. Lines 10-13 set up the IOPB for the _GetFilelnfo trap at line 14. A successful trap causes the code at lines 17-22 to move the entire 80-byte IOPB back to the application-specified buffer. The I/O reference number or error code is loaded into D0.W before return.

**SETFINFO**

The SETFINFO macro performs the inverse of GETINFO. The 80-byte file information area is associated with an existing file on the disk. A subsequent GETINFO will return the updated information. The SETFINFO macro appears in Listing 8.66.

This macro has the same parameters as the GETINFO macro: a file name address, a buffer address, and a volume number. Lines 2-4 place the file name address in register A0 and the buffer address in register A1. The volume reference number can be omitted or set to the string DEFAULT, either of which places a zero in D1.W. A nonblank volume reference number different from DEFAULT is placed in D1.W at line 9. The run-time routine is called XXSETF and appears in Listing 8.67.

Lines 2-6 move the 80-byte area into the IOPB in the run-time library data area. Line 7 places the file name address into the IOPB in preparation for the _SetFilelnfo trap at line 10. Lines 11-13 return to the application.
1: XXGETF: ; Entry point
2: SAVE ; Save caller's registers
3: LEA TryGetF,A6 ; Do volume scan for file
4: MOVE.L Al,FileBuf(A5) ; Save Al in global area
5: BRA Gopen ; Do general open stuff
6: ;
7: ; TryGetF routine. Attempts to get file info for file.
8: ;
9: TryGetF: ;
10: MOVE.L AO,iOPB+ioFileName(A5); Stuff file name
11: LEA iOPB(A5),AO ; AO -> iOPB now
12: MOVE.W Dl,ioVRefNum(AO); Clear vol ref field
13: CLR.W ioFDirIndex(AO); Clear directory index field
14: GetFileInfo ; Try it
15: MOVE.W ioResult(AO),DO ; Error?
16: BNE GETNFG ; Yes, return error
17: MOVE.W #ioFQElSize-1,DO; Load count
18: LEA iOPB(A5),A2 ; A2 -> iOPB
19: MOVE.L FileBuf(A5),Al ; Al -> User's buffer
20: GetMove: ; Move it in
21: MOVE.B (A2)+,(Al)+ ; Stuff a byte
22: DBRA DO,GetMove ; Until done
23: MOVE.W ioRefNum(AO),DO ; Load ref number
24: GETNFG: RTS ; and bail out

Listing 8.65 - The XXGETF routine

1: .MACRO SETINFO ; filename,buffer,volref = 2: MOVE.L AO/Al/Dl, -(SP) ; Save registers 3: LEA %1, AO ; AO -> File name 4: LEA %2, Al ; Al -> Buffer area 5: IF '%3' <> ' ' ; Vol ref specified? 6: IF '%3' = 'DEFAULT' 7: CLR.W Dl ; Do vol scan 8: ELSE ; Don't 9: MOVE.W %3,Dl ; Do specific vol 10: ENDF ; DEFAULT 11: ELSE ; 12: CLR.W Dl ; Not specified 13: ENDF ; Specified 14: XREF XXXSETF ; RTL routine name 15: JSR XXXSETF ; Call RTL 16: MOVE.L (SP)+,AO/Al/Dl ; Restore registers 17: .ENDM

Listing 8.66 - The SETINFO macro
### Listing 8.67 – The XXSETF routine

```assembly
1: XXSETF: SAVE ; Save registers
2: LEA IOPB(A5),A2 ; A2 -> IOPB
3: MOVE.W #ioPQSize-1,DO; D0 = Count
4: SetMove: ; Move parameters back
5: MOVE.B (A1)+,(A2)+ ; Move a byte
6: DBRA DO,SetMove ; Loop till done
7: MOVE.L AO,IOPB+ioFileName(A5); Stuff file name
8: LEA IOPB(A5),AO ; AO -> IOPB now
9: MOVE.W D1,ioVRefNum(AO); Set volume reference number
10: _SetFileInfo ; Try it
11: MOVE.W ioResult(AO),DO ; Get result code
12: EXT.L DO ; Extend to long
13: RETURN ; and bail out
```

### MENU ROUTINES

The run-time library supports several routines that assist the application in handling Macintosh menus:

1. The CHECK and UNCHECK macros indicate which items in a menu are currently active.
2. The ENABLE and DISABLE macros dynamically control whether an item in a menu can be selected.
3. The STYLE macro sets the type style of a menu item.

Each of these routines will now be described in detail.

### CHECK and UNCHECK

The source for the CHECK and UNCHECK macros appears in Listing 8.68. Each of these macros has two parameters: a menu resource ID and an item number. These are placed in D0.W and D1.W, respectively.

The run-time routines are XXCHECK and XXUNCHECK; these appear in Listing 8.69. Lines 4–5 and 8 place the appropriate character in register D2. A check mark has a value of 12 hex, and a zero value causes the check mark to be erased. Lines 9–13 perform a _GetResource call to return the menu handle for the menu ID passed in D0.W. Lines 15–17
Listing 8.68 – The CHECK and UNCHECK macros

Listing 8.69 – The XXCHECK and XXUNCHECK routines

perform a _SetI.tmMark call, which requires the menu handle, item number, and mark character as parameters. The mark character is placed in front of the menu selection. Note that the return value from _GetResource is simply left on the stack to serve as a parameter to _SetI.tmMark.
The following characters are legal in a _SetItemMark call:

<table>
<thead>
<tr>
<th>Value (hex)</th>
<th>Character</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Blank, removes any existing mark</td>
</tr>
<tr>
<td>11</td>
<td>Command key symbol</td>
</tr>
<tr>
<td>12</td>
<td>Check mark</td>
</tr>
<tr>
<td>13</td>
<td>Diamond symbol</td>
</tr>
<tr>
<td>14</td>
<td>Apple symbol</td>
</tr>
</tbody>
</table>

**ENABLE and DISABLE**

The ENABLE and DISABLE macros are similar to CHECK and UNCHECK. Listing 8.70 contains the ENABLE and DISABLE macro definitions. The parameters are the same as for CHECK and UNCHECK: a menu resource ID and an item number. These are loaded into D0.W and D1.W, respectively.

The run-time routines are XXENABLE and XXDISABLE, shown in Listing 8.71. Register D3.W is used as a flag to indicate whether an ENABLE or DISABLE operation is in progress. This flag is set to 1 for ENABLE and 0 for DISABLE. Lines 10–14 call _GetResource to get the menu handle, which is left on the stack to serve as a parameter to the next system call. Lines 15–22 execute either an _EnableItem or _DisableItem system call to complete the operation.

```
1: .MACRO ENABLE
2:     MOVEM.L DO-D1,-(SP) ; Push registers
3:     MOVE.W %1,DO       ; Menu to DO
4:     MOVE.W %2,D1       ; Item to D1
5:     XREF XXENABLE      ; For the linker
6:     JSR XXENABLE       ; Call RTL
7:     MOVEM.L (SP)+,DO-D1; Restore registers
8:     .ENDM
9: 
10: .MACRO DISABLE
11:    MOVEM.L DO-D1,-(SP) ; Push registers
12:    MOVE.W %1,DO       ; Menu to DO
13:    MOVE.W %2,D1       ; Item to D1
14:    XREF XXDISABLE     ; For the linker
15:    JSR XXDISABLE      ; Call RTL
16:    MOVEM.L (SP)+,DO-D1; Restore registers
17:    .ENDM
```

**Listing 8.70 - The ENABLE and DISABLE macros**
**STYLE**

The STYLE macro sets the style of the text in a menu selection. The macro definition appears in Listing 8.72. This macro has three parameters: a menu resource ID, an item number, and a style word. These are placed in registers D0.W, D1.W, and D2.W, respectively. The style word is explained in Chapter 6.

Listing 8.71 – The XXENABLE and XXDISABLE routines

```
1:   XDEF XXENABLE ; For the linker
2:   XDEF XXDISABLE ; Enable entry point
3:   XXENABLE ; Enable registers
4:   MOVE.W #1,D3 ; Set flag register
5:   BRA XXENDIS ; Branch around disable entry
6:   XXDISABLE ; Here to disable
7:   SAVE ; Save registers
8:   CLR.W D3 ; Clear flag register
9:   XXENDIS ; Here to disable
10:  MOVE.W D1,D4 ; Preserve item number
11:  CLR.L -(SP) ; Room for handle return
12:  MOVE.L #'MENU'-(SP) ; Resource type
13:  MOVE.W D0,-(SP) ; Resource ID
14:  GetResource ; Read resource into memory
15:  MOVE.W D4,-(SP) ; Push item number
16:  TST.W D3 ; Enable?
17:  BEQ DoDisable ; No, disable
18:  EnableItem ; Do the enable
19:  RETURN ; Back to caller
20:  DoDisable ; Here to disable
21: _DisableItem ; Disable it
22:  RETURN ; Back to caller
```

Listing 8.72 – The STYLE macro

```
1:   .MACRO STYLE
2:   MOVEM.L DO-D2,-(SP) ; Push registers
3:   MOVE.W $1,D0 ; Menu to D0
4:   MOVE.W $2,D1 ; Item to D1
5:   MOVE.W $3,D2 ; Style word to D2
6:   XREF XXSTYLE ; For the linker
7:   JSR XXSTYLE ; Call RTL
8:   MOVEM.L (SP)+,DO-D2 ; Restore registers
9:   .ENDM
```
The run-time routine is XXSTYLE and appears in Listing 8.73. Lines 5–9 perform a _GetResource call to return the menu handle on the stack. This handle is the first parameter to the _SetItmStyle call at line 13. Other parameters are the item number and style word.

**MISCELLANEOUS RUN-TIME LIBRARY ROUTINES**

There are three routines that do not fall into any of the categories previously explained:

1. The EXIT routine, which returns to the Finder
2. The QUIT routine, which exits after a Quit menu choice
3. The WTITLE routine, which sets the window title

**EXIT**

The EXIT macro definition appears in Listing 8.74. It is a simple jump to the run-time routine XXEXIT. The XXEXIT code appears in Listing 8.75.

Line 1 calls the DoFlush routine to ensure that all disk data in memory are written to disk before exiting. Lines 2–3 retrieve the original stack pointer and the return address for the Finder. The JMP instruction at line 4 terminates the program.

The DoFlush routine at line 9 traverses the volume control block list in a manner similar to the Gopen routine used to search all mounted disks.

```assembly
1: XDEF XXSTYLE ; For the linker
2: XXSTYLE ;
3: SAVE ;
4: MOVE.W D1,D3 ; Save registers
5: MOVE.W D2,D4 ; Preserve item number
6: CLR.L -(SP) ; and style word
7: MOVE.L #'MENU',-(SP) ; Result area
8: MOVE.W DO,-(SP) ; Specify resource type
9: _GetResource ; Convert
10: _ ;
11: MOVE.W D3,-(SP) ; to handle (SP)
12: MOVE.W D4,-(SP) ;
13: _SetItmStyle ;
14: RETURN ;
```

*Listing 8.73 - The XXSTYLE routine*
Listing 8.74 – The EXIT macro

```
1:   MACRO   EXIT  =
2:    XREF   XXEXIT  ; For linker
3:    JMP   XXEXIT  ; Call RTL exit routine
```

### Listing 8.75 – The XXEXIT routine

```assembly
1:   XXEXIT:  BSR   DoFlush  ; Flush vols first
2:    MOVE.L  EXITAddr(A5),AO  ; AO -> Exit routine
3:    MOVE.L  ORGSP(A5),SP  ; Take stack to original
4:    JMP  (AO)  ; Quit
5:    ;
6:    ;   DoFlush routine. Flushes all volumes.
7:    ;
8:    ;
9:    DoFlush  MOVE.L  VCBQHdr+2,A3  ; A3 -> VCB entry
10:  EVScan:  TST.W  VCBDrvNum(A3)  ; Is volume on line?
11:  BEQ  ENextV  ; No, get next
12:  LEA  IOPB(A5),AO  ; AO -> I/O parameter block
13:  MOVE.L  VCBVN(A3),ioVNPtr(AO); Set volume name
14:  CLR.W  ioVDrvNum(AO)  ; Specify no drive number
15:  _FlushVol  ; Flush the volume
16:  ENextV:  
17:  MOVE.L  (A3),A3  ; A3 -> Next in chain
18:  MOVE.L  A3,D1  ; Move to D reg
19:  BNE  EVScan  ; Try again
20:  RTS  ; Back to caller
```

The `_FlushVol` call at line 15 uses an IOPB, which contains the volume name address. The address of volume name in the volume control block is specified in line 13. This routine is also called by the XXCLOSE routine in Listing 8.54.

### QUIT

The QUIT macro is shown in Listing 8.76. This macro issues a GETEVENT call and checks the return for the first selection from the second (File) menu. If GETEVENT returns anything other than this event, the macro simply calls GETEVENT again. When the user selects Quit, the macro issues an EXIT call.
Listing 8.76 - The QUIT macro

Note that this macro is useful only if the File menu contains Quit as its first choice. This is the case only for simple programs, such as those contained in Chapter 4.

WTITLE

The WTITLE macro (Listing 8.77) changes the title in the current application window. The macro loads the address of the new title string into register A0 and calls the run-time routine XXWTITLE (Listing 8.78). The _SetWTitle trap at line 6 of the XXWTITLE routine takes the window address and title string as parameters.

SUMMARY

The code in this chapter illustrates a methodology for reducing the complexity of writing a Macintosh application. It simplifies the use of the most common functions, at the expense of program flexibility.

You have seen how to write code that you can reuse with each new program you write, as well as how to add a macro library interface that
makes using this code simpler. Programming effort can be measured in terms of the number of lines of code you have to write. Since you can treat the macro calls as a single line of code, they represent a considerable reduction in length and complexity over the 40–60 lines that some of them actually take.

In addition, the event system (the GETEVENT macro) standardizes a large amount of code that every Macintosh application must contain. Code that relates to other windows on the screen, such as desk accessories, is completely isolated in the run-time library. Menu selection is considerably less complicated, as are window sizing and window positioning. Scrolling and window closing are also aided, though to a lesser extent.

There is considerable room for expansion. For instance, scrolling and sizing could be made to work on text windows, and multiwindow capability could be added. See the exercises for more information.

EXERCISES

1. There is a system trap called _ExitToShell, which takes no parameters. Executing this trap causes a return to the Finder. Modify the initialization code in Listing 8.2 to specify a restart procedure that calls the _ExitToShell trap.

2. Modify the PRINT macro so that only one call is made to the run-time library.

3. Write the MoveCnt routine.

4. Modify the menu routines to call a common subroutine that issues the _GetResource call.

5. Write the routines from Table 8.2 that are not shown in Listing 8.20.
The following are research projects, meaning that the effort involved is not trivial and that the answers are not in the back of the book:

6. Implement scrolling and sizing for text windows. This means that you should not delete the lines scrolled off the top of the window, but allow the user to scroll back through them, if desired.

7. Redesign the library macros to allow the use of multiple application windows. Include support for opening and closing windows. (You’ll need a copy of Inside Macintosh for this one.)

8. Modify the library so that it can be used with your favorite language compiler.
Answers to Exercises

Problems are the price of progress.
—Charles Kettering

This appendix gives the answers to the Exercise questions found at the end of each chapter.

CHAPTER 1

1. There are many correct solutions to this question. Here is one:

   1. Select the highest place value from the table that will divide into the number to be converted. Let the converted number be the initial remainder.
   2. Calculate the new quotient and remainder when the current remainder is divided by the present table entry.
   3. If place value table entries remain, repeat step 2 with the next table entry and the remainder just calculated.
   4. Read the answer as the successive quotients.

2. The flowchart for the above would look like Figure A.1.

3. The machine language program would look like Table A.1. You must load the contents of location 105 first because the difference to be computed is (location 105 – location 104). The subtraction
instruction works by subtracting memory from the register. Therefore, you must have the contents of location 105 in the register to perform the subtraction operation.

Figure A.1 - Flowchart for Exercise 2
4. Moving to location 200 yields the results in Table A.2.

5. This is the assembly language version:

LOAD A,Y
SUB A,X
STORE A,Z
STOP

X: DC 300
Y: DC 400
Z: DC 0

<table>
<thead>
<tr>
<th>Location</th>
<th>Contents</th>
<th>Instruction</th>
</tr>
</thead>
<tbody>
<tr>
<td>200</td>
<td>1205</td>
<td>Load A from location 205</td>
</tr>
<tr>
<td>201</td>
<td>5204</td>
<td>Subtract location 204</td>
</tr>
<tr>
<td>202</td>
<td>3206</td>
<td>Store into location 206</td>
</tr>
<tr>
<td>204</td>
<td>0300</td>
<td>&lt;Data&gt;</td>
</tr>
<tr>
<td>205</td>
<td>0400</td>
<td>&lt;Data&gt;</td>
</tr>
<tr>
<td>206</td>
<td>0000</td>
<td>&lt;Data&gt;</td>
</tr>
</tbody>
</table>

**Table A.1 – Machine Language Program at Location 100**

<table>
<thead>
<tr>
<th>Location</th>
<th>Contents</th>
<th>Instruction</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>1105</td>
<td>Load A from location 105</td>
</tr>
<tr>
<td>101</td>
<td>5104</td>
<td>Subtract location 104</td>
</tr>
<tr>
<td>102</td>
<td>3106</td>
<td>Store into location 106</td>
</tr>
<tr>
<td>104</td>
<td>0300</td>
<td>&lt;Data&gt;</td>
</tr>
<tr>
<td>105</td>
<td>0400</td>
<td>&lt;Data&gt;</td>
</tr>
<tr>
<td>106</td>
<td>0000</td>
<td>&lt;Data&gt;</td>
</tr>
</tbody>
</table>

**Table A.2 – Machine Language Program at Location 200**
6. To add the first five integers, a modified version of the previous program will work:

```
LOAD A,A
ADD A,B
ADD A,C
ADD A,D
ADD A,E
STORE A,F
STOP
```

A: DC 1
B: DC 2
C: DC 3
D: DC 4
E: DC 5
F: DC 0

7. Conversion to hex and binary is shown in Table A.3.

8. Conversion to binary and decimal is shown in Table A.4.

<table>
<thead>
<tr>
<th>Decimal</th>
<th>Hex</th>
<th>Binary</th>
</tr>
</thead>
<tbody>
<tr>
<td>273</td>
<td>111</td>
<td>0001 0001 0001</td>
</tr>
<tr>
<td>421</td>
<td>1A5</td>
<td>0001 1010 0101</td>
</tr>
<tr>
<td>1024</td>
<td>400</td>
<td>0100 0000 0000</td>
</tr>
<tr>
<td>100</td>
<td>64</td>
<td>0000 0110 0100</td>
</tr>
</tbody>
</table>

Table A.3 – Conversion to Hex and Binary

<table>
<thead>
<tr>
<th>Hex</th>
<th>Binary</th>
<th>Decimal</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABE</td>
<td>0000 1010 1011 1110</td>
<td>2750</td>
</tr>
<tr>
<td>100</td>
<td>0000 0001 0000 0000</td>
<td>256</td>
</tr>
<tr>
<td>64</td>
<td>0000 0000 0110 0100</td>
<td>100</td>
</tr>
<tr>
<td>1024</td>
<td>0001 0000 0010 0100</td>
<td>4132</td>
</tr>
<tr>
<td>505</td>
<td>0000 0101 0000 0101</td>
<td>1285</td>
</tr>
</tbody>
</table>

Table A.4 – Conversion to Binary and Decimal
9. Complements are shown in Table A.5.

10. Binary operations are shown in Table A.6.

11. Shift and Rotate Tables:

Logical Shifts

<table>
<thead>
<tr>
<th>Times</th>
<th>Left</th>
<th>Right</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1111 1111 (FF hex)</td>
<td>1111 1111 (FF hex)</td>
</tr>
<tr>
<td>1</td>
<td>1111 1110 (FE hex)</td>
<td>0111 1111 (7F hex)</td>
</tr>
<tr>
<td>2</td>
<td>1111 1100 (FC hex)</td>
<td>0011 1111 (3F hex)</td>
</tr>
<tr>
<td>3</td>
<td>1111 1000 (F8 hex)</td>
<td>0001 1111 (1F hex)</td>
</tr>
<tr>
<td>4</td>
<td>1111 0000 (F0 hex)</td>
<td>0000 1111 (0F hex)</td>
</tr>
<tr>
<td>5</td>
<td>1110 0000 (E0 hex)</td>
<td>0000 0111 (07 hex)</td>
</tr>
<tr>
<td>6</td>
<td>1100 0000 (C0 hex)</td>
<td>0000 0011 (03 hex)</td>
</tr>
<tr>
<td>7</td>
<td>1000 0000 (80 hex)</td>
<td>0000 0001 (01 hex)</td>
</tr>
<tr>
<td>8</td>
<td>0000 0000 (00 hex)</td>
<td>0000 0000 (00 hex)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Number</th>
<th>One's Complement</th>
<th>Two's Complement</th>
</tr>
</thead>
<tbody>
<tr>
<td>0ABE</td>
<td>F541</td>
<td>F542</td>
</tr>
<tr>
<td>0100</td>
<td>FEFF</td>
<td>FF00</td>
</tr>
<tr>
<td>0064</td>
<td>FF9B</td>
<td>FF9C</td>
</tr>
<tr>
<td>1024</td>
<td>EFDB</td>
<td>EFDC</td>
</tr>
<tr>
<td>0505</td>
<td>FAFA</td>
<td>FAFB</td>
</tr>
</tbody>
</table>

Table A.5 – Complements

<table>
<thead>
<tr>
<th>Number</th>
<th>Pair</th>
<th>AND</th>
<th>OR</th>
<th>XOR</th>
<th>ADD</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>A5A5</td>
<td>5A5A</td>
<td>0000</td>
<td>FFFF</td>
<td>FFFF</td>
<td>FFFF</td>
<td>0</td>
</tr>
<tr>
<td>FFFF</td>
<td>0001</td>
<td>0001</td>
<td>FFFF</td>
<td>FFFE</td>
<td>0000</td>
<td>1</td>
</tr>
<tr>
<td>1234</td>
<td>4321</td>
<td>0220</td>
<td>5335</td>
<td>5115</td>
<td>5555</td>
<td>0</td>
</tr>
</tbody>
</table>

Table A.6 – Binary Operations
<table>
<thead>
<tr>
<th>Times</th>
<th>Left</th>
<th>Right</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0101 0101 (55 hex)</td>
<td>0101 0101 (55 hex)</td>
</tr>
<tr>
<td>1</td>
<td>1010 1010 (AA hex)</td>
<td>0010 1010 (2A hex)</td>
</tr>
<tr>
<td>2</td>
<td>0101 0100 (54 hex)</td>
<td>0001 0101 (15 hex)</td>
</tr>
<tr>
<td>3</td>
<td>1010 1000 (A8 hex)</td>
<td>0000 1010 (0A hex)</td>
</tr>
<tr>
<td>4</td>
<td>0101 0000 (50 hex)</td>
<td>0000 0101 (05 hex)</td>
</tr>
<tr>
<td>5</td>
<td>1010 0000 (A0 hex)</td>
<td>0000 0010 (02 hex)</td>
</tr>
<tr>
<td>6</td>
<td>0100 0000 (40 hex)</td>
<td>0000 0001 (01 hex)</td>
</tr>
<tr>
<td>7</td>
<td>1000 0000 (80 hex)</td>
<td>0000 0000 (00 hex)</td>
</tr>
<tr>
<td>8</td>
<td>0000 0000 (00 hex)</td>
<td>0000 0000 (00 hex)</td>
</tr>
</tbody>
</table>

Arithmetic Shifts

<table>
<thead>
<tr>
<th>Times</th>
<th>Left</th>
<th>Right</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1111 1111 (FF hex)</td>
<td>1111 1111 (FF hex)</td>
</tr>
<tr>
<td>1</td>
<td>1111 1110 (FE hex)</td>
<td>1111 1111 (FF hex)</td>
</tr>
<tr>
<td>2</td>
<td>1111 1100 (FC hex)</td>
<td>1111 1111 (FF hex)</td>
</tr>
<tr>
<td>3</td>
<td>1111 1000 (F8 hex)</td>
<td>1111 1111 (FF hex)</td>
</tr>
<tr>
<td>4</td>
<td>1111 0000 (F0 hex)</td>
<td>1111 1111 (FF hex)</td>
</tr>
<tr>
<td>5</td>
<td>1110 0000 (E0 hex)</td>
<td>1111 1111 (FF hex)</td>
</tr>
<tr>
<td>6</td>
<td>1100 0000 (C0 hex)</td>
<td>1111 1111 (FF hex)</td>
</tr>
<tr>
<td>7</td>
<td>1000 0000 (80 hex)</td>
<td>1111 1111 (FF hex)</td>
</tr>
<tr>
<td>8</td>
<td>0000 0000 (00 hex)</td>
<td>1111 1111 (FF hex)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Times</th>
<th>Left</th>
<th>Right</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0101 0101 (55 hex)</td>
<td>0101 0101 (55 hex)</td>
</tr>
<tr>
<td>1</td>
<td>1010 1010 (AA hex)</td>
<td>0010 1010 (2A hex)</td>
</tr>
<tr>
<td>2</td>
<td>0101 0100 (54 hex)</td>
<td>0001 0101 (15 hex)</td>
</tr>
<tr>
<td>3</td>
<td>1010 1000 (A8 hex)</td>
<td>0000 1010 (0A hex)</td>
</tr>
<tr>
<td>4</td>
<td>0101 0000 (50 hex)</td>
<td>0000 0101 (05 hex)</td>
</tr>
<tr>
<td>5</td>
<td>1010 0000 (A0 hex)</td>
<td>0000 0010 (02 hex)</td>
</tr>
<tr>
<td>6</td>
<td>0100 0000 (40 hex)</td>
<td>0000 0001 (01 hex)</td>
</tr>
<tr>
<td>7</td>
<td>1000 0000 (80 hex)</td>
<td>0000 0000 (00 hex)</td>
</tr>
<tr>
<td>8</td>
<td>0000 0000 (00 hex)</td>
<td>0000 0000 (00 hex)</td>
</tr>
</tbody>
</table>

Rotates

<table>
<thead>
<tr>
<th>Times</th>
<th>C</th>
<th>Left</th>
<th>Right</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>1111 1111 (FF hex)</td>
<td>1111 1111 0 (FF hex)</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>1111 1110 (FE hex)</td>
<td>0111 1111 1 (7F hex)</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>1111 1101 (FD hex)</td>
<td>1011 1111 1 (BF hex)</td>
<td></td>
</tr>
</tbody>
</table>
3  1 1111 1011 (FB hex)  1101 1111 1 (DF hex)
4  1 1111 0111 (F7 hex)  1110 1111 1 (EF hex)
5  1 1110 1111 (EF hex)  1111 0111 1 (F7 hex)
6  1 1101 1111 (DF hex)  1111 1011 1 (FB hex)
7  1 1011 1111 (BF hex)  1111 1101 1 (FD hex)
8  1 0111 1111 (7F hex)  1111 1110 1 (FE hex)
9  0 1111 1111 (FF hex)  1111 1111 0 (FF hex)

<table>
<thead>
<tr>
<th>Times</th>
<th>C</th>
<th>Left</th>
<th>Right</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0101 0101 (55 hex)</td>
<td>0101 0101 0 (55 hex)</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>0100 1010 (AA hex)</td>
<td>0010 1010 1 (2A hex)</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>0101 0100 (54 hex)</td>
<td>1001 0101 0 (95 hex)</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>0</td>
<td>0100 1001 (A9 hex)</td>
<td>0100 1010 1 (4A hex)</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>0101 0010 (52 hex)</td>
<td>1010 0101 0 (A5 hex)</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>0</td>
<td>0100 1010 (4A hex)</td>
<td>0101 0010 1 (52 hex)</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>1</td>
<td>0100 1001 (95 hex)</td>
<td>1010 1001 0 (AA hex)</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>0</td>
<td>0010 1010 (2A hex)</td>
<td>1010 1010 0 (AA hex)</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>0</td>
<td>0101 0101 (55 hex)</td>
<td>0101 0101 0 (55 hex)</td>
<td></td>
</tr>
</tbody>
</table>

CHAPTER 2

1. The instructions would result in this illegal instruction:

   MOVE.B D0,A0

   This instruction is illegal because address registers can only be accessed as words or longwords. Give yourself extra points if you knew that an illegal-instruction exception would occur.

   MOVE.W D0,A0

   This instruction causes the contents of register A0 to become FFFF8000. Remember that word moves to an address register cause sign extension.

   MOVE.B D0,(A0) +

   The byte at location 1000 becomes 0. Register A0 becomes 1001.

   MOVE.B D0, -(A7)
The byte at memory location 10000 becomes 0. The contents of register A7 become FFFE. Remember that A7 is the hardware stack pointer and is incremented or decremented by 2 in byte operations.

2. These are the instructions as modified:

<table>
<thead>
<tr>
<th>Instruction</th>
<th>Hex</th>
<th>Changes</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADD.L D1,D0</td>
<td>D081</td>
<td>D0= 01234566</td>
</tr>
<tr>
<td>ADD.L A1,D0</td>
<td>D089</td>
<td>D0= 01234566</td>
</tr>
<tr>
<td>ADD.L (A1),D0</td>
<td>D091</td>
<td>D0= 01234566</td>
</tr>
<tr>
<td>ADD.L (A1)+,D0</td>
<td>D099</td>
<td>D0= 01234566</td>
</tr>
<tr>
<td>ADD.L -(A1),D0</td>
<td>D0A1</td>
<td>D0= 01234566</td>
</tr>
<tr>
<td>ADD.L 4(A1),D0</td>
<td>D0A9</td>
<td>D0= 01234566</td>
</tr>
<tr>
<td>ADD.L 4(A1,A2.L),D0</td>
<td>D0B1</td>
<td>D0= 01234566</td>
</tr>
<tr>
<td>ADD.L $1000,D0</td>
<td>D0B8</td>
<td>D0= 01234566</td>
</tr>
<tr>
<td>ADD.L $10000,D0</td>
<td>D0B9</td>
<td>D0= 01234566</td>
</tr>
<tr>
<td>ADD.L $100(PC),D0</td>
<td>D0BA</td>
<td>D0= 01234566</td>
</tr>
<tr>
<td>ADD.L $10(PC,A1.L)</td>
<td>D0BB</td>
<td>D0= 01234566</td>
</tr>
<tr>
<td>ADD.L #$10002000,D0</td>
<td>D0BC</td>
<td>D0= 11234566</td>
</tr>
</tbody>
</table>

3. The pre-decrement and post-increment modes can be used to implement a stack as follows:

PUSH operation is MOVE.s xxx,(An)+
POP operation is MOVE.s −(An),xxx

The difference between this technique and a stack that grows toward lower addresses is that the address register no longer contains the address of the top item of the stack. Instead, the register points to the next stack location to be used. By changing the addressing modes to pre-increment and post-decrement (+ (An) and (An)−), the stacking would be equivalent to the present technique.

CHAPTER 3

1–2. There aren’t any answers back here. Either you can use your system or you can’t. If you can’t, you should first learn how. The basic mechanical steps are essential, and you will learn to program faster if you can do the mechanics well.
3. The ADDX and SUBX instructions perform arithmetic on multiple memory locations. You must start with the least significant digit in doing arithmetic. Comparisons, however, must be done starting with the most significant digit.

4. The RTE instruction reloads the status register (SR). This changes the trace bit in the status register. Normally, the trace bit is cleared by an RTE instruction. This prevents the instruction from being traced and causes the debugger to lose control. Other instructions that can clear the trace bit will have the same effect: MOVE to SR, ANDI to SR, and EORI to SR.

**CHAPTER 4**

1. The long division routine is shown in Listing A.1. Handling negative numbers is not required for the next question. The disadvantage to

```
1: ;
2: ; 32-bit division routine
3: ; Enter with:
4: ; DO.L = dividend
5: ; DL.L = divisor
6: ; Exit with:
7: ; DO.L = quotient
8: ; DL.L = remainder
9: ;
10: ; XDEF LDiv
11: LDiv MOVEM.L D2-D3,-(SP) ; Save some working registers
12: CLR.L D2 ; Temporary quotient
13: CLR.L D3 ; Sign flag
14: TST.L DO ; Dividend > 0?
15: BGE @1 ; Yes
16: NBG.L DO ; Force positive
17: ADDQ.L #1,D3 ; Increment sign flag
18: @1 TST.L D1 ; Divisor > 0?
19: BGE @2 ; Yes
20: NBG.L DL ; Force positive
21: ADDQ.L #1,D3 ; Increment sign flag
22: @2 CMP.L DO,D1 ; Dividend : divisor
23: BTQ @3 ; If divisor > dividend, done
24: SUB.L DL,DO ; Subtract divisor from dividend
25: ADDQ.L #1,D2 ; Increment quotient
26: BRA @2 ; Loop till done
27: @3 BTST #0,D3 ; Need negative quotient?
28: BBQ @4 ; No, both positive
29: NBG.L D2 ; Negate quotient
30: NBG.L DO ; Negate remainder
31: @4 MOVE.L DO,D1 ; This is remainder
32: MOVE.L D2,DO ; This is quotient
33: MOVEM.L (SP)+,D2-D3 ; Restore working registers
34: RTS ; Return to caller
```

**Listing A.1 - The LDIV routine**
doing division in this manner is the excessive amount of time required to divide a very large number by a very small one. It can take several minutes for a single division operation.

2. The modified binary-to-decimal ASCII-conversion routine is shown in Listing A.2.

Listing A.3 illustrates the use of a divisor table in converting binary to decimal. This is the conventional method and is much faster than the algorithm in Listing A.2.

```
1; BinDec routine. Converts binary to decimal ASCII.
3; Enter with:
5; DO.W = Number to convert
7; AO.L -> 10-byte output area
9; XDEF BinDec
10; XREF LDiv
11; BinDec: MOVEM.L DO-D2/AO,-(SP) ; Preserve registers
12; MOVE.B #',,D1 ; Assume positive number
13; TST.L DO ; Is number negative?
14; BPL NotNeg ; No, use ' ' sign
15; BPL NotNeg ; Number is negative, use '-'
16; MOVE.B #',,D1 ; Force positive
17; NotNeg: MOVE.B D1,(AO)+ ; Put sign in buffer
18; ADDA.L #9,A0 ; AO -> 1 beyond last digit
19; MOVE.W #8,D2 ; DBRA-adjusted loop count
20; Loop: MOVE.L #10,D1 ; Set quotient
21; JSR LDiv ; Divide by 10
22; MOVM.W D1,-(AO) ; Put in buffer (0-9 binary)
23; ADD.B #0',,(AO) ; Add ASCII offset (0-9 ASCII)
24; DBRA D2,Loop ; Do all digits
25; MOVM.L (SP)+,DO-D2/AO ; Restore registers
26; RTS ; Return to caller
```

Listing A.2 - Modified BinDec routine

```
1; BinDec routine. Converts binary to decimal ASCII.
3; Enter with:
5; DO.W = Number to convert
```

Listing A.3 - The BinDec routine using a divisor table (continued)
Answers to Exercises 555

7: ; \[A0.L \rightarrow 10\text{-byte output area}\]

8: ;

9: XDEF BinDec

10: BinDec MOVEM.L DO-D3/A0-Al,-(SP); Preserve registers

11: MOVE.W #9,D2 ; Loop count

12: LEA DivTab,Al ; Al \rightarrow Table of divisors

13: CLR.L D3 ; Assume positive number

14: TST.L D0 ; Is number negative?

15: BPL @1 ; No

16: SUBQ.L #1,D3 ; Number is negative, use '-'

17: NEG.L D0 ; Force positive

18: SUBQ.W #1,D2 ; Down count

19: ADDQ.L #4,A1 ; Al \rightarrow Next divisor

20: MOVE.B #'',(A0)+ ; Clobber first byte of output area

21: @1 CMP.L (A1)+,D0 ; Number too big?

22: BHI Stars ; Yes, fill with asterisks

23: @2 CMP.L (A1)+,D0 ; Find

24: @3 SUBQ.L #4,Al ; first digit

25: MOVE.B #'',(A0)+ ; Space fill

26: DBRA 02,@2 ; Loop till done

27: CMP.L (A1)+,D0 ; Zero is special case

28: BRA DoRet ; Done

29: @3 SUBQ.L #4,A1 ; Al \rightarrow First divisor

30: TST.L D3 ; Negative?

31: EQ B2 ;

32: MOVE.B #'\-',-1(A0) ; Set sign

33: @4 CLR.L D3 ; Clear divisor

34: @5 CMP.L (A1),D0 ; Compare divisor to dividend

35: BLT @6 ; Done with this one

36: SUB.L (A1),D0 ; Subtract

37: ADDQ.L #1,D3 ; Increment quotient

38: @6 BRA @5 ; Loop till done

39: @6 ADDQ.L #4,A1 ; Al \rightarrow Next divisor

40: MOVE.B D3,(A0) ; Set digit

41: ADD.B #'0',(A0)+ ;

42: DBRA D2,@4 ; Loop till done

43: BRA DoRet ; Done

44: Stars ; Here if number too big

45: @1 MOVE.B '#**',(A0)+ ; Fill with asterisks

46: DBRA D2,@1

47: DoRet MOVEM.L (SP)+,DO-D3/A0-Al; Restore registers

48: RTS ; Return

49: DivTab DC.L 10000000000 ; First number too large

50: ; Highest value allowed

51: DC.L 10000000000

52: DC.L 1000000000

53: DC.L 10000000

54: DC.L 100000

55: DC.L 10000

56: DC.L 1000

57: DC.L 100

58: DC.L 10

59: DC.L 1

Listing A.3 – The BinDec routine using a divisor table
3. The finished conversion program looks like Listing A.4. Notice that the only change required is the expansion of the size of the decimal output conversion area.

4. The hex conversion routine looks like Listing A.5. A slightly tricky piece of code to yield the proper binary nibble uses register D1 as the factor to be subtracted from the ASCII byte.

5. The program for converting hex to decimal can be derived from the earlier solution for converting the longword decimal to hex, as shown in Listing A.6.


---

**Listing A.4** – The modified DecHex program

```assembly
1: DecHex program. This program converts decimal numbers
2: to hex. Numbers are input from the keyboard and output
3: to the screen.
4: 
5: Include MACLIB.ASM
6: XREF BinHex ; Hex output conversion
7: XREF BinDec ; Decimal output conversion
8: XREF DecBin ; Decimal input conversion
9: 
10: PROGRAM DecHex
11: Loop: PRINT 'Enter Decimal Number: ',$ ; Prompt for input
12: INPUT InBuff(A5) ; Get a line of input
13: TST.B InBuff(A5) ; Check for null line
14: BEQ Done If null, quit
15: LEA InBuff+1(A5),AO ; AO -> Digits input
16: JSR DecBin ; Convert to binary
17: LEA DecBuf,AO ; AO -> Decimal output area
18: JSR BinDec ; Convert to decimal ASCII
19: LEA HexBuf,AO ; AO -> Hex output area
20: JSR BinHex ; Convert to hex ASCII
21: PRINT OutLine ; Type the answer
22: BRA Loop ; Do it again
23: Done: EXIT ; Back to Finder
24: STRING FORMAT 0 ; No count bytes
25: OutLine DC.B - EndLine-DecBuf ; Count Byte
26: DecBuf: DC.B 'XXXXXXXXX Decimal is'
27: HexBuf: DC.B 'XXXXXXXX Hex'
28: EndLine: ; Tag for end of line
29: Inbuff: DS.B 81 ; Input area
30: ENDPROGRAM
```
7. The entire Dump program appears in Appendix E.

8. The listing program source file is shown in Listing A.8.

CHAPTER 5

1. The Fibonacci routine is shown in Listing A.9.

```
1: ;
2: ; This subroutine converts hex ASCII to longword binary.
3: ;
4: ; Enter with:
5: ;
6: ; AO  -> Hex string
7: ;
8: ; Exit with:
9: ;
10: ; DO.L = Converted number
11: ;
12: ; Conversion terminates on first nonhexadecimal character.
13: ; No overflow detection.
14: ;
15: XDEF HexBin
16: HexBin MOVEM.L D1-D2/AO,-(SP) ; Save temporary registers
17: CLR.L D0 ; Clear out accumulator
18: Loop CLR.L D1 ; Zero out D1
19: CMPI.B #'9',(AO) ; Upper decimal bound
20: BHI NotDec ; Not a decimal digit
21: CMPI.B #'0' ,(AO) ; Lower decimal bound
22: BLO NotHex ; Not a hex (or decimal) digit
23: MOVE.B #'0',D1 ; Correction factor
24: BRA GotDig ; It's a hex digit
25: NotDec CMPI.B #'A', (AO) ; Lower UC hex bound
26: BLO NotHex ; Not a hex digit
27: CMPI.B #'F', (AO) ; Upper UC hex bound
28: BHI NotUC ; Not uppercase hex
29: MOVE.B #'A'-10,D1 ; Correction factor
30: BRA GotDig ; It's a hex digit
31: NotUC CMPI.B #'a', (AO) ; Test lower LC bound
32: BLO NotHex ; Not hex
33: CMPI.B #'f', (AO) ; Test upper LC bound
34: BHI NotHex ; Not hex
35: MOVE.B #'a'-10,D1 ; Correction factor
36: GotDig CLR.L D2 ; Clear scratch register
37: MOVE.B (AO)+,D2 ; Pick up digit
38: SUB.L D1,D2 ; Convert to binary
39: LSL.L #4,D0 ; Multiply by 16
40: ADD.L D2,D0 ; Add in new digit
41: BRA Loop ; Repeat till done
42: NotHex MOVEM.L (SP)+,AO/D1-D2 ; Pop registers
43: RTS ; Return
```

Listing A.5 – The HexBin routine
2. The code in Listing A.9 can be called directly from C. Listing A.10 contains the BASIC version. Listing A.11 contains the Pascal version. This routine uses the Pascal calling sequence to accomplish the recursion, rather than the optimized assembly language in Listings A.9 and A.10. Note the overhead involved in passing the parameters on the stack.

CHAPTER 6

1. Restricting MacDoodle to run on a 512K Macintosh means that all of the code dealing with dynamically allocated buffers becomes much simpler. You would allocate only the file buffer dynamically. This buffer would be required only during the reading and writing process. The screen and undo buffers would be

```
1: ;  HexDec program. This program converts hex numbers
2: ;  to decimal. Numbers are input from the keyboard
3: ;  and output to the screen.
4: ;
5: ;
6: include MACLIB.ASM
7: ; XREF BinHex ; Hex output conversion
8: ; XREF BinDec ; Decimal output conversion
9: ; XREF HexBin ; Hex input conversion
10: PROGRAM DecHex ;
11: Loop: PRINT 'Enter Hex Number: ',$: Prompt for input
12: INPUT InBuff(A5) ; Get a line of input
13: TST.B InBuff(A5) ; Check for null line
14: BQ Done ; If null, quit
15: LEA InBuff+1(A5),AO ; AO -> Digits input
16: JSR HexBin ; Convert to binary
17: LEA HexBuf,AO ; AO -> Hex output area
18: JSR BinHex ; Convert to hex ASCII
19: LEA DecBuf,AO ; AO -> Hex output area
20: JSR BinDec ; Convert to decimal ASCII
21: PRINT OutLine ; Type the answer
22: BRA Loop ; Do it again
23: Done: EXIT ; Back to Finder
24: STRING FORMAT 0 ; No count bytes
25: Outline DC.B EndLine-HexBuf ; Count byte
26: HexBuf: DC.B 'XXXXXXXX Hex is'
27: DecBuf: DC.B 'XXXXXXXX Decimal'
28: EndLine: ; Tag for end of line
29: Inbuff: DS.B 81 ; Input area
30: ENDPROGRAM
```

Listing A.6 - The HexDec program
DecBin routine. Converts decimal ASCII to longword binary.
Enter with:
A0.L -> Input string
Exit with:
D0.L = Converted number
Conversion stops at the first nondecimal digit. No
overflow or error detection.
Revision history:
20-Jan-85 Added support for negative numbers
and leading spaces

Listing A.7 - The modified DecBin routine
Lister program. This program generates a numbered listing file from a .asm file.

Listing A.8 - The Lister program
Listing A.8 - The Lister program (continued)

1: ; Recursive Fibonacci routine
2: ;
3: 4: ; Enter with number in DO.W
5: ; Exit with answer in DO.W
6: ;
7: 8: ; XDEF Fib
8: Fib CMP.W #1,DO ; Easy?
9: ;
10: ; RTS ; F(1) is 1
11: ; DoFib MOVE.W DO,-(A7) ; Save input value
12: ; SUB.W #1,DO ; Take
13: ; BSR Fib ; F(n-1)

Listing A.9 - The recursive Fibonacci routine
Listing A.9 - The recursive Fibonacci routine (continued)

```
14:   MOVE.W DO,-(A7) ; Save the result
15:   MOVE.W 2(A7),DO ; Get original number
16:   SUB.W #2,DO ; Take
17:   BSR Fib ; F(n-2)
18:   ADD.W (A7)+,DO ; Calculate F(n-1) + F(n-2)
19:   ADD.L #2,A7 ; Pop original number
20:   RTS ; Done
```

Listing A.10 - The BASIC Fibonacci routine

```
1:   ; Recursive Fibonacci routine (BASIC version)
2:   ; Call with:
3:   ; CALL BFIB(num%,ans%)  
4:   ; Where:
5:   ; num% is the number desired
6:   ; ans% is the resulting Fibonacci number
7:   ;
8:   ; INCLUDE BASIC.D ; Include BASIC def
9:   ; bfib JSR GetNextLibArg(A5); Fetch next parameter
10:  ; JSR IntegerArg(A5) ; Convert parameter
11:  ; MOVE.W D3,-(SP) ; Save number
12:  ; JSR GetNextLibArg(A5); Fetch next parameter
13:  ; CMP.W #$3,DO ; Integer variable?
14:  ; BNE @1 ; No, bail out
15:  ; JSR GetNextLibArg(A5); Fetch next parameter
16:  ; MOVE.W (SP)+,DO ; Number to DO
17:  ; BSR Fib ; Call recursive routine
18:  ; MOVE.W DO,(A2) ; Set return variable
19:  ; RTS ; Return
20:  ; @1: MOVE.W #5,D2 ; Here if parameter mismatch
21:  ; JSR BasicError(A5) ; "Illegal Function Call"
22:  ;
23:  ; The original Fibonacci routine
24:  ; Fib CMP.W #1,D0 ; Easy?
25:  ; BGT DoFib ; No, recurse for it
26:  ; RTS ; F(1) is 1
27:  ; DoFib MOVE.W DO,-(A7) ; Save input value
28:  ; SUB.W #1,D0 ; Take
29:  ; BSR Fib ; F(n-1)
30:  ; MOVE.W DO,-(A7) ; Save the result
31:  ; MOVE.W 2(A7),DO ; Get original number
32:  ; SUB.W #2,D0 ; Take
33:  ; BSR Fib ; F(n-2)
34:  ; ADD.W (A7)+,DO ; Calculate F(n-1) + F(n-2)
35:  ; ADD.L #2,A7 ; Pop original number
36:  ; RTS ; Done
```
allocated with DS directives. There would be no packing and unpacking operations during scrolling. The program itself would become much simpler. (This is the reason why many Macintosh applications run only on 512K machines.)

2–4. The answers to these questions appear in the MacDoodle listings in Appendix E.

5. These resources should be preloaded:
   a. Menu definitions
   b. Main window definition
   c. Window scroll bar definitions

CHAPTER 8

The answers to all Exercises in Chapter 8 are contained in the listings in Appendix E.

```
1: ;  Fibonacc i program (Pascal version)
2: ;
3: ;
4: .PROC FibAsm ; Procedure statement
5: .DEF fib ; Make accessible
6: fib MOVE.L (SP)+,Al ; Al = Return address
7: MOV E.W (SP)+,DO ; DO = Original number
8: CMP.W $1,DO ; Easy?
9: BGT DoFib ; No, recurse for it
10: MOV E.W DO,(SP) ; Set return value
11: JMP (AL) ; F(1) is 1
12: DoFib MOV E.L Al, -(SP) ; Save return address
13: MOV E.W DO,-(A7) ; Save input value
14: SUB.W $1,DO ; Take F(n-1)
15: CLR.W -(SP) ; Space for result
16: MOV E.W DO,-(A7) ; Function parameter
17: BSR Fib ; Recurse
18: MOV E.W 2(A7),DO ; Get original number
19: SUB.W $2,DO ; Take F(n-2)
20: CLR.W -(SP) ; Space for result
21: MOV E.W DO,-(A7) ; Function parameter
22: BSR Fib ; Recurse
23: MOV E.W (A7)+,DO ; Fetch returned value
24: ADD.W (A7)+,DO ; Calculate F(n-1) + F(n-2)
25: ADD.L $4,A7 ; Pop original number
26: MOV E.L (SP)+,Al ; Pop return address
27: MOV E.W DO,-(SP) ; Set return value
28: JMP (AL) ; Return
29: .END ; Mandatory END statement
```

Listing A.11 - The Pascal Fibonacci routine
The Macintosh uses a variation on the ASCII (American Standard Code for Information Interchange) character set. Table B.1 gives the decimal and hexadecimal values for each character in the standard ASCII character set.

The ASCII character set consists of seven-bit characters. The high-order bit of a byte containing an ASCII character is normally zero.

The Macintosh, however, uses all eight bits of the character value. Figure B.1 shows the Macintosh character set. This table contains all 256 characters in the Macintosh Chicago font. Each character is identified by two hex digits. The first hex digit appears in the first column of the table, and the second hex digit appears in the first row of the table. To find the character corresponding to the hex value 12, find the intersection of the row labeled 1 and the column labeled 2 (the check mark character). The box symbol indicates a character that is not in the font. Note that there is no easy way (or any way at all) to generate some of these font symbols from the keyboard.
<table>
<thead>
<tr>
<th>Dec</th>
<th>Hex</th>
<th>Character</th>
<th>Dec</th>
<th>Hex</th>
<th>Character</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>00</td>
<td>CTL-@ NULL</td>
<td>34</td>
<td>22</td>
<td>&quot;</td>
</tr>
<tr>
<td>1</td>
<td>01</td>
<td>CTL-A SOH</td>
<td>35</td>
<td>23</td>
<td>#</td>
</tr>
<tr>
<td>2</td>
<td>02</td>
<td>CTL-B STX</td>
<td>36</td>
<td>24</td>
<td>$</td>
</tr>
<tr>
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<td>03</td>
<td>CTL-C ETX</td>
<td>37</td>
<td>25</td>
<td>%</td>
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<td>4</td>
<td>04</td>
<td>CTL-D EOT</td>
<td>38</td>
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<td>&amp;</td>
</tr>
<tr>
<td>5</td>
<td>05</td>
<td>CTL-E ENQ</td>
<td>39</td>
<td>27</td>
<td>'</td>
</tr>
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<td>6</td>
<td>06</td>
<td>CTL-F ACK</td>
<td>40</td>
<td>28</td>
<td>(</td>
</tr>
<tr>
<td>7</td>
<td>07</td>
<td>CTL-G BEL</td>
<td>41</td>
<td>29</td>
<td>)</td>
</tr>
<tr>
<td>8</td>
<td>08</td>
<td>CTL-H BS</td>
<td>42</td>
<td>2A</td>
<td>*</td>
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<td>09</td>
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Table B.1 – The Standard ASCII Character Set
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<th>Character</th>
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<td>S</td>
<td>113</td>
<td>71</td>
<td>q</td>
</tr>
<tr>
<td>84</td>
<td>54</td>
<td>T</td>
<td>114</td>
<td>72</td>
<td>r</td>
</tr>
<tr>
<td>85</td>
<td>55</td>
<td>U</td>
<td>115</td>
<td>73</td>
<td>s</td>
</tr>
<tr>
<td>86</td>
<td>56</td>
<td>V</td>
<td>116</td>
<td>74</td>
<td>t</td>
</tr>
<tr>
<td>87</td>
<td>57</td>
<td>W</td>
<td>117</td>
<td>75</td>
<td>u</td>
</tr>
<tr>
<td>88</td>
<td>58</td>
<td>X</td>
<td>118</td>
<td>76</td>
<td>v</td>
</tr>
<tr>
<td>89</td>
<td>59</td>
<td>Y</td>
<td>119</td>
<td>77</td>
<td>w</td>
</tr>
<tr>
<td>90</td>
<td>5A</td>
<td>Z</td>
<td>120</td>
<td>78</td>
<td>x</td>
</tr>
<tr>
<td>91</td>
<td>5B</td>
<td>[</td>
<td>121</td>
<td>79</td>
<td>y</td>
</tr>
<tr>
<td>92</td>
<td>5C</td>
<td>\</td>
<td>122</td>
<td>7A</td>
<td>z</td>
</tr>
<tr>
<td>93</td>
<td>5D</td>
<td>]</td>
<td>123</td>
<td>7B</td>
<td>{</td>
</tr>
<tr>
<td>94</td>
<td>5E</td>
<td>^</td>
<td>124</td>
<td>7C</td>
<td></td>
</tr>
<tr>
<td>95</td>
<td>5F</td>
<td>_</td>
<td>125</td>
<td>7D</td>
<td>}</td>
</tr>
<tr>
<td>96</td>
<td>60</td>
<td>'</td>
<td>126</td>
<td>7E</td>
<td></td>
</tr>
<tr>
<td>97</td>
<td>61</td>
<td>a</td>
<td>127</td>
<td>7F</td>
<td>DEL</td>
</tr>
</tbody>
</table>

Table B.1 – The Standard ASCII Character Set (continued)


Second Digit

<table>
<thead>
<tr>
<th></th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>[]</td>
<td>[]</td>
<td>[]</td>
<td>[]</td>
<td>[]</td>
<td>[]</td>
<td>[]</td>
<td>[]</td>
<td>[]</td>
<td>[]</td>
<td>[]</td>
<td>[]</td>
<td>[]</td>
<td>[]</td>
<td>[]</td>
<td>[]</td>
</tr>
<tr>
<td>3</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>:</td>
<td>;</td>
<td>&lt;</td>
<td>=</td>
<td>&gt;</td>
<td>?</td>
</tr>
<tr>
<td>4</td>
<td>@</td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
<td>E</td>
<td>F</td>
<td>G</td>
<td>H</td>
<td>I</td>
<td>J</td>
<td>K</td>
<td>L</td>
<td>M</td>
<td>N</td>
<td>O</td>
</tr>
<tr>
<td>5</td>
<td>P</td>
<td>Q</td>
<td>R</td>
<td>S</td>
<td>T</td>
<td>U</td>
<td>V</td>
<td>W</td>
<td>X</td>
<td>Y</td>
<td>Z</td>
<td>[</td>
<td>\</td>
<td>]</td>
<td>^</td>
<td>_</td>
</tr>
<tr>
<td>6</td>
<td>a</td>
<td>b</td>
<td>c</td>
<td>d</td>
<td>e</td>
<td>f</td>
<td>g</td>
<td>h</td>
<td>i</td>
<td>j</td>
<td>k</td>
<td>l</td>
<td>m</td>
<td>n</td>
<td>o</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>p</td>
<td>q</td>
<td>r</td>
<td>s</td>
<td>t</td>
<td>u</td>
<td>v</td>
<td>w</td>
<td>x</td>
<td>y</td>
<td>z</td>
<td>{</td>
<td></td>
<td></td>
<td>~</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Å</td>
<td>Å</td>
<td>Ç</td>
<td>É</td>
<td>Ñ</td>
<td>Ô</td>
<td>Õ</td>
<td>Ú</td>
<td>Ü</td>
<td>á</td>
<td>à</td>
<td>â</td>
<td>â</td>
<td>â</td>
<td>ç</td>
<td>è</td>
</tr>
<tr>
<td>9</td>
<td>é</td>
<td>è</td>
<td>í</td>
<td>ì</td>
<td>î</td>
<td>ì</td>
<td>ò</td>
<td>ô</td>
<td>õ</td>
<td>õ</td>
<td>ù</td>
<td>û</td>
<td>û</td>
<td>û</td>
<td>û</td>
<td>û</td>
</tr>
</tbody>
</table>

Figure B.1 – The Macintosh character set
Give me the right word and the right accent and I will move the world.

—Joseph Conrad

This appendix is a quick reference for the macros used in writing programs that work with the run-time library. These macros are defined in the source file MACLIB.ASM.

**ALERT**

**Syntax:** ALERT ID

**Parameter:** ID

**Data Type:** Word

**Purpose:** Resource ID of alert template

**Description:** The ALERT macro causes an alert box to be displayed on the Macintosh screen. Alert boxes are shown in Figure 6.16 (Chapter 6). The box drawn by the ALERT macro has no icon in the upper-left corner.
CAUTIONALERT

Syntax: CAUTIONALERT ID
Parameter: ID
Data Type: Word
Purpose: Resource ID of alert template

Description: The CAUTIONALERT macro causes an alert box to be displayed on the Macintosh screen. Alert boxes are shown in Figure 6.16 (Chapter 6). The box drawn by the CAUTIONALERT macro has the question mark icon in the upper-left corner.

CHECK

Syntax: CHECK menuID,selection

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Data Type</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>menuID</td>
<td>Word</td>
<td>Resource ID of a menu in the menu bar</td>
</tr>
<tr>
<td>selection</td>
<td>Word</td>
<td>Item number within the menu</td>
</tr>
</tbody>
</table>

Description: The CHECK macro places a check mark in front of the item indicated by the selection parameter. Menu items are numbered consecutively from 1. The menuID is the resource ID of the menu on which the item is to be found. Menus used with the run-time library must also be numbered consecutively from 1.

CHKABORT

Syntax: CHKABORT
Parameters: None

Return Values: D0.L is nonzero if the user wishes to stop the program. D0.L is zero otherwise.

Description: The CHKABORT macro determines whether the Macintosh user has typed Command-Period, indicating a desire to stop the program.
CLOSE

Syntax: CLOSE refnum

Parameter: refnum

Data Type: Word

Purpose: File reference number returned by CREATE, OPEN, OPENR, or POPEN macros

Description: The CLOSE macro terminates operations on a file. The file must have been opened by one of the macros listed above.

CREATE

Syntax: CREATE filename[,buffer][,volref]

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Data Type</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>filename</td>
<td>Pascal string</td>
<td>Name of the file to be created</td>
</tr>
<tr>
<td>buffer</td>
<td>Address</td>
<td>522-byte area for file buffer</td>
</tr>
<tr>
<td>volref</td>
<td>Word</td>
<td>Volume reference number for file</td>
</tr>
</tbody>
</table>

Return Values: D0.W contains the file reference number for the open file.

Description: The CREATE macro places a new file on the disk and opens the data fork for reading or writing. Any previously existing file with the same name on the same disk is deleted. The buffer parameter is the optional address of a 522-byte area used by the operating system for operations on this file. Use of this buffer will significantly improve the performance of I/O operations on this file. The volume reference number is an optional indicator of the disk on which the file is to be placed. If this parameter is not specified, the file will be placed on the default drive.

DELETE

Syntax: DELETE filename[,volref]

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Data Type</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>filename</td>
<td>Pascal string</td>
<td>Name of file to be deleted</td>
</tr>
<tr>
<td>volref</td>
<td>Word</td>
<td>Optional drive specifier</td>
</tr>
</tbody>
</table>
Return Values: D0.W = 0 if no error; D0.W = error code if DELETE is unsuccessful.

Description: The DELETE macro removes an existing file from the specified drive. If the volume reference number is not specified, all drives will be searched for the indicated file.

**DIALOG**

Syntax: DIALOG ID

Parameter: ID

Data Type: Word

Purpose: Resource ID of dialog template

Return Values: D0.W = item number selected by the user.

Description: The DIALOG macro invokes the Macintosh modal dialog routine. A dialog box is placed on the screen, and the user must select an item before the program will continue. The item number selected is returned in D0.W. Item numbers are defined by the order in which the dialog items are specified in the program's resource file. Items are numbered consecutively from 1.

**DISABLE**

Syntax: DISABLE menuID,selection

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Data Type</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>menuID</td>
<td>Word</td>
<td>Resource ID of a menu in the menu bar</td>
</tr>
<tr>
<td>selection</td>
<td>Word</td>
<td>Item number within the menu</td>
</tr>
</tbody>
</table>

Description: The DISABLE macro inhibits selection of the menu item indicated by the selection parameter. Menu items are numbered consecutively from 1. The menuID is the resource ID of the menu on which the item is to be found. Menus used with the run-time library must also be numbered consecutively from 1.

**ENABLE**

Syntax: ENABLE menuID,selection
Parameters | Data Type | Purpose
--- | --- | ---
menuID | Word | Resource ID of a menu in the menu bar
selection | Word | Item number within the menu

**Description:** The ENABLE macro allows selection of the menu item indicated by the selection parameter, undoing the action of any previous DISABLE macro. Menu items are numbered consecutively from 1. The menuID is the resource ID of the menu on which the item is to be found. Menus used with the run-time library must also be numbered consecutively from 1.

**ENDPROGRAM**

**Syntax:** ENDPROGRAM

**Parameters:** None

**Description:** The ENDPROGRAM macro is the last line in the program source file, other than an END statement. This macro generates no code and serves only to ensure the correct format of quoted strings declared as instruction operands.

**EXIT**

**Syntax:** EXIT

**Parameters:** None

**Description:** The EXIT macro causes a return to the Finder. The only action taken before invoking the Finder is to ensure that all data output to disk files is actually written to disk.

**GETEVENT**

**Syntax:** GETEVENT [cursor]

**Parameter:** cursor

**Data Type:** Word

**Purpose:** Resource ID of cursor
Return Values:

<table>
<thead>
<tr>
<th>D0 Low</th>
<th>D0 High</th>
<th>D1 High</th>
<th>D1 Low</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>No event is ready</td>
</tr>
<tr>
<td>01</td>
<td>–</td>
<td>Mouse V</td>
<td>Mouse H</td>
<td>Mouse down (D1 = point)</td>
</tr>
<tr>
<td>02</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>Mouse up</td>
</tr>
<tr>
<td>03</td>
<td>Modifier</td>
<td>–</td>
<td>Character</td>
<td>Key down</td>
</tr>
<tr>
<td>04</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>Key up</td>
</tr>
<tr>
<td>05</td>
<td>Modifier</td>
<td>–</td>
<td>Character</td>
<td>(Repeated) Key down</td>
</tr>
<tr>
<td>06</td>
<td>–</td>
<td>Window address</td>
<td></td>
<td>Update-window event</td>
</tr>
<tr>
<td>07</td>
<td>–</td>
<td>–</td>
<td>Drive #</td>
<td>Disk-inserted event</td>
</tr>
<tr>
<td>08</td>
<td>–</td>
<td>Window address</td>
<td></td>
<td>Activate event</td>
</tr>
<tr>
<td>09</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>Abort event</td>
</tr>
<tr>
<td>10</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>Network event</td>
</tr>
<tr>
<td>11</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>Driver event</td>
</tr>
<tr>
<td>12–15</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>Application event 1–4</td>
</tr>
<tr>
<td>16</td>
<td>–</td>
<td>Menu #</td>
<td>Item #</td>
<td>Menu selection</td>
</tr>
<tr>
<td>17</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>Close-window event</td>
</tr>
<tr>
<td>18</td>
<td>–</td>
<td>Height</td>
<td>Width</td>
<td>Resize-window event</td>
</tr>
<tr>
<td>19</td>
<td>SType</td>
<td>Control ID</td>
<td></td>
<td>Plain scroll event</td>
</tr>
<tr>
<td>20</td>
<td>Value</td>
<td>Control ID</td>
<td></td>
<td>Vertical thumb scroll</td>
</tr>
<tr>
<td>21</td>
<td>Value</td>
<td>Control ID</td>
<td></td>
<td>Horizontal thumb scroll</td>
</tr>
</tbody>
</table>

Description: The GETEVENT macro fetches the next event from the runtime library. On return, the low-order word of D0 contains the event type. The high word of D0 and all of D1 contain additional return parameters that depend on the event type. The cursor parameter specifies a cursor to be used when the mouse is inside the application window. If this parameter is omitted, the I-beam (text) cursor will be used. The arrow cursor is used outside the application window. These are the standard cursors:

<table>
<thead>
<tr>
<th>Code</th>
<th>Resulting Cursor</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Arrow</td>
</tr>
<tr>
<td>1</td>
<td>I-beam (text)</td>
</tr>
</tbody>
</table>
**GETINFO**

Syntax: `GETINFO filename, buffer[, volref]`

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Data Type</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>filename</td>
<td>Pascal string</td>
<td>Name of file for which information is desired</td>
</tr>
<tr>
<td>buffer</td>
<td>Address</td>
<td>80-byte area to receive information</td>
</tr>
<tr>
<td>volref</td>
<td>Word</td>
<td>Optional drive specifier</td>
</tr>
</tbody>
</table>

Return Values: D0.W = 0 if no error; D0.W < 0 if GETINFO fails.

Description: The GETINFO macro returns the file information for the specified file. The format of this information is shown in Figure 4.7 (Chapter 4).

**INPUT**

Syntax: `INPUT buffer[, length]`

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Data Type</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>buffer</td>
<td>Address</td>
<td>Memory area to receive data</td>
</tr>
<tr>
<td>length</td>
<td>Word</td>
<td>Number of data bytes in buffer area</td>
</tr>
</tbody>
</table>

Description: The INPUT macro reads a line of keyboard input and places the characters read in the input buffer. Unused bytes in the input buffer are set to zero. If the length parameter is not specified, a length of 80 is assumed.

The input buffer is formatted as a Pascal string. The first byte of the buffer contains the number of characters read. This count byte is not included in the length parameter. For instance, if you do not specify the length parameter, a length of 80 data bytes is assumed. You would need a data area of at least 81 data bytes to allow for the count byte.
**NOTEALERT**

**Syntax:** NOTEALERT  ID  

**Parameter:** ID  

**Data Type:** Word  

**Purpose:** Resource ID of alert template  

**Return Values:** D0.W = item number selected by the user.  

**Description:** The NOTEALERT macro causes an alert box to be displayed on the Macintosh screen. Alert boxes are shown in Figure 6.16 (Chapter 6). The box drawn by the NOTEALERT macro has the asterisk icon in the upper-left corner.

**OPEN**

**Syntax:** OPEN  filename[,buffer][,volref]  

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Data Type</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>filename</td>
<td>Pascal string</td>
<td>Name of file to open</td>
</tr>
<tr>
<td>buffer</td>
<td>Address</td>
<td>Optional 522-byte file buffer</td>
</tr>
<tr>
<td>volref</td>
<td>Word</td>
<td>Optional drive specifier</td>
</tr>
</tbody>
</table>

**Return Values:** D0.W = file reference number if no error; D0.W < 0 if OPEN is unsuccessful.  

**Description:** The OPEN macro connects the application to the data fork of an existing file. The file reference number returned by OPEN identifies the file on subsequent CLOSE, READ, READLN, WRITE, and SEEK operations.

**OPENR**

**Syntax:** OPENR  filename[,buffer][,volref]  

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Data Type</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>filename</td>
<td>Pascal string</td>
<td>Name of file to open</td>
</tr>
<tr>
<td>buffer</td>
<td>Address</td>
<td>Optional 522-byte file buffer</td>
</tr>
<tr>
<td>volref</td>
<td>Word</td>
<td>Optional drive specifier</td>
</tr>
</tbody>
</table>
Return Values: \( D0.W = \) file reference number if no error; \( D0.W < 0 \) if OPENR is unsuccessful.

Description: The OPENR macro connects the application to the resource fork of an existing file. The file reference number returned by OPENR identifies the file on subsequent CLOSE, READ, READLN, WRITE, and SEEK operations.

**PCREATE**

Syntax: \[ \text{PCREATE \ prompt,defname,namebuf,buffer} \]

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Data Type</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>prompt</td>
<td>Pascal string</td>
<td>Prompt string for dialog box</td>
</tr>
<tr>
<td>defname</td>
<td>Pascal string</td>
<td>Initial file name for dialog box</td>
</tr>
<tr>
<td>namebuf</td>
<td>Address</td>
<td>Buffer area for final file name</td>
</tr>
<tr>
<td>buffer</td>
<td>Address</td>
<td>522-byte area for file buffer</td>
</tr>
</tbody>
</table>

Return Values: \( D0.W \) contains the file reference number for the open file. \( D0.W < 0 \) if PCREATE failed. \( D1.W \) contains the volume reference number.

Description: The PCREATE macro places a new file on the disk and opens the data fork for reading or writing. Any previously existing file with the same name on the same disk is deleted. This macro uses the Macintosh standard file package to allow the user to specify the file name and drive. The defname parameter specifies a name that can be edited by the user. The namebuf parameter is the address of an area that will receive the final file name chosen by the user. The buffer parameter is the optional address of a 522-byte area used by the operating system for operations on this file. Use of this buffer will significantly improve the performance of I/O operations on this file.

**POPER**

Syntax: \[ \text{POPER \ types,ext,namebuf,buffer} \]

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Data Type</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>types</td>
<td>Address</td>
<td>File type array</td>
</tr>
<tr>
<td>ext</td>
<td>Pascal string</td>
<td>File extension string</td>
</tr>
<tr>
<td>namebuf</td>
<td>Address</td>
<td>Buffer area for final file name</td>
</tr>
<tr>
<td>buffer</td>
<td>Address</td>
<td>522-byte area for file buffer</td>
</tr>
</tbody>
</table>
Return Values: D0.W contains the file reference number for the open file. D0.W < 0 if POPEN failed. D1.W contains the volume reference number.

Description: The POPEN macro connects the application with the data fork of an existing file. This macro uses the Macintosh standard file package to allow the user to specify the file name and drive. The types parameter is the address of an array that gives the acceptable file types. Any file that does not have one of these types will not appear in the selection window presented to the user. This array has a 16-bit count followed by 32-bit file types. If this parameter is not specified, all file types will be selected. The ext parameter is a Pascal string that specifies the final characters in each file name selected for display. You can use this feature to select all files ending in .asm, for instance. All letters in the ext string must be uppercase. The namebuf parameter is the address of an area that will receive the final file name chosen by the user. The buffer parameter is the optional address of a 522-byte area used by the operating system for operations on this file. Use of this buffer will significantly improve the performance of I/O operations on this file.

**PRINT**

Syntax: PRINT   string[,crflag]

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Data Type</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>string</td>
<td>Pascal string</td>
<td>Characters to output to the screen</td>
</tr>
<tr>
<td>crflag</td>
<td>(none)</td>
<td>No line advance if nonblank</td>
</tr>
</tbody>
</table>

Description: The PRINT macro displays a string of text in the application window. The string can have embedded carriage-return characters, which will produce multiple lines. If the crflag parameter is omitted, a carriage return will be appended to the end of the string. Any nonblank crflag parameter will inhibit this final line advance.

**PROGRAM**

Syntax: PROGRAM   [name[,debug[,menus]]

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Data Type</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>name</td>
<td>Quoted string</td>
<td>Name to appear in program window</td>
</tr>
<tr>
<td>debug</td>
<td>(none)</td>
<td>DEBUGON to use debugger</td>
</tr>
<tr>
<td>menus</td>
<td>16-bit constant</td>
<td>Number of menus in resource file</td>
</tr>
</tbody>
</table>
Return Values: $A0.L =$ window address; $D0.L =$ window size.

Description: The PROGRAM macro immediately precedes the first instruction to be executed in the application. The name parameter specifies a name to appear as the title of the window created during initialization. The name is also used in locating the resource file for the application. If the file Name.RSRC exists, it will be used as the application's resource file. The debug parameter is the string DEBUGON; it is used when you want to enter the debugger just prior to executing the first instruction following the PROGRAM macro. The menu parameter is the number of menus in the resource file. Menu resource IDs must be numbered consecutively from 1.

QUIT

Syntax: QUIT

Parameters: None

Description: The QUIT macro waits for a Quit choice from the File menu. This macro calls GETEVENT repeatedly until the first item is selected from the second menu. After the selection is made, the macro exits to the Finder.

READ

Syntax: READ refnum, buffer, count

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Data Type</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>refnum</td>
<td>Word</td>
<td>Reference number of open file</td>
</tr>
<tr>
<td>buffer</td>
<td>Address</td>
<td>Memory address to receive data from file</td>
</tr>
<tr>
<td>count</td>
<td>Longword</td>
<td>Number of bytes to transfer</td>
</tr>
</tbody>
</table>

Return Values: $D0.L =$ number of bytes actually transferred; $D0.L < 0$ if READ is unsuccessful.

Description: The READ macro transfers data from an open file into application memory. The transfer from the file begins immediately following the last transfer unless the file pointer was altered by a SEEK macro. On return, $D0.L$ contains the number of bytes actually read. This may be less than the number requested if the number of bytes left before the end of the file is less than the count parameter.
READLN

Syntax: READLN refnum,buffer,count

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Data Type</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>refnum</td>
<td>Word</td>
<td>Reference number of open file</td>
</tr>
<tr>
<td>buffer</td>
<td>Address</td>
<td>Memory address to receive data from file</td>
</tr>
<tr>
<td>count</td>
<td>Longword</td>
<td>Maximum number of bytes to transfer</td>
</tr>
</tbody>
</table>

Return Values: D0.L = number of bytes actually transferred; D0.L < 0 if READLN is unsuccessful.

Description: The READLN macro transfers data from an open file into application memory. The transfer from the file begins immediately following the last transfer unless the file pointer was altered by a SEEK macro. The transfer ends on the next carriage-return character in the file or when the count is satisfied. On return, D0.L contains the number of bytes actually read.

SCURSOR

Syntax: SCURSOR ID

Parameter: ID

Data Type: Word

Purpose: Resource ID of desired cursor

Description: The SCURSOR changes the mouse cursor to a shape contained in the application or system resource file. The system file contains the following standard cursors:

<table>
<thead>
<tr>
<th>Code</th>
<th>Resulting Cursor</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Arrow</td>
</tr>
<tr>
<td>1</td>
<td>I-beam (text)</td>
</tr>
<tr>
<td>2</td>
<td>Cross</td>
</tr>
<tr>
<td>3</td>
<td>Plus</td>
</tr>
<tr>
<td>4</td>
<td>Watch</td>
</tr>
</tbody>
</table>

SEEK

Syntax: SEEK refnum,offset,sense
Parameters | Data Type | Purpose
--- | --- | ---
refnum | Word | Reference number for open file
offset | Longword | File offset
sense | Word | Interpretation of offset parameter:
0 | From beginning of file
1 | From current position
2 | From end of file

Return Values: D0.L contains resulting file position.

Description: The SEEK macro specifies the file location at which the next transfer operation will begin. An attempt to position the file pointer beyond the end of file places it one byte beyond the end.

**SETINFO**

Syntax: SETINFO filename,buffer[],volref

Parameters | Data Type | Purpose
--- | --- | ---
filename | Pascal string | Name of file for which information is desired
buffer | Address | 80-byte area containing information
volref | Word | Optional drive specifier

Return Values: D0.W = 0 if no error; D0.W < 0 if SETINFO failed.

Description: The SETINFO macro modifies the file information for the specified file. The format of this information is shown in Figure 4.7 (Chapter 4).

**SETHMAX**

Syntax: SETHMAX value

Parameter: value

Data Type: Word

Purpose: New maximum value

Description: The SETHMAX macro sets the maximum value associated with the horizontal scroll bar. This is the value returned in a scrolling event when the document is positioned all the way to the right.
**SETHMIN**

Syntax: SETHMIN value

Parameter: value

Data Type: Word

Purpose: New minimum value

Description: The SETHMIN macro sets the minimum value associated with the horizontal scroll bar. This is the value returned in a scrolling event when the document is positioned all the way to the left.

**SETHVAL**

Syntax: SETHVAL value

Parameter: value

Data Type: Word

Purpose: New horizontal value

Description: The SETHVAL macro sets the thumb value associated with the horizontal scroll bar. Setting the value causes the thumb to be repositioned.

**SETVMAX**

Syntax: SETVMAX value

Parameter: value

Data Type: Word

Purpose: New maximum value

Description: The SETVMAX macro sets the maximum value associated with the vertical scroll bar. This is the value returned in a scrolling event when the document is positioned all the way at the bottom.

**SETVMIN**

Syntax: SETVMIN value

Parameter: value
Data Type: Word
Purpose: New minimum value

Description: The SETVMIN macro sets the minimum value associated with the vertical scroll bar. This is the value returned in a scrolling event when the document is positioned all the way at the top.

**SETVVAL**

Syntax: SETVVAL value
Parameter: value
Data Type: Word
Purpose: New vertical value

Description: The SETVVAL macro sets the thumb value associated with the vertical scroll bar. Setting the value causes the thumb to be repositioned.

**STOPALERT**

Syntax: STOPALERT ID
Parameter: ID
Data Type: Word
Purpose: Resource ID of alert template

Return Values: D0.W = item number selected by the user.

Description: The STOPALERT macro causes an alert box to be displayed on the Macintosh screen. Alert boxes are shown in Figure 6.16 (Chapter 6). The box drawn by the STOPALERT macro has the exclamation point icon in the upper-left corner.

**STYLE**

Syntax: STYLE menuID,selection,style

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Data Type</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>menuID</td>
<td>Word</td>
<td>Resource ID of a menu in the menu bar</td>
</tr>
<tr>
<td>selection</td>
<td>Word</td>
<td>Item number within the menu</td>
</tr>
<tr>
<td>style</td>
<td>Word</td>
<td>Text style mask</td>
</tr>
</tbody>
</table>
**Description:** The STYLE macro changes the text style of the item indicated by the selection parameter. Menu items are numbered consecutively from 1. The menud is the resource ID of the menu on which the item is to be found. Menus used with the run-time library must also be numbered consecutively from 1. The style word contains the text attributes, as described in Figure 6.10 (Chapter 6).

**TRACK**

**Syntax:** TRACK  controllD,scrollproc

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Data Type</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>controllD</td>
<td>Longword</td>
<td>Scroll bar ID from scrolling event</td>
</tr>
<tr>
<td>scrollproc</td>
<td>Address</td>
<td>Pointer to function handling scrolling</td>
</tr>
</tbody>
</table>

**Description:** The TRACK macro causes line and page scrolls to repeat until the mouse button is released. This macro handles highlighting of the appropriate controls while the mouse button remains down. The scrollproc procedure should perform a single instance of the desired scrolling action. The TRACK macro calls this procedure repeatedly until the user releases the mouse button.

**UNCHECK**

**Syntax:** UNCHECK  menud,selection

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Data Type</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>menud</td>
<td>Word</td>
<td>Resource ID of a menu in the menu bar</td>
</tr>
<tr>
<td>selection</td>
<td>Word</td>
<td>Item number within the menu</td>
</tr>
</tbody>
</table>

**Description:** The UNCHECK macro removes any check mark in front of the item indicated by the selection parameter. Menu items are numbered consecutively from 1. The menud is the resource ID of the menu on which the item is to be found. Menus used with the run-time library must also be numbered consecutively from 1.

**WRITE**

**Syntax:** WRITE  refnum,buffer,count
<table>
<thead>
<tr>
<th>Parameters</th>
<th>Data Type</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>refnum</td>
<td>Word</td>
<td>Reference number of open file</td>
</tr>
<tr>
<td>buffer</td>
<td>Address</td>
<td>Memory address containing data for file</td>
</tr>
<tr>
<td>count</td>
<td>Longword</td>
<td>Number of bytes to transfer</td>
</tr>
</tbody>
</table>

Return Values: D0.L = number of bytes actually transferred; D0.L < 0 if WRITE is unsuccessful.

Description: The WRITE macro transfers data from application memory to an open file. The transfer to the file begins immediately following the last transfer unless the file pointer was altered by a SEEK macro. On return, D0.L contains the number of bytes actually written. If this number is less than the number requested, an error occurred.

**WTITLE**

Syntax: WTITLE string

Parameter: string

Data Type: Pascal string

Purpose: New window title

Description: The WTITLE macro replaces the title in the application window. The title is initially set to the name specified in the PROGRAM macro.
# 68000 Quick Reference

A man is only as good as the tool he uses.

—Goethe

## EFFECTIVE ADDRESS SUMMARY

<table>
<thead>
<tr>
<th>Bit</th>
<th>Instruction Format:</th>
<th>Op Code</th>
<th>Effective Address</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Addressing Mode Name

<table>
<thead>
<tr>
<th>Mode Name</th>
<th>Syntax</th>
<th>Mode</th>
<th>Register</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data Register Direct</td>
<td>Dn</td>
<td>000</td>
<td>Data Register</td>
</tr>
<tr>
<td>Address Register Direct</td>
<td>An</td>
<td>001</td>
<td>Address Register</td>
</tr>
<tr>
<td>Address Register Indirect</td>
<td>An</td>
<td>010</td>
<td>Address Register</td>
</tr>
<tr>
<td>Address Register Indirect Postincrement</td>
<td>(An)+</td>
<td>011</td>
<td>Address Register</td>
</tr>
<tr>
<td>Address Register Indirect Predecrement</td>
<td>(An)</td>
<td>100</td>
<td>Address Register</td>
</tr>
<tr>
<td>Address Register Indirect with Displacement</td>
<td>w(An)</td>
<td>101</td>
<td>Address Register</td>
</tr>
<tr>
<td>Address Register Indirect with Index</td>
<td>b(An,Rx)</td>
<td>110</td>
<td>Address Register</td>
</tr>
<tr>
<td>Absolute Short</td>
<td>w</td>
<td>111</td>
<td>000</td>
</tr>
<tr>
<td>Absolute Long</td>
<td>l</td>
<td>111</td>
<td>001</td>
</tr>
<tr>
<td>Program Counter with Displacement</td>
<td>w(PC)</td>
<td>111</td>
<td>010</td>
</tr>
<tr>
<td>Program Counter with Index</td>
<td>b(PC,Rx)</td>
<td>111</td>
<td>011</td>
</tr>
<tr>
<td>Immediate</td>
<td>#x</td>
<td>111</td>
<td>100</td>
</tr>
<tr>
<td>Status Register</td>
<td>SR</td>
<td>111</td>
<td>100</td>
</tr>
<tr>
<td>Condition Code Register</td>
<td>CCR</td>
<td>111</td>
<td>100</td>
</tr>
</tbody>
</table>
Legend:

Dn  Data Register  (n is 0-7)
An  Address Register (n is 0-7)
b  08-bit constant
w  16-bit constant
l  32-bit constant
x  8-, 16-, or 32-bit constant
Rx  Index Register Specification, one of:
    Dn.W  Low 16 bits of Data Register
    Dn.L  All 32 bits of Data Register
    An.W  Low 16 bits of Address Register
    An.L  All 32 bits of Address Register

```
    Bit     15  14  13  12  11  10  9  8  7  6  5  4  3  2  1  0
    Index
    Extension Word: A  Register  Sz  0  0  0  8-bit Displacement
```

"A" is the type of index register: 1 for an address register, 0 for a data register. "Sz" is 1 for a long index, 0 for word.

**OPERATION CODE SUMMARY**

<table>
<thead>
<tr>
<th>Bits 12 through 15</th>
<th>Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>Bit Manipulation/MOVEP/Immediate</td>
</tr>
<tr>
<td>0001</td>
<td>Move Byte</td>
</tr>
<tr>
<td>0010</td>
<td>Move Long</td>
</tr>
<tr>
<td>0011</td>
<td>Move Word</td>
</tr>
<tr>
<td>0100</td>
<td>Miscellaneous</td>
</tr>
<tr>
<td>0101</td>
<td>ADDQ/SUBQ/Scc/DBcc</td>
</tr>
<tr>
<td>0110</td>
<td>Bcc / BSR</td>
</tr>
<tr>
<td>0111</td>
<td>MOVEQ</td>
</tr>
<tr>
<td>1000</td>
<td>OR / DIV / SBCD</td>
</tr>
<tr>
<td>1001</td>
<td>SUB / SUBX</td>
</tr>
<tr>
<td>1010</td>
<td>(unassigned)</td>
</tr>
<tr>
<td>1011</td>
<td>CMP / EOR</td>
</tr>
<tr>
<td>1100</td>
<td>AND / MUL / ABCD / EXG</td>
</tr>
<tr>
<td>1101</td>
<td>ADD / ADDX</td>
</tr>
<tr>
<td>1110</td>
<td>ASL/ASR/ROL/ROR/ROXL/ROXR</td>
</tr>
<tr>
<td>1111</td>
<td>(unassigned)</td>
</tr>
</tbody>
</table>

**CONDITION CODE NOTATION**

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>•</td>
<td>Set according to result of operation</td>
</tr>
<tr>
<td>–</td>
<td>Not affected</td>
</tr>
<tr>
<td>0</td>
<td>Cleared</td>
</tr>
<tr>
<td>1</td>
<td>Set</td>
</tr>
<tr>
<td>U</td>
<td>Outcome (state after operation) undefined</td>
</tr>
<tr>
<td>1</td>
<td>Set by immediate data</td>
</tr>
</tbody>
</table>
### NUMERICAL INSTRUCTION SUMMARY

<table>
<thead>
<tr>
<th>Instruction</th>
<th>Machine Code Format</th>
<th>Condition Codes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ORI</strong></td>
<td>15-12 11 10 9 8 7 6 5 4 3 2 1 0</td>
<td>X N Z V C - * * 0 0</td>
</tr>
<tr>
<td></td>
<td>0000 0 0 0 0 Size Effective Address</td>
<td></td>
</tr>
<tr>
<td><strong>BTST</strong> (Dynamic)</td>
<td>15-12 11 10 9 8 7 6 5 4 3 2 1 0</td>
<td>X N Z V C - - * - -</td>
</tr>
<tr>
<td></td>
<td>0000 D Reg. 1 0 0 Effective Address</td>
<td></td>
</tr>
<tr>
<td><strong>BCHG</strong> (Dynamic)</td>
<td>15-12 11 10 9 8 7 6 5 4 3 2 1 0</td>
<td>X N Z V C - - * - -</td>
</tr>
<tr>
<td></td>
<td>0000 D Reg. 1 0 1 Effective Address</td>
<td></td>
</tr>
<tr>
<td><strong>BCLR</strong> (Dynamic)</td>
<td>15-12 11 10 9 8 7 6 5 4 3 2 1 0</td>
<td>X N Z V C - - * - -</td>
</tr>
<tr>
<td></td>
<td>0000 D Reg. 1 1 0 Effective Address</td>
<td></td>
</tr>
<tr>
<td><strong>BSET</strong> (Dynamic)</td>
<td>15-12 11 10 9 8 7 6 5 4 3 2 1 0</td>
<td>X N Z V C - - * - -</td>
</tr>
<tr>
<td></td>
<td>0000 D Reg. 1 1 1 Effective Address</td>
<td></td>
</tr>
<tr>
<td><strong>MOVEP</strong></td>
<td>15-12 11 10 9 8 7 6 5 4 3 2 1 0</td>
<td>X N Z V C - - - -</td>
</tr>
<tr>
<td></td>
<td>0000 D Reg. 1 Dr Sz 0 0 1 Address Register</td>
<td></td>
</tr>
<tr>
<td>Instruction</td>
<td>Machine Code Format</td>
<td>Condition Codes</td>
</tr>
<tr>
<td>-------------</td>
<td>---------------------</td>
<td>-----------------</td>
</tr>
<tr>
<td>ANDI</td>
<td>15-12 11 10 9 8 7 6 5 4 3 2 1 0</td>
<td>X N Z V C</td>
</tr>
<tr>
<td></td>
<td>0000 0 0 1 0</td>
<td>Size Effective Address</td>
</tr>
<tr>
<td>SUBI</td>
<td>15-12 11 10 9 8 7 6 5 4 3 2 1 0</td>
<td>X N Z V C</td>
</tr>
<tr>
<td></td>
<td>0000 0 1 0 0</td>
<td>Size Effective Address</td>
</tr>
<tr>
<td>ADDI</td>
<td>15-12 11 10 9 8 7 6 5 4 3 2 1 0</td>
<td>X N Z V C</td>
</tr>
<tr>
<td></td>
<td>0000 0 1 1 0</td>
<td>Size Effective Address</td>
</tr>
<tr>
<td>BTST (Static)</td>
<td>15-12 11 10 9 8 7 6 5 4 3 2 1 0</td>
<td>X N Z V C</td>
</tr>
<tr>
<td></td>
<td>0000 1 0 0 0 0 0</td>
<td>Effective Address</td>
</tr>
<tr>
<td>BCHG (Static)</td>
<td>15-12 11 10 9 8 7 6 5 4 3 2 1 0</td>
<td>X N Z V C</td>
</tr>
<tr>
<td></td>
<td>0000 1 0 0 0 0 1</td>
<td>Effective Address</td>
</tr>
<tr>
<td>BCLR (Static)</td>
<td>15-12 11 10 9 8 7 6 5 4 3 2 1 0</td>
<td>X N Z V C</td>
</tr>
<tr>
<td></td>
<td>0000 1 0 0 0 1 0</td>
<td>Effective Address</td>
</tr>
<tr>
<td>BSET (Static)</td>
<td>15-12 11 10 9 8 7 6 5 4 3 2 1 0</td>
<td>X N Z V C</td>
</tr>
<tr>
<td></td>
<td>0000 1 0 0 0 1 1</td>
<td>Effective Address</td>
</tr>
<tr>
<td>Instruction</td>
<td>Machine Code Format</td>
<td>Condition Codes</td>
</tr>
<tr>
<td>-------------</td>
<td>---------------------</td>
<td>-----------------</td>
</tr>
<tr>
<td>EORI</td>
<td>15–12 11 10 9 8 7 6 5 4 3 2 1 0</td>
<td>X N Z V C</td>
</tr>
<tr>
<td></td>
<td>0000 1 0 1 0</td>
<td>- * * 0 0</td>
</tr>
<tr>
<td></td>
<td>Size</td>
<td>Effective Address</td>
</tr>
<tr>
<td>CMPI</td>
<td>15–12 11 10 9 8 7 6 5 4 3 2 1 0</td>
<td>X N Z V C</td>
</tr>
<tr>
<td></td>
<td>0000 1 1 0 0</td>
<td>* * * * *</td>
</tr>
<tr>
<td></td>
<td>Size</td>
<td>Effective Address</td>
</tr>
<tr>
<td>MOVES</td>
<td>15–12 11 10 9 8 7 6 5 4 3 2 1 0</td>
<td>X N Z V C</td>
</tr>
<tr>
<td>(68010)</td>
<td>0000 1 1 1 0</td>
<td>- - - - -</td>
</tr>
<tr>
<td></td>
<td>Size</td>
<td>Effective Address</td>
</tr>
<tr>
<td>MOVE.B</td>
<td>15–12 11 10 9 8 7 6 5 4 3 2 1 0</td>
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| 0011 | Register | 0 0 | Mode | Register |
| | ← Destination | → Source |
MOVE.W | 15-12 11 10 9 8 7 6 5 4 3 2 1 0 | X N Z V C
| 0011 | Register | Mode | Mode | Register |
| | ← Destination | → Source |
NEGX | 15-12 11 10 9 8 7 6 5 4 3 2 1 0 | X N Z V C
| 0100 | 0 0 0 0 | Size | Effective | Address |
| | * * * * * |
MOVE From SR | 15-12 11 10 9 8 7 6 5 4 3 2 1 0 | X N Z V C
| 0100 | 0 0 0 0 1 1 | Effective | Address |
CHK | 15-12 11 10 9 8 7 6 5 4 3 2 1 0 | X N Z V C
| 0100 | D Reg. 1 1 0 | Effective | Address |
| | * U U U |
LEA | 15-12 11 10 9 8 7 6 5 4 3 2 1 0 | X N Z V C
<p>| 0100 | A Reg. 1 1 1 | Effective | Address |
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|             | 0100 1 0 0 0 0 0 0 | Effective Address  
|             |                     | * U * U * |
| **SWAP**    | 15-12 11 10 9 8 7 6 5 4 3 2 1 0 | X N Z V C  
|             | 0100 1 0 0 0 0 0 1 0 0 0 | D Reg.  
|             |                     | - * * 0 0 |
| **PEA**     | 15-12 11 10 9 8 7 6 5 4 3 2 1 0 | X N Z V C  
|             | 0100 1 0 0 0 0 0 1 | Effective Address  
|             |                     | - - - - |
| **EXT.W**   | 15-12 11 10 9 8 7 6 5 4 3 2 1 0 | X N Z V C  
|             | 0100 1 0 0 0 0 1 0 0 0 0 | D Reg.  
|             |                     | - * * 0 0 |
| **MOVEM**   | (Regs to EA) 15-12 11 10 9 8 7 6 5 4 3 2 1 0 | X N Z V C  
|             | 0100 1 0 0 0 0 1 |Sz|Effective Address  
|             |                     | - - - - |
| **EXT.L**   | 15-12 11 10 9 8 7 6 5 4 3 2 1 0 | X N Z V C  
|             | 0100 1 0 0 0 0 1 1 0 0 0 | D Reg.  
|             |                     | - * * 0 0 |
| **TST**     | 15-12 11 10 9 8 7 6 5 4 3 2 1 0 | X N Z V C  
|             | 0100 1 0 1 0 | Size|Effective Address  
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<td>Condition Codes</td>
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### Instruction | Machine Code Format | Condition Codes
--- | --- | ---
**ROR**  
(Register form)  
| 15-12 | 11 10 9 8 7 6 5 4 3 2 1 0 | X N Z V C |
| 1110 | Cnt/Reg | 0 | Size | IR | 1 | 1 | D Reg. | - * * 0 *

**ROL**  
(Register form)  
| 15-12 | 11 10 9 8 7 6 5 4 3 2 1 0 | X N Z V C |
| 1110 | Cnt/Reg | 1 | Size | IR | 1 | 1 | D Reg. | - * * 0 *

Legend:

**Size**  
Specifies instruction data size:

- 00 Byte
- 01 Word
- 10 Long

**Dr**  
Specifies instruction direction:

- 0 EA or Memory to Dn
- 1 Dn to EA or Memory

**Sz**  
Specifies instruction data size:

- 0 Word
- 1 Long

**Rd**  
Specifies instruction direction:

- 0 Control register to General Register
- 1 General register to Control Register

**IData**  
3 bits of immediate data:

- 000 Specifies the value “8”.
- 001–111 Specify values 1–7.
Condition Specifies a branch condition:

<table>
<thead>
<tr>
<th>Condition</th>
<th>Instruction</th>
<th>Condition</th>
<th>Instruction</th>
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<td>BVC</td>
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<td>0010</td>
<td>BHI</td>
<td>1010</td>
<td>BPL</td>
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<td>1011</td>
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<td>0111</td>
<td>BEQ</td>
<td>1111</td>
<td>BLE</td>
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DA Specifies the type of registers used:
- 0 Data Registers
- 1 Address Registers

Cnt Reg Specifies a count or a register value:
- If the IR field is 0, then 3-bit IData format
- If the IR field is 1, then Data Register Number

ALPHABETICAL INSTRUCTION SUMMARY

<table>
<thead>
<tr>
<th>Instruction</th>
<th>Machine Code Format</th>
<th>Condition Codes</th>
</tr>
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</table>
| ABCD        | 15-12 11 10 9 8 7 6 5 4 3 2 1 0  X N Z V C | * U * * * *
|             | 1100 Dest Reg 1 0 0 0 0 DA Src Reg         |               |

| ADD         | 15-12 11 10 9 8 7 6 5 4 3 2 1 0  X N Z V C | ** * * * * *
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### Instruction | Machine Code Format | Condition Codes

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**SPECIAL STATUS WORD FORMAT**

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<td>Function</td>
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- **RR**: ReRun Bit Set by software for no hardware rerun
- **IF**: Instruction fetch
- **DF**: Data fetch
- **RM**: Read-modify-write cycle
- **HB**: Processor accessing high byte
- **BY**: Byte access
- **RW**: Read / Write bit
- **Function**: Function codes FC0–FC2
Source Listings

Bloody instructions, which, being taught, return to plague the inventor.

—Shakespeare (Macbeth)

INTRODUCTION

Many of the programs presented in Chapters 4–6 and 8 are too long to explain completely; to facilitate the presentation, we left out many lines of code from the listings in these chapters. In addition, many exercises call for completion or modification of these programs. This appendix presents the complete source listings of these programs.

To run the programs in Chapter 4 and 6, you will need to build the runtime library. See the section on Chapter 8 in this Appendix for instructions.

To obtain a disk containing the source files for all the programs in this book, send $19.95 plus $2.50 postage and handling in check or money order to this address:

MacDoodle Source Disk
P.O. Box 3262
Monterey, CA 93940

California residents add 6 percent sales tax. Make the check payable to MacDoodle Source Disk. Please allow 6–8 weeks for delivery.

CHAPTER 4

The Dump program in Chapter 4 consists of three files: Dump.asm, Dump.job, and Dump.link. These are contained in Listings E.1–E.3.
Programming the Macintosh in Assembly Language

Listing E.1 - The Dump.asm file

Dump.asm. This program dumps an arbitrary file to an ASCII textfile.

Version 01.00 18-Feb-85

This program prompts for a file to be dumped, changes the extension to .dmp, and prints the contents of the file in hex and ASCII in the output file.

The dump can be repeated as desired.

include MACLIB.ASM

Bufsize EQU 16 ; 16 bytes per dump line
Space EQU $20 ; ASCII value for a blank

PROORAM DUMP ; Setup program entry

Start: BSR OpenFiles ; Start with opening input/output

PRINT 'Dumping ',* ; Echo file names
PRINT INameBuf(A5),* ; to main window
PRINT ' To ',* ;
PRINT ORefNum(A5) ;

WRITE ORefNum(A5),InfoStr,InfLen; Write "File Information" on file

BSR DoFinfo ; Dump file information first
TST.L DO ; Successful?
BNE DQuit ; No, quit

WRITE ORefNum(A5),DataStr,DatLen; Write "Data Fork" on file

BSR DoFork ; Do the data fork
TST.L DO ; Successful?
BNE DQuit ; No, quit

CLOSE IRefNum(A5) ; Close the file

OPENR INnameBuf(A5),IPBuff(A5) ; Open resource fork now

MOVE.W DO,IRefNum(A5) ; Save file number

BGT ROpenOK ; If GT, then OK

PRINT 'Unable to Open Resource Fork: ',* ;

PRINT INameBuf(A5) ; Identify file name
CLOSE ORefNum(A5) ; Close output file

BRA Start ; To next file

ROpenOK: ; Here if resource open OK
WRITE ORefNum(A5),ResStr,ResLen; Write resource ID
BSR DoFork ; Do the dump
DQuit: CLOSE IRefNum(A5) ; Close the file
CLOSE ORefNum(A5) ; and output file
BRA Start ; Go get next file name

OpenFiles routine. Here to open input file and output file using POPEN and PCREATE macros.

Entry conditions:
Listing E.1 – The Dump.asm file (continued)

Listing E.1 – The Dump.asm file (continued)
Equates for file info:

```
106: ; Equates for file info:
107: DirIndex EQU 28 ; Directory index
108: Attr EQU 30 ; File attributes
109: Version EQU 31 ; File version number
110: FiFType EQU 32 ; Finder file type
111: FiCreate EQU 36 ; Finder file creator
112: FiFlags EQU 40 ; Finder flags word
113: FiIcon EQU 42 ; Finder icon location
114: FiFolder EQU 46 ; Finder folder number
115: FileNum EQU 48 ; File number
116: DataStart EQU 52 ; Data fork start block
117: DataLEOF EQU 54 ; Data fork logical EOF
118: DataPEOF EQU 58 ; Data fork physical EOF
119: RsrcStart EQU 62 ; Resource fork start block
120: RsrcLEXF EQU 64 ; Resource fork logical EOF
121: RsrcPEOF EQU 68 ; Resource fork physical EOF
122: CreateDate EQU 72 ; Creation date
123: ModifyDate EQU 76 ; Modification date
124: DoFinfo MOVEM.L D1-D7/A0-A4,-(SP) ; Save caller's registers
125: GETFINFO INameBuf(A5),InfoBuf(A5); Get file info for input file
126: LEA InfoBuf(A5),A3 ; A3 -> File information
127: MOVE.W DirIndex(A3),DO ; DO = Directory index
128: LEA Diridx,A0 ; AO -> Output area
129: BSR HexW ; Convert
130: MOVE.B Attr(A3),DO ; DO = File attribute byte
131: LEA Attr,A0 ; AO -> Output area
132: BSR HexB ; Convert
133: MOVE.B Version(A3),DO ; DO = File version number
134: LEA Vers,A0 ; AO -> Output area
135: BSR HexB ; Convert
136: MOVE.L FiFType(A3),DO ; DO = Finder file type
137: LEA FFFtype,A0 ; AO -> Output area
138: BSR HexL ; Convert
139: LEA FiFType(A3),AI ; AI -> Binary file type
140: LEA FFFAsc,A0 ; AO -> Output area
141: MOVBL #4,DO ; DO = Byte count
142: BSR DumpAsc ; Convert
143: MOVE.L FiCreate(A3),DO ; DO = Finder file creator
144: LEA FFCreat,A0 ; AO -> Output area
145: BSR HexL ; Convert
146: LEA FiCreate(A3),Al ; Al -> Creator binary
147: LEA FFCAsc,A0 ; AO -> Output area
148: MOVBL #4,DO ; DO = Byte count
149: BSR DumpAsc ; Convert
150: MOVE.W FiFlags(A3),DO ; DO = Finder flags word
151: LEA FFflags,A0 ; AO -> Output area
152: BSR HexW ; Convert
153: MOVE.L FiIcon(A3),DO ; DO = Finder icon location
154: LEA FFtloc,A0 ; AO -> Output area
155: BSR HexL ; Convert
156: MOVE.W FiFolder(A3),DO ; DO = Finder folder number
157: LEA FFNum,A0 ; AO -> Output Area
158: BSR HexW
```

Listing E.1 - The Dump.asm file (continued)
DoFork: This routine outputs the contents of an open file in hex to another open file. Called once for data fork and once for resource fork.

Listing E.1 - The Dump.asm file (continued)
Listing E.1 – The Dump.asm file (continued)

212: READXX:
213: LEA Buffer(A5),A3
214: MOVE.W #BufSize-1,D0
215: Clear: CLR.B (A3)+
216: DBRA D0, Clear
217: CHKABORT
218: TST.W D0
219: BNE Next
220: READ IRefNum(A5), BUFFER(A5), #BufSize
221: MOVE.L D0, BytesRead(A5)
222: BLE AtEOF
223: LEA DumpLine, AO
224: MOVE.L D7, D0
225: JSR HexL
226: ADD.L #10, AO
227: LEA Buffer(A5), Al
228: MOVE.W #3, D2
229: Hloop:
230: MOVE.L (Al)+, D0
231: BSR HexL
232: ADD.L #9, AO
233: DBRA D2, Hloop
234: LEA Buffer(A5), Al
235: MOVE.W #BufSize, D0
236: BSR DumpAsc
237: WRITE ORefNum(A5), DumpLine, Olen;
238: CMP.L Olen, D0
239: BNE Werror
240: ADD.L #BufSize, D7
241: CMP.L #BufSize, BytesRead(A5)
242: BQ随意 READXX
243: AtEOF: CLR.L D0
244: Next: MOVE.L (SP)+, D1-D7/A0-A4
245: RTS
246: ;
247: ; Hex output conversion routines.
248: ; HexL, HexW, and HexB convert longword, word, and byte to hex.
249: ;
250: ; Enter with:
251: ;
252: ; DO = Binary number
253: ; AO -> Output area
254: ;
255: ; Exit with:
256: ; (no change to registers)
257: ;
258: ; HexL: MOVE.L AO,-(SP)
259: ; Convert longword to ASCII
260: ; SWAP DO
261: ; BSR HexW
262: ; LEA 4(AO), AO
263: ; SWAP DO
264: ; BSR HexW
265: ; Do high word
266: ; Convert high word
267: ; Point to next area
268: ; Do low word
Dump ASCII conversion routine. Converts binary to printable ASCII. Unprintable binary characters are converted to periods.

Enter with:
AO -> Output area
Al -> Input data
DO = Byte count

Exit with:
(No change to registers)

Save registers
Adjust for DBRA
Printable?
Yes, use character
No, use '.'
Do loop end stuff
Move in actual character
Repeat until done
Restore registers
and return

Macintosh date conversion routine. Converts binary date to date/time: mm/dd/yy hh:mm:ss

Enter with:
318: ;
319: ;   DO.L = Binary date
320: ;   AO  -> Output area
321: ;
322: ;   Exit with:
323: ;
324: ;   (No change to registers)
325: ;
326: ;   Doesn't work for year 2100 (wrongly considers 2100 a leap year).
327: ;
328: ;   SecsMin BQU 60 ; Seconds/minute
329: ;   SecsHr BQU 3600 ; Seconds/hour
330: ;   SecsDay BQU 86400 ; Seconds/day
331: ;   SecsM28 BQU 2419200 ; Seconds/28-day month
332: ;   SecsM29 BQU 2505600 ; Seconds/29-day month
333: ;   SecsM30 BQU 2592000 ; Seconds/30-day month
334: ;   SecsM31 BQU 2678400 ; Seconds/31-day month
335: ;   SecsYr BQU 31536000 ; Seconds/(nonleap) year
336: ;   SecsLYr BQU 31622400 ; Seconds/leap year
337: ;   Date: MOVEM.L DO-DO/AO-Al,-(SP) ; Save registers
338: ;   MOV.L #4,Dl ; Dl to be year
339: ;   LYearLoop: ; Here to do years
340: ;   CMP.L #SecsLYr,D0 ; (Starts with 1904, a leap year)
341: ;   BLO YearFound ; Year is now correct
342: ;   SUB.L #SecsLYr,D0 ; Subtract off a year
343: ;   ADDQ.L #1,D1 ; Bump year counter
344: ;   MOVE.W #2,D3 ; Count 3 more nonleap years
345: ;   YearLoop: ; Loop of nonleap years
346: ;   CMP.L #SecsYr,D0 ; Another year left?
347: ;   BLO YearFound ; No, do the rest
348: ;   SUB.L #SecsYr,D0 ; Subtract a year
349: ;   ADDQ.L #1,D1 ; Bump year counter
350: ;   DBRA D3,YearLoop ; Repeat for nonleap years
351: ;   BRA LYearLoop ; Repeat till expired
352: ;   YearFound: ; Here when year found
353: ;   LEA MonthTab,Al ; Al  -> Table of secs/month
354: ;   MOVE.W D1,D3 ; Copy year to D3
355: ;   ANDI.W #3,D3 ; Check for divisible by 4
356: ;   BNE NotLeap ; Not a leap year
357: ;   LEA LMonthTab,Al ; Al  -> Secs/month for leap year
358: ;   NotLeap MOVQ.L #1,D2 ; D2 to be month
359: ;   MonthLoop: ; Now calculate month number
360: ;   CMP.L (Al),D0 ; Enough seconds left?
361: ;   BLT MonthFound ; No, month correct
362: ;   SUB.L (Al)+,D0 ; Subtract off month
363: ;   ADDQ.L #1,D2 ; Bump counter
364: ;   BRA MonthLoop ; Back for more
365: ;   MonthFound: ; D3 will accumulate days
366: ;   MOVQ.L #1,D3 ;
367: ;   DayLoop: ;
368: ;   SUB.L #SecsDay,D0 ; Subtract # seconds/day
369: ;   BLT DayFound ; Found day, quit
370: ;   ADDQ.L #1,D3 ; Increment D3

Listing E.1 – The Dump.asm file (continued)
371:  BRA  DayLoop  ; Loop till found
372:  DayFound:  ; Here when day found
373:  ADD.L #SecsDay,DO  ; Fix what we broke
374:  DIVS #SecsHR,DO  ; Can use 16-bit divide now
375:  MOVE.W DO,D4  ; D4 = hours
376:  SNAP DO  ; Remainder back to DO
377:  EXT.L DO  ; Clear high word
378:  DIVS #SecsMin,DO  ; Divide to get mins & secs
379:  MOVE.W DO,D5  ; D5 = Minutes
380:  SNAP DO  ; DO,W = Seconds
381:  MOVE.W DO,D6  ; Preserve in D6
382:  ; We have computed all fields in binary. Now convert them to ASCII.
383:  ;
384:  ;
385:  MOVE.W D2,DO  ; Month to DO
386:  BSR TwoDig  ; Convert
387:  MOVE.B '#',,(AO)+  ; Drop in separator
388:  MOVE.W D3,DO  ; Days to DO
389:  BSR TwoDig  ; Convert
390:  MOVE.B '#',,(AO)+  ; Separator
391:  MOVE.W D1,DO  ; Year to DO
392:  BSR TwoDig  ; Convert
393:  MOVE.B '#',,(AO)+  ; Separate date from time
394:  MOVE.W D4,DO  ; Hours to DO
395:  BSR TwoDig  ; Convert
396:  MOVE.B '#',,(AO)+  ; Separator
397:  MOVE.W D5,DO  ; Minutes to DO
398:  BSR TwoDig  ; Convert
399:  MOVE.B '#',,(AO)+  ; Separator
400:  MOVE.W D6,DO  ; Seconds to DO
401:  BSR TwoDig  ; Convert
402:  MOVEM.L (SP)+,DO-D6/10-Al  ; Restore registers
403:  RTS  ; Return
404:  ; "Thirty days hath September, April, June, and November."
405:  ;
406:  ;
407:  January Feb. March April May June
408:  July August Septem. October Novem. December
409:  Monthtab DC.L SecsM31,SecsM28,SecsM31,SecsM30,SecsM31,SecsM30
410:  DC.L SecsM31,SecsM31,SecsM30,SecsM31,SecsM30,SecsM31
411:  LMonthtab DC.L SecsM31,SecsM29,SecsM31,SecsM30,SecsM31,SecsM30
412:  DC.L SecsM31,SecsM31,SecsM30,SecsM31,SecsM31,SecsM31
413:  ;
414:  TwoDig routine. Converts byte in DO to two ASCII digits.
415:  ;
416:  ; Enter with:
417:  ;
418:  ; DO = Binary
419:  ; AO -> Output area
420:  ;
421:  ; Exit with:
422:  ;
423:  ; AO -> Next byte beyond output area

Listing E.1 – The Dump.asm file (continued)
Programming the Macintosh in Assembly Language

Listing E.1 - The Dump.asm file (continued)

424: ;
425: TwoDig: MOVE.L DO,-(SP) ; Save DO
426: ; EXT.L DO ; Clear high word
427: ; DIVS #10,DO ; Divide by 10
428: ; ADD.B #$'0',DO ; Convert to ASCII
429: ; MOVE.B DO,(AO)+ ; Place in buffer
430: ; SWAP DO ; Remainder to low word
431: ; ADD.B #$'0',DO ; Convert to ASCII
432: ; MOVE.B DO,(AO)+ ; Place in buffer
433: ; MOVE.L (SP)+,DO ; Restore DO
434: ; RTS ; Quit
435: ;
436: ; Dump program data area.
437: ; Strings that are written to the .DMP file:
438: ;
439: ; STRING_FORMAT 0
440: ; InfoStr: DC.B '13,'File Information:',13
441: ; InfEnd:
442: ; ReSStr: DC.B '13,'Resource Fork:',13
443: ; ResEnd:
444: ; DataStr: DC.B '13,'Data Fork:',13
445: ; DataEnd:
446: ; DumpLine: DC.B 'xxxxxxxx: XXXXXXXX XXXXXXXX XXXXXXXX XXXXXXXX XXXXXXXX ..............',13
447: ; EndDump:
448: ;
449: ; ASCII output area for file information
450: ;
451: ; InfoStr: DC.B 'Directory Index: '
452: ; Diridx: DC.B 'hhhh',13,'Attributes: '
453: ; Attri: DC.B 'hh',13,'Version: ' 
454: ; Vers: DC.B 'hh',13,'Finder File Type: ' 
455: ; FTPtype: DC.B 'hhhhhhhh' 
456: ; FTPAsc: DC.B '....',13,'Finder File Creator: '
457: ; FFFCreate: DC.B 'hhhhhhhh' 
458: ; FFCAsc: DC.B '....',13,'Finder Flags: '
459: ; FFlags: DC.B 'hh',13,'Finder Icon Location: '
460: ; FFIloc: DC.B 'hhhhhhhh',13,'Finder Folder Number: ' 
461: ; FNNum: DC.B 'hhhh',13,'File Number: ' 
462: ; OFileNum: DC.B 'hhhhhhhh',13,'Data Fork Start: ' 
463: ; DFStart: DC.B 'hhhh Logical EOF: ' 
464: ; DPLEOF: DC.B 'hhhhhhhh Physical EOF: ' 
465: ; DFPEOF: DC.B 'hhhhhhhh',13,'Resource Fork Start: ' 
466: ; RFStart: DC.B 'hhhh Logical EOF: ' 
467: ; RFLEOF: DC.B 'hhhhhhhh Physical EOF: ' 
468: ; RPFEOF: DC.B 'hhhhhhhh',13,'Creation Date: ' 
469: ; Creation: DC.B 'xx/xx/xx hh:mm:ss',13,'Modification Date: ' 
470: ; Modify: DC.B 'xx/xx/xx hh:mm:ss',13 
471: ; EndFinfo:
472: ;
473: ; Pascal strings
Listing E.1 - The Dump.asm file (continued)

1: Asm Dump.Asm Exec Edit
2: Asm RTL.Asm Exec Edit
3: Link Dump.Link Exec Edit

Listing E.2 - The Dump.job file

1:
2: Dump
3: RTL
4: IXXSTART
5: $
CHAPTER 5

The Lisa Pascal sieve program requires several files as part of its build procedure. The complete set of files to build the optimized program appear in Listings E.4–E.7.

Listing E.4 – Pascal source file for optimized sieve program

```
1: {$M+}
2: {$X-}
3: {$R-}
4: {$0-}
5: (***************************************************************************)
6: |
7: (* Lisa Pascal version of the sieve of Eratosthenes (optimized) *)
8: (* *)
9: (***************************************************************************)
10: PROGRAM xsieve; (* *)
11: USES {$U-}
12: {SU OBJ/Mentl'types} Mentl'types,
13: {SU OBJ/QuickDraw} QuickDraw,
14: {SU OBJ/OSintf} OSintf,
15: {SU OBJ/ToolIntf} ToolIntf;
16: CONST
17: ASIZE = 8190;
18: ITER = 10;
19: TIMELOC = 362;
20: TYPE
21: flagtype = array[0..ASIZE] of char;
22: VAR
23: i,j,k,count,prime : integer;
24: flags : flagtype;
25: start,stop : longint;
26: timeptr : ^longint;
27: 1:
28: PROCEDURE setflags(var flag : flagtype;
29: xcount: integer); external;
30: FUNCTION sieve (var flag : flagtype;
31: xcount: integer): integer;
32: external;
33: BEGIN
34: InitGraf(@trePort);
35: InitFonts;
36: InitWindows;
37: FlushEvents(everyEvent,0);
38: InitMenus;
39: TEInit;
40: InitDialogs(NIL);
41: InitCursor;
42: timeptr := pointer(TIMELOC);
43: start := timeptr^;
44: FOR j := 1 TO ITER DO
45: BEGIN
46: setflags(flags,ASIZE);
```
count := sieve(flags, ASIZE);  (* Do the sieve algorithm*)
END;  (* FOR J := 1 TO ITER *)
stop := timeptr;  (* Fetch stop time *)
writeln(count, ' primes ', stop-start, ' ticks');  (* Output time *)
END.

Listing E.4 – Pascal source file for optimized sieve program (continued)

.PROC SieveAsm
.DEF setflags
MOVE.L (SP)+, Al
SUB.W #1, Dl

.DEF sieve
MOVE.L (SP)+, Al
MOVE.W (SP)+, Dl
SUB.W #1, Dl
MOVL.W (SP)+, AO

@1: MOVEM.W 03-06 1 -(SP)
SUBJ.W #1, Dl
CLR.W 02
CLR.W 03
TST.B O(A0, 03.W)
BEQ @4
ADD.W 03, 05
ADDQ.W #3, 05
MOVE.W 03, 06
ADD.W 05, 06
CMP.W 04, 06
BGT @3
CLR.B O(A0, 06.W)
BRA @2

@3: ADDQ.W #1, 02

@4: ADDQ.W #1, 03
DBRA Dl, @1

LST (SP)+, 03-06
LST W 02, (SP)
JMP (Al)

Make accessible
Al = Return address
Dl = Array size
AD -> Flags array
Save registers
Replicate count
DBRA-adjust Dl
D2 = Count
D3 = i
If(flags[i])
Not prime, skip this one
D5 = "prime" variable
prime = i + 1
+ 3;
D6 = "k"
Add in "prime"
While (k <= SIZE)
Not <=, do next iteration
Flags[k] = 0;
Loop again
Increment count variable
Increment i
Loop till done
Restore registers
Set return value
Return
Mandatory END statement
Listing E.6 - EXEC file for optimized sieve program

```
1: $EXEC
2: P{ascal}$M+
3: xsieve.pas{Source File}
4: xsieve.lst{Listing File}
5: xpsieve{Object File}
6: A{semble}xpsieve.asm{Source file}
7: xpsieve.asm.lst{Listing File}
8: xasieve{Object File}
9: L{ink}? 
10: +X
11: {No more options}
12: xpsieve{Pascal Input file}
13: xasieve{Assembly Input file}
14: obj/quickdraw
15: obj/ostraps
16: obj/tooltraps
17: obj/pasinit
18: obj/paslib
19: obj/paslibasm
20: obj/rtlib
21: {no more input}
22: {list to console}
23: xsieve{output filename}
24: R{un}RMaker
25: xsieve.r{Input file}
26: R{un}Maccom
27: P{finder information}Y{es}L{isa to Macintosh}xpsieve.rs
28: xpsieve{Macintosh Filename}
29: APFL{Application Type}
30: JUNK{Application Signature}
31: {No bundle bit}
32: E{ject}Q{uit}
33: $ENDEXEC
```

Listing E.7 - Lisa RMAKER input file for sieve program

```
1: xpsieve.rs
2: 
3: TYPE JUNK = STR
4: ,0
5: Sievetest V 1.0
6: 
7: Type Code
8: xsieve.obj,0
```
CHAPTER 6

The MacDoodle program consists of nine files:

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</tr>
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</table>

1: ;
2: ;
3: ;
4: ;
5: ;
6: ;
7: ;
8: ;
9: ;
10: ;
11: ;
12: ;
13: ;
14: ;
15: ;
16: ;
17: ;
18: ;
19: ;
20: ;
21: ;
22: ;
23: ;
24: ;
25: ;
26: ;
27: ;
28: ;
29: ;

This is a multiframe application. The following files are required:

- MacDoodle.equ
- MacDoodleMenu.asm
- MacDoodleDraw.asm
- MacDoodleData.asm
- MacDoodle.asm
- MacDoodleRTL.asm
- MacDoodle.R
- MacDoodle.link
- MacDoodle.job

MacDoodle.asm. This program is a rather complete Macintosh application. It features drawing with QuickDraw, text entry, window scrolling and size control, and printing.

Version 1.00 30-May-1985

Listing E.8 - The MacDoodle.asm file
30:  XREF  VScroll ;  Vertical thumb scroll
31:  XREF  HScroll ;  Horizontal thumb scroll
32:  INCLUDE MAMLIB.ASM ;  Macro definitions
33:  INCLUDE MacDoodle.Equ ;  Global equates
34:  Program MacDoodle,DEBUGOFF,nMenu
35:  :    Perform initialization code
36:  :
37:  MOVE.L AO,WPointer(A5) ;  Save window address
38:  MOVE.L DO,SSize(A5) ;  " " size
39:  CLR.B Flags(A5) ;  Clear flags byte
40:  JSR DrawInit ;  Call initialization routines
41:  JSR MenuInit ;
42:  :
43:  :    This is the top of the event loop. Get an event from the run-time library routine, and call the proper routine to process it.
44:  :
45:  EVLoop: GETEVENT Cursor(A5) ;  Get next event
46:     LSL.W #2,DO ;  Multiply by 4
47:     LEA Jmprab,AO AO -> Jump array
48:     JSR O(A0,00) Jl.BTlp to event handler
49:     BRA EVLoop ;  Get next event
50:  :
51:  Event Jump Table
52:  :
53:  JmpTab:
54:     JMP NullEvt ;  Table of jumps to routine handlers
55:  ;  0  No event, get next
56:     JMP Mouse ;  1  Mouse down in window
57:     JMP NullEvt ;  2  Mouse up, ignore
58:     JMP KeyDown ;  3  Key down
59:     JMP NullEvt ;  4  Key up, ignore
60:     JMP KeyDown ;  5  Autokey (same as key down)
61:     JMP Update ;  6  Update event
62:     JMP NullEvt ;  7  Disk event, ignore
63:     JMP NullEvt ;  8  Activate event, ignore
64:     JMP NullEvt ;  9  Abort event, ignore
65:     JMP NullEvt ; 10  Network event, ignore
66:     JMP NullEvt ; 11  Driver event, ignore
67:     JMP NullEvt ; 12  Application event #1
68:     JMP NullEvt ; 13  Application event #2
69:     JMP NullEvt ; 14  Application event #3
70:     JMP NullEvt ; 15  Application event #4
71:     JMP MenuEvt ; 16  Menu choice
72:     JMP CloseEvt ; 17  Close-window event
73:     JMP Resize ; 18  Resize-window event
74:     JMP DoScroll ; 19  Scroll event
75:     JMP VScroll ; 20  Scroll V with thumb
76:     JMP HScroll ; 21  Scroll H with thumb
77:  NullEvt RTS ;  Null event handler
78:  ENDPROGRAM

Listing E.8 – The MacDoodle.asm file (continued)
MacDoodle equates. This file contains most of the symbolic definitions for the MacDoodle program.

Revision history:

<01> 31-Aug-85 Install NEWPACK conditional

Event system equates:

EvMenu EQU 16 ; Menu choice code
EvClose EQU 17 ; Close-window choice

Menu number equates

mApple EQU 1 ; Apple menu
mFile EQU 2 ; File menu
mEdit EQU 3 ; Edit menu
mDraw EQU 4 ; Draw menu
mPen EQU 5 ; PenSize menu
mFont EQU 6 ; Text menu
mStyle EQU 7 ; Style menu
nMenu EQU 7 ; Number of menus

CheckM EQU $12 ; Check mark character
CursChar EQU $5F ; Cursor character (underline)

NEWPACK EQU 1 ;<01> Set to zero to use O/S pack/unpack

Flags byte definitions

F_File EQU 0 ; 1 => File in window
F_Change EQU 1 ; 1 => Unsaved changes
F_Text EQU 2 ; 1 => Processing text

Macro to set Flags

.Macro SetFlag
    BSET #&1,Flags(A5) ; Set the flag
.Endm

Macro to clear Flags

.Macro ClrFlag
    BCLR #&1,Flags(A5)
.Endm

Macro to test Flags

.Macro TstFlag
    BTST #&1,Flags(A5)
.Endm

Listing E.9 – The MacDoodle.equ file
Cursor definitions

Arrow EQU 0 ; Arrow cursor
IBeam EQU 1 ; Text cursor
Cross EQU 2 ; Cross cursor
Plus EQU 3 ; Plus cursor
Watch EQU 4 ; Watch cursor

Data XREFs

Cursor EQU ; Current cursor value
PenSize EQU ; Pen size value
PenType EQU ; Pen type value
DrwType EQU ; Draw type value
FBufLen EQU ; File buffer data length
FileBuf EQU ; Paint file buffer
FBufSiz EQU ; File buffer size
UnDoBuf EQU ; Undo buffer handle
UtfBufLen EQU ; Undo buffer data length
UtfBufSiz EQU ; Undo buffer size
ScrBuf EQU ; Screen buffer
SBufSiz EQU ; Screen buffer data length
FName EQU ; File name buffer
InfoBuf EQU ; File info buffer
FType EQU ; Type array for FOPEN
HdrBuf EQU ; File header buffer
HBufLen EQU ; Length of header buffer
FBStart EQU ; Beginning of file buffer in window
FEnd EQU ; End of file buffer in window
WPointer EQU ; Window pointer
SRow EQU ; Row number on screen
SpPoint EQU ; Point for (0,0) on screen (in ScrBuf)
SSize EQU ; Screen size (local coords)
FontSize EQU ; Font selection number
FontNum EQU ; Text font number
TextFlag EQU ; Text flags word
TextSize EQU ; Text size in points
TextSel EQU ; Size selection on menu
VolRef EQU ; Volume reference number

TextFlag bit definitions

Bold EQU 0 ; Bold bit
Italic EQU 1 ; Italic
ULine EQU 2 ; Underline
Outline EQU 3 ; Outline
Compressed EQU 5 ; Compressed
Expanded EQU 6 ; Expanded
mBold EQU 1 ; Mask for bold bit
mItalic EQU 2 ; Mask for italic bit
mULine EQU 4 ; Mask for underline bit

Listing E.9 - The MacDoodle.equ file (continued)
107: mOutline EQU 8 ; Mask for outline
108: mShadow EQU 16 ; Mask for shadow
109: mCompress EQU 32 ; Mask for compressed
110: mExpand EQU 64 ; Mask for expanded
111: ;
112: ; Other text definitions
113: ;
114: BS EQU 8 ; Backspace character
115: CR EQU 13 ; Carriage-return character
116: TBuffSize EQU 512 ; Input buffer for keys
117: ;
118: ; Font definitions
119: ;
120: Chicago EQU 0 ; System font
121: NewYork EQU 2 ;
122: Geneva EQU 3 ;
123: Monaco EQU 4 ;
124: Venice EQU 5 ;
125: London EQU 6 ;
126: Athens EQU 7 ;
127: SanFran EQU 8 ;
128: Toronto EQU 9 ;
129: Cairo EQU 11 ;
130: LosAng EQU 12 ;
131: Seattle EQU 130 ;
132: ;
133: ; Macro to construct jump tables
134: ;
135: .MACRO JTAB ; Up to 9 labels
136: IF '\%1' <> '' ; Is parameter nonblank?
137: DC.W \%1-JBASE ; Offset from table base
138: ENDIF ; Parameter nonblank
139: IF '\%2' <> '' ; Is parameter nonblank?
140: DC.W \%2-JBASE ; Offset from table base
141: ENDIF ; Parameter nonblank
142: IF '\%3' <> '' ; Is parameter nonblank?
143: DC.W \%3-JBASE ; Offset from table base
144: ENDIF ; Parameter nonblank
145: IF '\%4' <> '' ; Is parameter nonblank?
146: DC.W \%4-JBASE ; Offset from table base
147: ENDIF ; Parameter nonblank
148: IF '\%5' <> '' ; Is parameter nonblank?
149: DC.W \%5-JBASE ; Offset from table base
150: ENDIF ; Parameter nonblank
151: IF '\%6' <> '' ; Is parameter nonblank?
152: DC.W \%6-JBASE ; Offset from table base
153: ENDIF ; Parameter nonblank
154: IF '\%7' <> '' ; Is parameter nonblank?
155: DC.W \%7-JBASE ; Offset from table base
156: ENDIF ; Parameter nonblank
157: IF '\%8' <> '' ; Is parameter nonblank?
158: DC.W \%8-JBASE ; Offset from table base
159: ENDIF ; Parameter nonblank

Listing E.9 – The MacDoodle.equ file (continued)
IF '9' <> '' ; Is parameter nonblank?
DC.W $9-JBASE ; Offset from table base
ENDIF ; Parameter nonblank
; Resource file equates
ProgramErr EQU 129 ; Program error alert template
Werr EQU 130 ; Write error alert template
Cerr EQU 131 ; File create error alert
Oerr EQU 132 ; File open error alert
BuffErr EQU 134 ; Buffer error alert
ReadErr EQU 135 ; Read error alert
MemErr EQU 136 ; Memory error
NotText EQU 137 ; Not doing text
; Dialogs
SaveIt EQU 2 ; Save changes to ... ?
DoSave EQU 1 ; 1 => Yes, save it
; File system equates
FType EQU 32 ; Finder file type offset
FFAppl EQU 36 ; Finder application signature
MPType EQU $504E5447 ; PNTG MacPaint file
DAppl EQU $444F4F44 ; DOOD Doodle signature
DFSize EQU 54 ; Offset to data fork size in bytes
HdrSize EQU 512 ; MacPaint file header size
FileSize EQU $4000 ; 16K file size
UnDoSize EQU $2000 ; 8K for undo buffer
ScrSize EQU $5460 ; 21.6K for screen image buffer
SwIdth EQU 72 ; Width in bytes
StLength EQU 300 ; Length in bytes
FLength EQU 720 ; File length in rows
NullPat EQU $9900 ; Null pattern
LScroll EQU 8 ; # pixels in a line scroll
; Register save/restore macros
.PUSHALL
MOVEM.L D0-D7/A0-A4/A6,-(SP)
.ENDM
; Startup data area equates
ParmHdl EQU 16 ; Offset to parameter handle
PMsg EQU 0 ; Parameter message

Listing E.9 – The MacDoodle.equ file (continued)
Listing E.9 - The MacDoodle.equ file (continued)

1: ;
2: ; MacDoodleData.asm. This file contains all global data items shared
3: ; between modules.
4: ;
5: ;
6: ; Initialized data:
7: ;
8: ;
9: ;
10: ;
11: ;
12: ; Uninitialized data:
13: ;
14: ;
15: ;
16: ;
17: ;
18: ;
19: ;
20: ;
21: ;
22: ;
23: ;
24: ;
25: ;

Listing E.10 - The MacDoodleData.asm file
Listing E.10 – The MacDoodleData.asm file (continued)
MacDoodleDraw.asm. This file contains the procedures related to the use of QuickDraw in the MacDoodle window.

Revision history:

<01> Install hand-coded Pack and UnPack routines

Include Maclib.Asm ; Include macro library
Include MacDoodle.Equ ; Include definition file
Include QuickEqu.D ; Include Quickdraw equates
Include MacTraps.D ; and trap definitions
XDEF KeyDown ; Key-down event
XDEF CloseText ; Close out text processing
XDEF UpDate ; Macintosh update event
XDEF ReDraw ; Redraw window
XDEF EScreen ; Erase-screen routine
XDEF PrDraw ; Perform drawing for printer
XDEF ReSize ; Resize window
XDEF RePack ; Create single packed buffer
XDEF UnBuf ; Create 2 packed, 1 unpacked buffer(s)
XDEF DoScroll ; Line, page scroll handler
XDEF VScroll ; Vertical thumb scroll handler
XDEF HScroll ; Horizontal " "
XDEF Mouse ; Mouse-down handler
XDEF DrawInit ; Initialize routine for draw
XDEF UnPack ; Unpack MacPaint file
XDEF Pack ; Pack MacPaint file
XDEF PackU ; Pack screen buffer to undo buffer

DrawInit routine. This code is executed before we begin handling events.

Entry conditions:

( none )

Exit conditions:

( none )

Here to initialize

Set vertical min to zero
Set horizontal min to zero
Init point to (0,0)
Quit

ReSize routine. This procedure is called to change the size of the window.

Normally called as the result of a resize event from the event system.

Entry conditions:
DO = ReSize code (18 decimal)

D1 = New bottom-right point

Exit conditions:

Listing E.11 – The MacDoodleDraw.asm file (continued)
Buffer is accurate

Exit conditions:

Window set to match buffer

Routine SaveScreen is called to save the current screen in the screen buffer (the inverse of ReDraw).

Entry conditions:

Routine SaveScreen is called to save the current screen in the screen buffer (the inverse of ReDraw).

Entry conditions:

CopySetup routine. Calculates values for the screen bitmap and source and destination rectangles for the screen and screen buffer.

Entry conditions:
Listing E.11 - The MacDoodleDraw.asm file (continued)

Exit conditions:
No registers saved

Listing E.11 - The MacDoodleDraw.asm file (continued)
Listing E.11 - The MacDoodleDraw.asm file (continued)
Listing E.11 – The MacDoodleDraw.asm file (continued)
318: ;
319: ; Stack purged of all of the above
320: ; If the part code is nonzero, we actually do the scrolling.
321: ; If zero, we just ignore. The variable ScrType tells us
322: ; what type of scroll to do.
323: ;
324: XScroll
325: MOVE.L (SP)+,AO ; Fetch return address
326: MOVE.W (SP)+,D1 ; and part code
327: MOVE.L (SP)+,DO ; and control handle
328: MOVE.L AO,-(SP) ; ReStack return address
329: TST.W D1 ; Still in right spot?
330: BNE @1 ; Yes, continue
331: RTS ; No, quit now
332: @1 PUSHALL ; Save registers
333: MOVE.W ScrType(A5),D2 ; Fetch scroll type
334: MOVE.W #$Scrroll,D3 ; Move pixel count to D3
335: MOVE.W SSize(A5),D4 ; D4 = Vertical page size
336: MOVE.W SRow(A5),D5 ; D5 = Vertical position of (0,0)
337: BTST #2,D2 ; Vertical or horizontal?
338: BNE TST.W ; Still in right spot?
339: RTS ; Yes, continue
340: MOVE.W SSize+2(A5),D4 ; Correct page size
341: MOVE.W SPoint+2(A5),D5 ; D5 = Horizontal position
342: @2 BMP ; Page or line scroll?
343: BNE TST.W ; Still in right spot?
344: ADD.W D5,D3 ; Make absolute
345: @4 ADD.W D3,DO ; Move to
346: SWAP D0 ; DO high word
347: BTST #2,D2 ; Vertical or horizontal?
348: BNE TST.W ; Still in right spot?
349: BRA xHScroll ; Else, go do vertical
350: ; Thumb scroll routines. Routines VScroll and HScroll
351: ; indicate a thumb scrolling request.
352: ; Entry conditions:
353: ;
354: ; Exit conditions:
355: ;
356: ; (none)
357: VScroll PUSHALL ; Save registers
358: xVScroll ; Here to skip PUSHALL
359: SWAP D0 ; Value to low half
360: TST.W D0 ; Value positive?
361: BGE @1 ; Yes, it's OK

Listing E.11 - The MacDoodleDraw.asm file (continued)
371:  CLR.W  DO              ; No, force it
372:  @1     MOVE.W #FLen,D1 ; D1 = Maximum size
373:  SUB.W  SSR(A5),D1    ; Check for > max
374:  CMP.W  00,D1        ; OK, leave it
375:  BGE @2             ; Too big, force to max
376:  @2     BSR RePack   ; Force back to single image
377:  @2     MOVE.W D0,SRow(A5) ; Set row number
378:  SetVVal D0         ; Move the thumb
379:  BSR UnBuf          ; Unpack proper amount of screen buffer
380:  POPALL             ; Restore registers
381:  RTS                ; Return to caller
383:  ; Equivalent routine for horizontal scroll
384:  ;
385:  ;
386:  HScroll PUSHALL    ; Save registers
387:  xHScroll           ; Here to skip PUSHALL
388:  SWAP D0            ; Value to low-order word
389:  TST.W  D0          ; Value OK?
390:  BGE  @1           ; Yes, must be > 0
391:  CLR.W  D0          ; No, make minimum
392:  @1     MOVE.W #$SWidth*8,D1 ; Fetch screen width
393:  SUB.W  SSize+2(A5),D1 ; Calculate largest value
394:  CMP.W  00,D1       ; Check it
395:  BGE @2            ; G.E. >= in range
396:  MOVE.W D1,D0      ; Else make maximum value
397:  @2     SetHVal D0  ; Set the value
398:  MOVE.W D0,SPoint+2(A5) ; Set for ReDraw
399:  POPALL            ; Pop registers
400:  BRA ReDraw         ; Refresh screen
401:  ;
402:  ; Routine Mouse is called when a mouse-down event occurs.
403:  ;
404:  ; Entry conditions:
405:  ;
406:  ;   D1.L = Mouse point (local coords)
407:  ;
408:  ; Exit conditions:
409:  ;    (Mouse up, correct thing drawn)
410:  ;
411:  ;
412:  Mouse:             ;
413:  TstFlag F Text     ; Text open?
414:  BBE  @1            ; No, continue
415:  JSR    CloseText   ; Yes, close first
416:  @1     MOVE.L D1,Point1(A5) ; Save original point
417:  BSR    PackD       ; Save screen in undo buffer
418:  PEA    OldPen(A5)  ; Save pen state
419:  ;
420:  MOVE.W PenSize(A5),D1 ; Fetch pen size
421:  MOVE.W DL,-(SP)   ; Push
422:  MOVE.W DL,-(SP)   ; Set new pen size
423:  PenSize           ;
424:  MOVE.L Point1(A5),-(SP); Push mouse point
425:  _MoveTo           ; Move pen to mouse point

Listing E.11 – The MacDoodleDraw.asm file (continued)
426: MOVE.W DrwType(A5),D0 ; Fetch draw routine index
427: SUBQ.W #1,D0 ; Force zero relative
428: LSL.W #1,D0 ; Multiply x 2 for word index
429: MOVE.W JBASE(D0,D0),D0 ; Fetch offset
430: JSR JBASE(D0,D0) ; Call proper routine
431: PEA OldPen(A5) ; Now
432: _SetPenState ; restore pen
433: SetFlag F Change ; Mark a change to file
434: CMP.L #5,DrwType(A5) ; Just start text?
435: BEQ @2 ; Yes, don't save screen
436: JSR SaveScreen ; Save screen in screen buffer
437: RTS ; Back for next event
438: Void: StopAlert #ProgramErr ; Fatal error!
439: EXIT ; Back to Finder
440: ;
441: ; Jump table for Draw routines
442: ;
443: JBASE JTAB Lines, FreeH, Boxes, Ovals
444: JTAB Text, Void, Eraser, Void
445: ;
446: ; Lines routine. Draw a straight line using the current
447: ; pen size.
448: ;
449: Lines:
450: MOVE.W #Patxor,-(SP) ; Line handler
451: _PenMode ; to XOR for dragging
452: MOVE.L Pointl(A5),D3 ; Save mouse point
453: MOVE.L D3,D4 ; Need original point
454: @1: PEA Pointl(A5) ; Temp point
455: _GetMouse ; Fetch mouse in local coords
456: CMP.L Pointl(A5),D3 ; Check against old
457: BEQ @2 ; Equal, don't update
458: BSR DrawLine ; Cancel old line
459: MOVE.L Pointl(A5),D3 ; Save new point
460: BSR DrawLine ; Draw new line
461: @2: CLR.W -(SP) ; Room for result
462: _StillDown ; Mouse still down?
463: TST.B (SP)+ ; IF NE,
464: BNE @1 ; yes, still down
465: MOVE.W #PatCopy,-(SP) ; Change pen
466: _PenMode ; to copy mode
467: BSR DrawLine ; Draw final line
468: RTS ; Return to caller
469: ;
470: ; DrawLine routine. Draws a line from point in D4.L
471: ; to point in D3.L.
472: ;
473: DrawLine ; Draw a line
474: MOVE.L D4,-(SP) ; Reposition
475: _Moveto ; pen
476: MOVE.L D3,-(SP) ; Cancel old line
477: _Lineeto ; thusly
478: RTS ; Return to caller

Listing E.11 – The MacDoodleDraw.asm file (continued)
Eraser routine. Take a freehand swipe at existing bitmap. Same as a Sketch with a BIC pen mode.

```
479: ;
480: ; Eraser routine. Take a freehand swipe at existing
481: ; bitmap. Same as a Sketch with a BIC pen mode.
482: ;
483: Eraser:
484: MOVE.W #patBic, -(SP) ; Push desired mode
485: _PenMode
486: ; Set the pen mode
487: ;
488: Fall through to FreeH
489: ;
490: FreeH routine. Draw a freehand line using the current
491: ; pen size.
492: ;
493: FreeH:
494: MOVE.L Pointl(A5), D3
495: @1: PEA Pointl(A5)
496: _GetMouse
497: CMP.L Pointl(A5), D3
498: BBQ @2
499: MOVE.L Pointl(A5), D3
500: _Lineto
501: @2: CLR.W -(SP) ; Sketch handler
502: _StillDown
503: TST.B (SP)+
504: BNE @1 ; Room for result
505: RTS ; If NE, yes, still down
506: ;
507: Routines Boxes and Ovals share common code to draw
508: ; stretchy boxes and ovals.
509: ;
510: Boxes
511: CLR.L D7
512: BRA DoRect
513: Ovals
514: MOV.EQ.L #1,D7
515: DoRect
516: MOVE.L Pointl(A5), D1
517: LEA NewRect(A5), A3
518: LEA OldRect(A5), A2
519: LEA TmpRect(A5), A4
520: MOVEM.L D1/D2, (A2)
521: MOVEM.L D1/D2, (A3)
522: MOVE.W #PatXor,-(SP)
523: @PenMode ; RectLoop
524: CLR.W -(SP) ; to Xor mode
525: _StillDown
526: TST.B (SP)+
527: BBQ DoFinal
528: PEA BotRight(A3)
529: _GetMouse
530: CLR.W -(SP)
531: MOVEM.L A2/A3, -(SP)
532: 
533: Listing E.11 – The MacDoodleDraw.asm file (continued)
```
Listing E.11 – The MacDoodleDraw.asm file (continued)
Listing E.11 - The MacDoodleDraw.asm file (continued)
CloseText routine. Closes out text entry.

Also carriage return

Save registers

Erase cursor character

Get character count

Set byte

Set text

to copy mode

Go back

to start position

Push string address

Redraw in copy mode

No longer in text mode

Save screen in buffer now

Restore registers

Done

DrawCursor routine. Draws a character for cursor.

Reset pen location

Delete cursor

Return to caller

Hand-coded pack/unpack

UnPack routine. Unpacks a MacPaint file to a bitmap.

File format is:

<positive count>"count" unique bytes

<negative count>repeated byte

There are 72 bytes/line, 720 lines total. Counts are

DBRA-adjusted in packed format.

Entry conditions:

AO -> Source area (packed format)

Al -> Destination area

A6 -> First byte beyond destination area

DO = Number of rows to unpack

Exit conditions:

AO -> First byte not unpacked

Al -> First byte not used in destination

This routine is rather time critical, so space is traded for speed where possible.

Listing E.11 – The MacDoodleDraw.asm file (continued)
Listing E.11 – The MacDoodleDraw.asm file (continued)
Listing E.11 – The MacDoodleDraw.asm file (continued)
Pack routine. This routine performs the inverse of UnPack.

Entry conditions:

AO → Source (raw bits)
A1 → Destination (packed)
A6 → Limit address
DO = Number of rows to pack

Exit conditions:

AO → First byte not packed
A1 → First free byte in destination

Listing E.11 – The MacDoodleDraw.asm file (continued)
850: ; Entry conditions: (none)
851: ; Exit conditions:
852: ;
853: ;
854: ; DO = Number of bytes unpacked
855: ;
856: PACKJ PUSHALL ; Save caller's registers
857: MOVE.L UndoBuf(A5), AO ; AO -> Undo handle
858: MOVE.L A0, A3 ; Save handle
859: HLock ; Lock it down, too
860: MOVE.L (AO), Al ; Al -> Undo buffer
861: MOVE.L Al, A4 ; Save this
862: MOVE.L ScrBuf(A5), AO ; AO -> Handle
863: MOVE.L A0, A2 ; Save handle
864: HLock ; Lock it down
865: MOVE.L (AO), AO ; AO -> Unpacked data
866: MOVE.W SSize(A5), DO ; DO = Count
867: MOVE.L Al, A6 ; Calculate
868: ADDA.L UBufSiz(A5), A6 ;
869: BSR Pack ; Pack it
870: SUB.L A4, Al ; Compute byte count
871: MOVE.L Al, (SP) ; Put it in DO (via POPALL)
872: MOVE.L A2, AO ; Unlock
873: HUnLock ;
874: MOVE.L A3, AO ; locked
875: HUnLock ; all
876: POPALL ; Restore registers
877: RTS ; Return to caller
878: ;
879: ; RePack routine. Packs all from the screen into one contiguous buffer.
880: ;
881: ; Entry conditions:
882: ;
883: ; SSize(A5) must be correct
884: ;
885: ; Exit conditions:
886: ;
887: ; (None)
888: ;
889: RePack PUSHALL ; Save all registers
890: BSR Packj ; Pack screen to UndoBuf
891: MOVE.L UndoBuf(A5), AO ; AO -> Undo buffer
892: MOVE.L (AO), AO ;
893: MOVE.L FileBuf(A5), Al ; Al -> File buffer
894: MOVE.L (Al), Al ; Save this
895: MOVE.L Al, A2 ;
896: CLR L D1 ; Clear D1 to convert
897: MOVE.W PBBend(A5), D1 ; D1 = # bytes in bottom area
898: SUB.L PBufSiz(A5), D1 ; Subtract buffer size
899: NEG L D1 ; D1 = Buffer offset
900: SUB.W D0, D1 ; Compute new buffer offset
901: LEA O(Al, DL.W), Al ; Al -> New buffer offset
902: MOVE.L Al, A4 ; Save this

Listing E.11 – The MacDoodleDraw.asm file (continued)
Listing E.11 - The MacDoodleDraw.asm file (continued)

```
903: SUBQ.W #1,DO ; Adjust DO for DBRA now
904: CMP.W FBStart(A5),DL ; Overlap?
905: BGE @1 ; No, it's OK
906: StopAlert #BuffErr ; Out of memory,
907: EXIT ; all is lost
908: @1 MOVE.B (AO)+,(A1)+ ; Move in undo buffer
909: DBRA DO,@1 ; Until done
910: SUB.W FBStart(A5),DL ; Subtract start length
911: ANDI.L #$FFFF,DL ; Mask off upper part
912: SUB.L FBSize(A5),DL ; Compute
913: NEG.L DL ; end length
914: MOVE.W DL,FBEnd(A5) ; Store new count
915: MOVE.W FBStart(A5),DO ; DO = # bytes to move
916: BEQ @3 ; EQ => Top region empty
917: LEA 0(A2,DO,W),A2 ; A2 -> End of start region
918: SUBQ.W #1,DO ; DBRA-adjusted
919: CLR.W FBStart(A5) ; No bytes here now
920: @2 MOVE.B -(A2),-(A4) ; Move in
921: DBRA DO,@2 ; start of buffer
922: @3 POPALL ; Restore registers
923: RTS ; Back to caller
924: ;
925: ; UnBuf routine. Unpacks a consolidated buffer (as when reading a file)
926: ; into the three separate regions: buffer start (FBStart), screen buffer
927: ; (unpacked), and buffer end (FBEnd).
928: ; Entry conditions:
929: ; Packed data in end of buffer
930: ; SSiz(A5) is correct
931: ; SRow(A5) is correct
932: ; Exit conditions:
933: ; Buffer split into three pieces
934: ; Save the registers
935: ; AO -> File buffer handle
936: ; Lock it
937: ; Move in undo buffer
938: ; Save for later
939: ; Load byte count
940: ; Compute offset
941: ; Remember this
942: ; D2 = # bytes
943: ; If EQ, do unpack
944: ; D3 = Temp
945: ; Fetch count byte
946: ; Store in buffer top

UnBuf
```

Listing E.11 – The MacDoodleDraw.asm file (continued)
Listing E.11 – The MacDoodleDraw.asm file (continued)

1: ; 
2: ; MacDoodleMenu.asm. This file contains the menu event handlers for the 
3: ; MacDoodle program.
4: ;
5: ; Revision history:
6: ;
7: ; <01> 31-Aug-85 Install changes for Exercises 6.2 and 6.3
8: ;
9: ; There are 7 menus, as follows:
10: ;
11: ;
12: ;
13: ;
14: ;
15: ;
16: ;
17: ;
18: ;
19: ;
20: ;
21: ;
22: ;
23: ;
24: ;
25: ;
26: ;
27: ;
28: ;
29: ;
30: ;
31: ;
32: ; Note that the lines drawn between items occupy a menu choice number 
33: ; that can never be selected.
34: ;
35: ; PlainSel EQU 1 ; Plain text selection
36: ; BoldSel EQU 2 ; First text attr selection
37: ; CompSel EQU 7 ; Compressed selection
38: ; ExpSel EQU 8 ; Last text attr selection
39: ; SizeBase EQU 10 ; First size entry
40: ;
41: ;
42: ; INCLUDE MACLIB.ASM ; Include macro library
43: ; INCLUDE MacDoodle.Equ ; Include MacDoodle equates file
44: ; XDEF MenuInit ; Initializer routine

Listing E.12 – The MacDoodleMenu.asm file
Listing E.12 - The MacDoodleMenu.asm file (continued)
Listing E.12 – The MacDoodleMenu.asm file (continued)
155: PDone    EXIT ; and quit
156: ;        APOpen routine. Opens a file from application parameter area.
157: ;
158: ;
159: APOpen    LEA PFName(A4),AO ; AO -> Finder-supplied name
160: LEA FName(A5),AI ; AI -> File name area
161: CLR.W    DO ; DO = Count byte
162: MOVE.B  (AO),DO ;
163: &2 MOVE.B (AO)+(AI)+ ; Move to expected area
164: DBRA     FName(A5);<01> Display file name
165: WITLE    FName(A5);<01> Save volume reference 
166: MOVE.W  VolRef(A4),VolRef(A5); Open file
167: OPEN     FName(A5),DEFAULT,PVRef(A4); Open file
168: MOVE.W  DO,D2 ; Save file number
169: BPL      @2 ; If OK
170: StopAlert #OErr ; Tell user we couldn't do it
171: EXIT ; then die
172: @4 MOVE.W VolRef(A5),D1 ;<01> Set D1 to vol ref
173: BSR      OpenOK ; Complete the open
174: TstFlag  F File ; Did it go ok?
175: BEQ @3 ; EQ => No, alert already done
176: RTS ;<01> Back to caller
177: MemError ; Here if out of memory
178: StopAlert #MemErr ; Croak
179: EXIT ;
180: FCount   DS.W 1 ;<01> Space for file count
181: LastF    DS.L 1 ;<01> -> Last file done
182: ;
183: ; Close event. This routine is called when the user clicks in the window
184: ; close box. We treat this exactly like a New choice from the File
185: ; menu. This deviates from standard Macintosh behavior in that we don't
186: ; close the window.
187: ;
188: CloseEvt:    ; Called from the event loop
189: MOVE.L #$20001,D1 ; Fake out menu handler
190: ;
191: ; Menu event handler. Entered with constant 10 (hex) in DO.W
192: ; and the menu number in DL.W. The high word of DL has the selection
193: ; number. The menu number is in the range 2-n and the choice number
194: ; is in the range 1-n. (RTL handles menu #1, the Apple menu.)
195: ;
196: MenuEvt:    ; Here for a menu choice
197: TstFlag  F Text ; Text open?
198: BEQ @1 ; Yes, continue
199: JSR      CloseText ; Yes, close first
200: @1: MOVE.W DL,D2 ; Copy menu choice to D2
201: SUBQ.W #1,D2 ; Force choice zero relative
202: SWAP      D1 ; Menu number to DL.W
203: SUBQ.W #2,D1 ; Force zero relative
204: MOVE.W DL,D3 ; Copy to D3
205: SWAP      D1 ; Choice back to DL.W
206: MULU     #Menu-1,D2 ; Multiply D2 by # menus
207: ADD.W    D2,D3 ; Add in menu choice
208: LSL.W    #1,D3 ; Multiply by entry size (word)
209: MOVE.W JBASE(D3.W),D3 ; Fetch offset word

Listing E.12 - The MacDoodleMenu.asm file (continued)
210:  JMP     JBASE(D3.W) ; Go to routine
211:  Void:  StopAlert #ProgramErr    ; Here if a real problem
212:       EXIT            ; Fade away
213:       ;
214:       ; Define menu jump table
215:       ;
216:  JBASE: ; Offset for jump
217:       ;
218:  ;       File    Edit    Draw    PenSize    Font    Style
219:       ;
220:       JTAB     New, Undc, Lines, SetPen, SetFont, Plain ; 1
221:       JTAB     xOpen, Void, FreeH, SetPen, SetFont, TStyle ; 2
222:       JTAB     Save, Cut, Boxes, SetPen, SetFont, TStyle ; 3
223:       JTAB     SaveAs, Copy, Ovals, SetPen, SetFont, TStyle ; 4
224:       JTAB     Void, Paste, Text, SetPen, SetFont, TStyle ; 5
225:       JTAB     xPrint, Void, Void, SetPen, SetFont, TStyle ; 6
226:       JTAB     Void, Void, Eraser, SetPen, SetFont, TCompress ; 7
227:       JTAB     xQuit, Void, Void, SetPen, SetFont, TExpand ; 8
228:       JTAB     Void, Void, EraseA, SetPen, SetFont, Void ; 9
229:       JTAB     Void, Void, Void, SetPen, SetFont, TSize ; 10
230:       JTAB     Void, Void, Void, SetPen, SetFont, TSize ; 11
231:       JTAB     Void, Void, Void, SetPen, SetFont, TSize ; 12
233:       JTAB     Void, Void, Void, Void, SetPen, TSize ; 14
234:       JTAB     Void, Void, Void, Void, SetPen, TSize ; 15
235:       JTAB     Void, Void, Void, Void, SetPen, TSize ; 16
236:       JTAB     Void, Void, Void, Void, Void, TSize ; 17
237:       JTAB     Void, Void, Void, Void, Void, TSize ; 18
238:       ;
239:       ; New menu selection. Check for modifications and ask the
240:       ; user if he wants to save them. Do a save if requested.
241:       ; Then obliterate (zero) the buffers and display.
242:       ;
243:       ; New:
244:       ;
245:       BSR     ChkSave        ; Check for save first
246:       MOVE.L  HdrBuf(A5),AO  ; AO -> header buffer
247:       MOVE.L  (AO),AO       ;
248:       MOVE.L  HBufLen(A5),DO ; DO = Byte Count
249:       SUBQ.L  #1,DO        ; Adjust for DBRA
250:       @1: CLR.B (AO)+      ; Clear out header buffer
251:       DBRA  D0,@1         ;
252:       MOVE.L  FileBuf(A5),A4 ; A4 -> File buffer
253:       MOVE.L  (A4),A4      ;
254:       MOVE.L  #FLength*2,D3 ; Buffer length
255:       MOVE.L  D3,D4        ; Copy to D4
256:       MOVE.W  D3,DO       ; and to DO
257:       LSR.W  #1,DO        ; Adjust DO for word count
258:       SUBQ.W  #1,DO       ; and DBRA
259:       SUB.L  FBufSz(A5),D4 ; Compute buffer offset
260:       NEG.L  D4           ;
261:       LEA  0(A4,D4.L),A4 ; Copy to AO
262:       MOVE.L  A4,AO       ; Fill buffer with
263:       DBRA  D0,@2         ; Compressed zero pattern

Listing E.12 – The MacDoodleMenu.asm file (continued)
264:  ClrFlag F_File          ; No file name for buffer now
265:  WRtitle 'No File'     ; Set the window title
266:  BRA DoUpdate          ; Otherwise, it's just like a finished read
267:  ; xOpen routine. (The "x" is necessary to prevent assembler
268:  ; confusion between the Open label and the OPEN macro.)
269:  ; Open a new file and read it into the buffer.
270:  ;
271:  ;
272:  ;
273:  xOpen
274:  ;
275:  BSR ChkSave            ; Check for unsaved changes
276:  MOV.W DO,D2            ; Save file reference number
277:  BPL OpenOK             ; If > 0, OK
278:  CMP.W #Cancelled,D0    ; Cancelled?
279:  BNE @l                ; No
280:  RTS                    ; Yes, just return
281:  @l MOV.L #OBErr,D0     ; Indicate open error
282:  BRA Bail               ; Bail out
283:  OpenOK                ;
284:  SCursor #Watch        ; Indicate patience required
285:  MOV.W DL,VolRef(A5)    ; Save volume reference number
286:  GETINFO FName(A5),InfoBuf(A5),VolRef(A5); Get file info
287:  LEA InfoBuf(A5),AO    ; AO -> File Information
288:  MOV.L DSize(AO),D4    ; Copy file size to D4
289:  SUB.L HBufLen(A5),D4   ; Subtract file header size
290:  MOV.L (AO),A4          ; Dereference
291:  MOV.L HBufLen(A5),D3   ; Byte count to D3
292:  BSR IssueRd           ; Go read it
293:  MOV.L D4,D3            ; Main byte count to D3 now
294:  CMP.L FBufSiz(A5),D3   ; Enough room in buffer?
295:  BLT BufOK             ; Yes
296:  MOV.L #MemErr,D0       ; No, notify user
297:  BRA OBail              ; Bail out
298:  BufOK
299:  MOV.L FileBuf(A5),AO   ; AO -> Buffer pointer
300:  MOV.L (AO),A4          ; A4 -> Buffer
301:  SUB.L FBufSiz(A5),D4   ; Calculate offset to bottom
302:  NEG.L D4               ;
303:  LEA 0(A4,D4.L),A4      ; A4 -> File offset in buffer
304:  BSR IssueRd           ; Do the read
305:  CLOSE D2              ; Close the open file
306:  WRtitle FName(A5)      ; Set the window title
307:  SetFlag F_File         ; Now have a file in the buffer
308:  DoUpdate:              ; Now get ready to update screen
309:  CLR.W FBStart(A5)      ; No bytes in buffer beginning
310:  CLR.W SRow(A5)         ; Screen buffer is row #0
311:  MOV.W D3,PBEnd(A5)     ; Set up proper # of bytes
312:  JSR UnBuf             ; Convert to screen image
313:  ClrFlag F_Change      ; No changes now
314:  MOV.L SSize(A5),D1    ; Set size variable
315:  JMP ReSize            ; Reinit screen
316:  ; IssueRd routine. This routine issues a read into a dynamic
317:  ; buffer. Locks the buffer beforehand.
318:  ;

Listing E.12 – The MacDoodleMenu.asm file (continued)
Entry conditions:
- D2 = I/O reference number for file
- A0 = Buffer handle
- A4 -> Buffer address for transfer
- D3 = Desired byte count

Exit conditions: (none)

Listing E.12 – The MacDoodleMenu.asm file (continued)
Listing E.12 – The MacDoodleMenu.asm file (continued)
Listing E.12 - The MacDoodleMenu.asm file (continued)

425: WBITLE Pname(A5) ; Set title to new name
426: BRA DoWrite ; Now go write the file
427: CFileErr ; Can't create file
428: MOVE.L #Cerr,DO ; Set error code
429: BRA Bail ; Quit
430: ; Alert handling routines. Branch to OBail if file is open,
432: ; Bail if not.
433: ; Entry conditions:
435: ; Bail if not.
436: ; DO = Alert template number
437: ; D2 = File reference number (OBail only)
438: ; Exit conditions:
439: ; (None)
440: ; OBail CLOSE D2 ; Open bail out routine
442: ; Bail SCursor #Arrow ; Set the cursor to the arrow
444: ; StopAlert DO ; Do the alert
446: ; RTS ; Return to caller
447: ; Print routine. This code prints the file found in FileBuf on the
449: ; printer. We use the generic code supplied with the MDS system here
450: ; (in file PRLink.rel).
452: ; We use the bitmap printing feature.
453: ; Write routine
455: SCursor #Watch ; Here when print selected
456: JSR PrDrvrOpen ; Set cursor to watch
457: ; Call print draw routine (in MacDoodleDraw.asm)
458: ; JSR PrDraw ; Open the printer driver
460: ; JSR PrDrvrClose ; Do print drawing
462: ; RTS ; Close the printer driver
463: ; Quit routine. This code checks for unsaved changes and exits to the
465: ; Finder.
466: ; UnDo routine. Replaces screen buffer with unpacked UnDoBuf.
467: xQuit: BSR ChkSave ; Check on unsaved changes
468: EXIT ; Back to the Finder
469: ; Entry conditions:
470: ; (none)
476: ; Exit conditions:
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Listing E.12 - The MacDoodleMenu.asm file (continued)

478: ; (none)
479: Undo
480: MOVE.L UndoBuf(A5),A0 ; A0 -> Undo buffer
481: MOVE.L (A0),A0 ; Al -> Screen buffer start
482: MOVE.L ScrBuf(A5),Al ;
483: MOVE.L (Al),Al ;
484: MOVE.W SSize(A5),DO ; DO = number of rows to unpack
485: MOVE.L A1,A6 ; Calculate limit
486: ADDA.L SBufSz(A5),A6 ;
487: BSR UnPack ; Unpack data to screen buffer
488: JMP ReDraw ; Now redraw screen
489: Cut
490: Copy
491: Paste
492: RTS ; Return to caller
493: ;
494: Draw menu handlers. These routines set the value of
495: global DrwType to the menu selection and the
496: value of PenType to the proper cursor.
497: ;
498: Lines
499: FreeH
500: Boxes
501: Ovals
502: Text
503: Eraser
504: UNCHECK #mDraw,DrwType(A5); Uncheck old item
505: CHECK #mDraw,DL ; Check new item
506: MOVE.W DL,DrwType(A5) ; Save item number
507: SUBQ.W #1,DL ; Convert to zero-relative
508: MOVE.B PenTbl(DL),DO ; Fetch pen byte
509: EXT.W DO ; Out to word
510: MOVE.W DO,PenType(A5) ; Set pen type
511: MOVE.B CurTbl(DL),DO ; Fetch cursor
512: BBQ SetCursor ; None, compute it
513: MOVE.W DO,Cursor(A5) ; Set cursor
514: RTS ; and return
515: PenTbl DC.B 2 ; Lines
516: DC.B 2 ; FreeHand
517: DC.B 0 ; Boxes
518: DC.B 0 ; Ovals
519: DC.B 0 ; Text
520: DC.B 0 ; (Unused)
521: DC.B 1 ; Eraser
522: CurTbl DC.B 0 ; Lines
523: DC.B 0 ; FreeHand
524: DC.B Cross ; Boxes
525: DC.B Cross ; Ovals
526: DC.B IBeam ; Text
527: DC.B 0 ; (Unused)
528: DC.B 0 ; Eraser
529: ;
530: Erase-screen routine. Calls routine EScreen in
MacDoodleDraw to erase window area in document.

SetPen routine. This routine sets the value of the PenSize variable and alters the cursor.

SetFont routine. Handles a font menu selection.
Listing E.12 - The MacDoodleMenu.asm file (continued)

584: RTS ; If none real, leave alone
586: DC.W SanFran,Toronto,Cairo,LosAng,Seattle,-1
587:
588: ; Plain routine. Sets Plain text mode.
589:
590: Plain: CLR.W TextFlg(A5) ; Clear all attr bits
591: MOVE.W #mStyle,D2 ; D2 = Menu number
592: MOVE.W #BoldSel,D3 ; D3 = First style selection
593: PLoop:
594: UNCHECK D2,D3 ; Uncheck a bit
595: ADDI.W #1,D3 ; Bump D3
596: CMP.W #ExpSel,D3 ; Last one?
597: BLE PLoop ; No, continue
598: CHECK #mStyle,#PlainSel; Now check Plain
599: RTS ; and return
600:
601: ; TStyle routine. Add a style bit to TextFlg word.
602:
603: TStyle: UNCHECK #mStyle,#PlainSel; Uncheck plain
604: CHECK #mStyle,D1 ; Check whatever
605: SUB.W #BoldSel,D1 ; Subtract base
606: BSET.B D1,TextFlg+1(A5); Set the bit in memory
607: RTS ; Done
608:
609: ; Compress and Expand are different. Treat them as
610: ; mutually exclusive.
611:
612: TCompress ; Compress selected
613: BCLR.B #Expand,TextFlg+1(A5); Clear expanded bit
614: UNCHECK #mStyle,#ExpSel ; Uncheck it
615: BRA Tstyle ; Otherwise, its the same
616: TExpand ; Expanded selected
617: BCLR.B #Compress,TextFlg+1(A5); Clear Compressed bit
618: UNCHECK #mStyle,#CompSel; Uncheck it
619: BRA Tstyle ; Go select it
620:
621: ; TSize routine. Set text size in points.
622:
623: TSize: UNCHECK #mStyle,TextSel(A5); Uncheck previous
624: CHECK #mStyle,Dl ; Check current
625: MOVE.W DI,TextSel(A5); Remember for next time
626: SUB.W #SizeBase,Di ; Subtract size base
627: ADD.W DI,Di ; Double for word index
628: MOVE.W Points(DI),TextSiz(A5); Remember size in points also
629: RTS ; Done
630: Points DC.W 9,10,12,14,18,20,24,36,72; Point sizes
631: DC.W 0 ; End of table flag
1: ;
2: ; MacDoodle RTL. Configures the RTL code for use with MacDoodle.
3: ;
4: TEXTRL EQU -1 ; Not text RTL
5: CONTROL EQU 0 ; Does have window controls
6: RESFILE EQU -1 ; No separate resource file
7: Include RTLcode.Asm ; Include RTL
8: END

Listing E.13 – The MacDoodleRTL.asm file

1: *
2: * This is the resource file for the MacDoodle program
3: *
4: *
5: !MacDoodle
6: *
7: *
8: * Bundle resource definition. Specifies use of the
9: * MacDoodle private icon to the Finder
10: *
11: Type BNDL
12: ,128
13: DOOD 0
14: ICN#
15: 0 128 1 129
16: FREF
17: 0 128 1 129
18: *
19: Type FREF
20: ,128
21: APPL 0 ;; Application maps to icon #0
22: ,129
23: PNTG 1 ;; Document maps to icon #1
24: *
25: *
26: * Version number resource
27: *
28: Type DOOD = GNRL
29: ,0
30: .P
31: MacDoodle Program Version 1.0
32: *
33: *
34: * MacDoodle icon definition
35: *
36: *
37: Type ICN# = GNRL
38: ,128
39: .H

Listing E.14 – The MacDoodle.R file
<p>| | | | | | | | | | | | | | | |</p>
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</tr>
</thead>
<tbody>
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<td>Type ICN# = GNRL</td>
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Listing E.14 – The MacDoodle.R file (continued)
Listing E.14 – The MacDoodle.R file (continued)
150:  16 x 16
151:  
152:  
153:  ,6(4)
154:  Font
155:  Chicago
156:  New York
157:  Geneva
158:  Monaco
159:  Venice
160:  London
161:  Athens
162:  San Francisco
163:  Toronto
164:  Cairo
165:  Los Angeles
166:  Seattle
167:  
168:  
169:  ,7(4)
170:  Style
171:  Plain/P
172:  <BBold/B
173:  <IIItalic/I
174:  <UUnderline/U
175:  <OOutline/O
176:  <SSShadow/S
177:  Compressed
178:  Expanded
179:  (-
180:  9 Point
181:  10 Point
182:  12 Point
183:  14 Point
184:  18 Point
185:  20 Point
186:  24 Point
187:  36 Point
188:  72 Point
189:  
190:  
191:  
192:  Type DLOG
193:  ,l
194:  
195:  100 100 190 450
196:  Visible NoGoAway
197:  1
198:  0
199:  1
200:  
201:  
202:  Type DITL
203:  ,l
204:  3

Listing E.14 – The MacDoodle.R file (continued)
This is the MacDoodle Program

By Steve Williams

Type DLOG ,2

Visible NoGoAway

Type DITL ,2

Type AIRL!

Listing E.14 – The MacDoodle.R file (continued)
260: QUIT
261:
262: StaticText
263: 20 60 40 225
264: MAJOR PROGRAM BUG
265:
266: StaticText
267: 50 20 70 225
268: This should "Never Happen"
269:
270:
271: Type ALRT
272: ,130
273: 50 50 160 325
274: 4
275: 5555
276:
277: Type DITL
278: ,4
279: 3
280:
281: Button
282: 85 205 105 265
283: OK
284:
285: StaticText
286: 20 60 40 225
287: Write Error
288:
289: StaticText
290: 50 20 70 225
291: On Output File
292:
293:
294: Type ALRT
295: ,131
296: 50 50 160 325
297: 5
298: 5555
299:
300: Type DITL
301: ,5
302: 2
303:
304: Button
305: 85 205 105 265
306: OK
307:
308: StaticText
309: 20 60 40 225
310: File Create Error
311:
312:
313: Type ALRT
314: ,132

Listing E.14 – The MacDoodle.R file (continued)
Listing E.14 – The MacDoodle.R file (continued)

315:  50 50 160 325
316:  6
317:  5555
318:
319: Type DITL
320:  ,6
321:  2
322:
323: Button
324:  85 205 105 265
325: OK
326:
327: StaticText
328:  20 60 40 225
329: File Open Error
330:
331:
332: Type ALRT
333:  ,134
334:  50 50 160 325
335:  7
336:  5555
337:
338: Type DITL
339:  ,7
340:  2
341:
342: Button
343:  85 205 105 265
344: OK
345:
346: StaticText
347:  20 60 40 225
348: Buffer Overflow Error
349:
350: Type ALRT
351:  ,135
352:  50 50 160 325
353:  8
354:  5555
355:
356: Type DITL
357:  ,8
358:  2
359:
360: Button
361:  85 205 105 265
362: OK
363:
364: StaticText
365:  20 60 40 225
366: File Read Error
367:
368: Type ALRT
369:  ,136
370: 50 50 160 325
371: 9
372: 5555
373:
374: Type DITL
375: ,9
376: 2
377:
378: Button
379: 85 205 105 265
380: QUIT
381:
382: StaticText
383: 20 60 40 225
384: Insufficient Memory
385:
386:
387:
388: Type ALRT
389: ,137
390: 50 50 160 325
391: 10
392: 5555
393:
394: Type DITL
395: ,10
396: 2
397:
398: Button
399: 85 205 105 265
400: OK
401:
402: StaticText
403: 20 60 40 225
404: Please select TEXT First!
405:
406: *
407: * Main window definition
408: *
409:
410: Type WIND
411: ,1(4)
412:
413: 40 5 300 500
414: Visible GoAway
415: 0
416: 0
417:
418: *
419: * Scroll bar controls for main window
420: *
421:
422: Type CNTL
423: ,256(4)
424: x

Listing E.14 – The MacDoodle.R file (continued)
425: 0 480 245 495
426: Visible
427: 16
428: 0
429: 0 720 0
430:
431: Type CNTL
432: ,257(4)
433: x
434: 245 0 260 480
435: Visible
436: 16
437: 0
438: 0 576 0
439:
440:
441: * 1 x 1 eraser cursor
442: *
443: *
444: Type CURS = GNRL ;; Cursor type definition
445: ,16(4) ;; Resource ID
446: .H
447: * 16 words of cursor pattern
448: 8000
449: 0000
450: 0000
451: 0000
452: 0000
453: 0000
454: 0000
455: 0000
456: 0000
457: 0000
458: 0000
459: 0000
460: 0000
461: 0000
462: 0000
463: 0000
464: * 16 words of cursor mask
465: 0000
466: 0000
467: 0000
468: 0000
469: 0000
470: 0000
471: 0000
472: 0000
473: 0000
474: 0000
475: 0000
476: 0000
477: 0000

Listing E.14 – The MacDoodle.R file (continued)
Listing E.14 - The MacDoodle.R file (continued)

478: 0000
479: 0000
480: 0000
481: * Hot spot point
482: 0000
483: 0000
484:
485: *
486: * 2 x 2 eraser cursor
487: *
488:
489: Type CURS = GNRL
490: ,17
491: .H
492: * 16 words of cursor pattern
493: c000
494: c000
495: 0000
496: 0000
497: 0000
498: 0000
499: 0000
500: 0000
501: 0000
502: 0000
503: 0000
504: 0000
505: 0000
506: 0000
507: 0000
508: 0000
509: * 16 words of cursor mask
510: 0000
511: 0000
512: 0000
513: 0000
514: 0000
515: 0000
516: 0000
517: 0000
518: 0000
519: 0000
520: 0000
521: 0000
522: 0000
523: 0000
524: 0000
525: 0000
526: * Hot spot point
527: 0000
528: 0000
529:
530: *
531: * 3 x 3 eraser cursor
532: *
533:
534: Type CURS = GNRL
535: \`{18
536: .H
537: * 16 words of cursor pattern
538: E000
539: A000
540: E000
541: 0000
542: 0000
543: 0000
544: 0000
545: 0000
546: 0000
547: 0000
548: 0000
549: 0000
550: 0000
551: 0000
552: 0000
553: 0000
554: * 16 words of cursor mask
555: E000
556: E000
557: E000
558: 0000
559: 0000
560: 0000
561: 0000
562: 0000
563: 0000
564: 0000
565: 0000
566: 0000
567: 0000
568: 0000
569: 0000
570: 0000
571: * Hot spot point
572: 0000
573: 0000
574:
575:
576: *
577: * 4 x 4 eraser cursor
578: *
579:
580: Type CURS = GNRL ;; Cursor type definition
581: .{19 ;; Resource ID
582: .H
583: * 16 words of cursor pattern

Listing E.14 – The MacDoodle.R file (continued)
<table>
<thead>
<tr>
<th>Line</th>
<th>Memory Address</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>584</td>
<td>F000</td>
<td></td>
</tr>
<tr>
<td>585</td>
<td>9000</td>
<td></td>
</tr>
<tr>
<td>586</td>
<td>9000</td>
<td></td>
</tr>
<tr>
<td>587</td>
<td>F000</td>
<td></td>
</tr>
<tr>
<td>588</td>
<td>0000</td>
<td></td>
</tr>
<tr>
<td>589</td>
<td>0000</td>
<td></td>
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<tr>
<td>590</td>
<td>0000</td>
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<tr>
<td>591</td>
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<tr>
<td>598</td>
<td>0000</td>
<td></td>
</tr>
<tr>
<td>599</td>
<td>0000</td>
<td></td>
</tr>
<tr>
<td>600</td>
<td>*</td>
<td>16 words of cursor mask</td>
</tr>
<tr>
<td>601</td>
<td>F000</td>
<td></td>
</tr>
<tr>
<td>602</td>
<td>F000</td>
<td></td>
</tr>
<tr>
<td>603</td>
<td>F000</td>
<td></td>
</tr>
<tr>
<td>604</td>
<td>F000</td>
<td></td>
</tr>
<tr>
<td>605</td>
<td>0000</td>
<td></td>
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<tr>
<td>606</td>
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<tr>
<td>607</td>
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<td>608</td>
<td>0000</td>
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<tr>
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<td>0000</td>
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<tr>
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<tr>
<td>612</td>
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<tr>
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<td>0000</td>
<td></td>
</tr>
<tr>
<td>614</td>
<td>0000</td>
<td></td>
</tr>
<tr>
<td>615</td>
<td>0000</td>
<td></td>
</tr>
<tr>
<td>616</td>
<td>0000</td>
<td></td>
</tr>
<tr>
<td>617</td>
<td>*</td>
<td>Hot spot point</td>
</tr>
<tr>
<td>618</td>
<td>0000</td>
<td></td>
</tr>
<tr>
<td>619</td>
<td>0000</td>
<td></td>
</tr>
<tr>
<td>620</td>
<td></td>
<td></td>
</tr>
<tr>
<td>621</td>
<td>*</td>
<td>5 x 5 eraser cursor</td>
</tr>
<tr>
<td>622</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>623</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>624</td>
<td></td>
<td></td>
</tr>
<tr>
<td>625</td>
<td>Type CURS = GNRL</td>
<td></td>
</tr>
<tr>
<td>626</td>
<td>,20</td>
<td></td>
</tr>
<tr>
<td>627</td>
<td>.H</td>
<td></td>
</tr>
<tr>
<td>628</td>
<td>*</td>
<td>16 words of cursor pattern</td>
</tr>
<tr>
<td>629</td>
<td>f800</td>
<td></td>
</tr>
<tr>
<td>630</td>
<td>8800</td>
<td></td>
</tr>
<tr>
<td>631</td>
<td>8800</td>
<td></td>
</tr>
<tr>
<td>632</td>
<td>8800</td>
<td></td>
</tr>
<tr>
<td>633</td>
<td>f800</td>
<td></td>
</tr>
<tr>
<td>634</td>
<td>0000</td>
<td></td>
</tr>
<tr>
<td>635</td>
<td>0000</td>
<td></td>
</tr>
<tr>
<td>636</td>
<td>0000</td>
<td></td>
</tr>
</tbody>
</table>

**Listing E.14** – The MacDoodle.R file (continued)
Listing E.14 – The MacDoodle.R file (continued)
690: *      16 words of cursor mask
691: FCO0
692: FCO0
693: FCO0
694: FCO0
695: FCO0
696: FCO0
697: 0000
698: 0000
699: 0000
700: 0000
701: 0000
702: 0000
703: 0000
704: 0000
705: 0000
706: 0000
707: *      Hot spot point
708: 0000
709: 0000
710:
711:
712: *      7 x 7 eraser cursor
713: *      7 x 7 eraser cursor
714: *
715:
716: Type CURS = GNRL
717: ,22
718: ,H
719: *      16 words of cursor pattern
720: FBO0
721: 8200
722: 8200
723: 8200
724: 8200
725: 8200
726: FBO0
727: 0000
728: 0000
729: 0000
730: 0000
731: 0000
732: 0000
733: 0000
734: 0000
735: 0000
736: *      16 words of cursor mask
737: FBO0
738: FBO0
739: FBO0
740: FBO0
741: FBO0
742: FBO0
743: FBO0

Listing E.14 – The MacDoodle.R file (continued)
Listing E.14 – The MacDoodle.R file (continued)
```
797: 0000
798: 0000
799: 0000
800: *  Hot spot point
801: 0000
802: 0000
803:
804: *  9 x 9 point eraser cursor
805: *  
806: *
807:
808: Type CURS = GNRL  ;; Cursor type definition
809:  ,24  ;; Resource ID
810: .H
811: *  16 words of cursor pattern
812: FF80
813: 8080
814: 8080
815: 8080
816: 8080
817: 8080
818: 8080
819: 8080
820: FF80
821: 0000
822: 0000
823: 0000
824: 0000
825: 0000
826: 0000
827: 0000
828: *  16 words of cursor mask
829: FF80
830: FF80
831: FF80
832: FF80
833: FF80
834: FF80
835: FF80
836: FF80
837: FF80
838: 0000
839: 0000
840: 0000
841: 0000
842: 0000
843: 0000
844: 0000
845: *  Hot spot point
846: 0000
847: 0000
848: *
849: *
```

Listing E.14 – The MacDoodle.R file (continued)
10 x 10 point eraser cursor

Type CURS = GNRL ;; Cursor type definition

;; Resource ID

.25

16 words of cursor pattern

16 words of cursor mask

Hot spot point

11 x 11 point eraser cursor

16 words of cursor pattern

Listing E.14 – The MacDoodle.R file (continued)
Listing E.14 – The MacDoodle.R file (continued)
Listing E.14 - The MacDoodle.R file (continued)
1009: FFF8
1010: FFF8
1011: FFF8
1012: FFF8
1013: FFF8
1014: FFF8
1015: FFF8
1016: FFF8
1017: FFF8
1018: FFF8
1019: FFF8
1020: FFF8
1021: FFF8
1022: 0000
1023: 0000
1024: 0000
1025: *    Hot spot point
1026: 0000
1027: 0000
1028: 
1029: *
1030: *    14 x 14 point eraser cursor
1031: *
1032: 
1033: Type CURS = GNRL    ;; Cursor type definition
1034: ,29  ;; Resource ID
1035: .H   
1036: *    16 words of cursor pattern
1037: FFFC
1038: 8004
1039: 8004
1040: 8004
1041: 8004
1042: 8004
1043: 8004
1044: 8004
1045: 8004
1046: 8004
1047: 8004
1048: 8004
1049: 8004
1050: FFFC
1051: 0000
1052: 0000
1053: *    16 words of cursor mask
1054: FFFC
1055: FFFC
1056: FFFC
1057: FFFC
1058: FFFC
1059: FFFC
1060: FFFC
1061: FFFC

Listing E.14 – The MacDoodle.R file (continued)
Hot spot point

15 x 15 point eraser cursor

Listing E.14 – The MacDoodle.R file (continued)
1115: *        Hot spot point
1116: 0000
1117: 0000
1118:
1119: *
1120: *        16 x 16 point eraser cursor
1121: *
1122:
1123: Type CURS = GNRL        ;; Cursor type definition
1124: ,31        ;; Resource ID
1125: .H
1126: *        16 words of cursor pattern
1127: FFFF
1128: 8001
1129: 8001
1130: 8001
1131: 8001
1132: 8001
1133: 8001
1134: 8001
1135: 8001
1136: 8001
1137: 8001
1138: 8001
1139: 8001
1140: 8001
1141: 8001
1142: FFFF
1143: *        16 words of cursor mask
1144: FFFF
1145: FFFF
1146: FFFF
1147: FFFF
1148: FFFF
1149: FFFF
1150: FFFF
1151: FFFF
1152: FFFF
1153: FFFF
1154: FFFF
1155: FFFF
1156: FFFF
1157: FFFF
1158: FFFF
1159: FFFF
1160: *        Hot spot point
1161: 0000
1162: 0000
1163:
1164:

Listing E.14 – The MacDoodle.R file (continued)
Single point pen cursor

```
Type CURS = GNRL ; ; Cursor type definition
,32 ; ; Resource ID
.H
16 words of cursor pattern
```

```
8000
0000
0000
0000
0000
0000
0000
0000
0000
0000
0000
0000
0000
0000
0000
0000
16 words of cursor mask
```

```
2 x 2 point pen cursor
```

Listing E.14 – The MacDoodle.R file (continued)
1215: Type CURS = GNRL ;; Cursor type definition
1216: 33 ;; Resource ID
1217: .H
1218: * 16 words of cursor pattern
1219: C000
1220: C000
1221: 0000
1222: 0000
1223: 0000
1224: 0000
1225: 0000
1226: 0000
1227: 0000
1228: 0000
1229: 0000
1230: 0000
1231: 0000
1232: 0000
1233: 0000
1234: 0000
1235: * 16 words of cursor mask
1236: 0000
1237: 0000
1238: 0000
1239: 0000
1240: 0000
1241: 0000
1242: 0000
1243: 0000
1244: 0000
1245: 0000
1246: 0000
1247: 0000
1248: 0000
1249: 0000
1250: 0000
1251: 0000
1252: * Hot spot point
1253: 0000
1254: 0000
1255:
1256: *
1257: * 3 x 3 pen cursor
1258: *
1259:
1260: Type CURS = GNRL
1261: 34
1262: .H
1263: * 16 words of cursor pattern
1264: 8000

Listing E.14 – The MacDoodle.R file (continued)
Listing E.14 - The MacDoodle.R file (continued)
1315: 0000
1316: 0000
1317: 0000
1318: 0000
1319: 0000
1320: 0000
1321: 0000
1322: 0000
1323: 0000
1324: 0000
1325: 0000
1326: * 16 words of cursor mask
1327: 0000
1328: 0000
1329: 0000
1330: 0000
1331: 0000
1332: 0000
1333: 0000
1334: 0000
1335: 0000
1336: 0000
1337: 0000
1338: 0000
1339: 0000
1340: 0000
1341: 0000
1342: 0000
1343: * Hot spot point
1344: 0000
1345: 0000
1346: 1347: *
1348: * 5 x 5 pen cursor
1349: *
1350: 1351: Type CURS = GNRL
1352: ,36
1353: .H
1354: * 16 words of cursor pattern
1355: F800
1356: F800
1357: F800
1358: F800
1359: F800
1360: 0000
1361: 0000
1362: 0000
1363: 0000
1364: 0000

Listing E.14 – The MacDoodle.R file (continued)
1365: 0000
1366: 0000
1367: 0000
1368: 0000
1369: 0000
1370: 0000
1371: * 16 words of cursor mask
1372: 0000
1373: 0000
1374: 0000
1375: 0000
1376: 0000
1377: 0000
1378: 0000
1379: 0000
1380: 0000
1381: 0000
1382: 0000
1383: 0000
1384: 0000
1385: 0000
1386: 0000
1387: 0000
1388: * Hot spot point
1389: 0000
1390: 0000
1391:
1392: *
1393: * 6 x 6 pen cursor
1394: *
1395:
1396: Type CURS = GNRL
1397: ,37
1398: .H
1399: * 16 words of cursor pattern
1400: FC00
1401: FC00
1402: FC00
1403: FC00
1404: FC00
1405: FC00
1406: 0000
1407: 0000
1408: 0000
1409: 0000
1410: 0000
1411: 0000
1412: 0000
1413: 0000
1414: 0000

Listing E.14 – The MacDoodle.R file (continued)
1415: 0000
1416: * 16 words of cursor mask
1417: 0000
1418: 0000
1419: 0000
1420: 0000
1421: 0000
1422: 0000
1423: 0000
1424: 0000
1425: 0000
1426: 0000
1427: 0000
1428: 0000
1429: 0000
1430: 0000
1431: 0000
1432: 0000
1433: * Hot spot point
1434: 0000
1435: 0000
1436:
1437: * 7 x 7 pen cursor
1438: *
1439: *
1440:
1441: Type CURS = GNRL
1442: ,38
1443: .H
1444: * 16 words of cursor pattern
1445: FE00
1446: FE00
1447: FE00
1448: FE00
1449: FE00
1450: FE00
1451: FE00
1452: 0000
1453: 0000
1454: 0000
1455: 0000
1456: 0000
1457: 0000
1458: 0000
1459: 0000
1460: 0000
1461: * 16 words of cursor mask
1462: 0000
1463: 0000
1464: 0000

Listing E.14 – The MacDoodle.R file (continued)
Listing E.14 – The MacDoodle.R file (continued)

1465: 0000
1466: 0000
1467: 0000
1468: 0000
1469: 0000
1470: 0000
1471: 0000
1472: 0000
1473: 0000
1474: 0000
1475: 0000
1476: 0000
1477: 0000
1478: *  Hot spot point
1479: 0000
1480: 0000
1481: 
1482: 
1483: * 
1484: * 8 x 8 pen cursor
1485: *
1486: 
1487: Type CURS = GNRL
1488: ,39
1489: .H
1490: * 16 words of cursor pattern
1491: FFOO
1492: FFOO
1493: FFOO
1494: FFOO
1495: FFOO
1496: FFOO
1497: FFOO
1498: FFOO
1499: 0000
1500: 0000
1501: 0000
1502: 0000
1503: 0000
1504: 0000
1505: 0000
1506: 0000
1507: * 16 words of cursor mask
1508: 0000
1509: 0000
1510: 0000
1511: 0000
1512: 0000
1513: 0000
1514: 0000
1515: 0000
1516: 0000
1517: 0000
1518: 0000
1519: 0000
1520: 0000
1521: 0000
1522: 0000
1523: 0000
1524: * Hot spot point
1525: 0000
1526: 0000
1527:
1528: *
1529: * 9 x 9 point pen cursor
1530: *
1531:
1532: Type CURS = GNRL ;; Cursor type definition
1533: ,40 ;; Resource ID
1534: .H
1535: * 16 words of cursor pattern
1536: FF80
1537: FF80
1538: FF80
1539: FF80
1540: FF80
1541: FF80
1542: FF80
1543: FF80
1544: FF80
1545: 0000
1546: 0000
1547: 0000
1548: 0000
1549: 0000
1550: 0000
1551: 0000
1552: * 16 words of cursor mask
1553: 0000
1554: 0000
1555: 0000
1556: 0000
1557: 0000
1558: 0000
1559: 0000
1560: 0000
1561: 0000
1562: 0000
1563: 0000
1564: 0000
Hot spot point
10 x 10 point pen cursor

Listing E.14 – The MacDoodle.R file (continued)
1615: 0000
1616: 0000
1617:
1618: *
1619: * 11 x 11 point pen cursor
1620: *
1621:
1622: Type CURS = GNRL ; Cursor type definition
1623: .42 ; Resource ID
1624: .H
1625: * 16 words of cursor pattern
1626: FFEO
1627: FFEO
1628: FFEO
1629: FFEO
1630: FFEO
1631: FFEO
1632: FFEO
1633: FFEO
1634: FFEO
1635: FFEO
1636: FFEO
1637: 0000
1638: 0000
1639: 0000
1640: 0000
1641: 0000
1642: * 16 words of cursor mask
1643: 0000
1644: 0000
1645: 0000
1646: 0000
1647: 0000
1648: 0000
1649: 0000
1650: 0000
1651: 0000
1652: 0000
1653: 0000
1654: 0000
1655: 0000
1656: 0000
1657: 0000
1658: 0000
1659: * Hot spot point
1660: 0000
1661: 0000
1662:
1663: *
1664: * 12 x 12 point pen cursor

Listing E.14 - The MacDoodle.R file (continued)
1665: *
1666:
1667: Type CURS = GNRL         ;; Cursor type definition
1668: .43                     ;; Resource ID
1669: .H
1670: *                       16 words of cursor pattern
1671: FFF0
1672: FFF0
1673: FFF0
1674: FFF0
1675: FFF0
1676: FFF0
1677: FFF0
1678: FFF0
1679: FFF0
1680: FFF0
1681: FFF0
1682: FFF0
1683: 0000
1684: 0000
1685: 0000
1686: 0000
1687: *                       16 words of cursor mask
1688: 0000
1689: 0000
1690: 0000
1691: 0000
1692: 0000
1693: 0000
1694: 0000
1695: 0000
1696: 0000
1697: 0000
1698: 0000
1699: 0000
1700: 0000
1701: 0000
1702: 0000
1703: 0000
1704: *                       Hot spot point
1705: 0000
1706: 0000
1707: 
1708: *
1709: *                       13 x 13 point pen cursor
1710: *
1711: 
1712: Type CURS = GNRL         ;; Cursor type definition
1713: .44                     ;; Resource ID
1714: .H

Listing E.14 – The MacDoodle.R file (continued)
1715: * 16 words of cursor pattern
1716: FFF8
1717: FFF8
1718: FFF8
1719: FFF8
1720: FFF8
1721: FFF8
1722: FFF8
1723: FFF8
1724: FFF8
1725: FFF8
1726: FFF8
1727: FFF8
1728: FFF8
1729: 0000
1730: 0000
1731: 0000
1732: * 16 words of cursor mask
1733: 0000
1734: 0000
1735: 0000
1736: 0000
1737: 0000
1738: 0000
1739: 0000
1740: 0000
1741: 0000
1742: 0000
1743: 0000
1744: 0000
1745: 0000
1746: 0000
1747: 0000
1748: 0000
1749: * Hot spot point
1750: 0000
1751: 0000
1752: 
1753: *
1754: * 14 x 14 point pen cursor
1755: *
1756: 
1757: Type CURS = GNRL ; Cursor type definition
1758: .45 ; Resource ID
1759: .H
1760: * 16 words of cursor pattern
1761: FFFC
1762: FFFC
1763: FFFC
1764: FFFC

Listing E.14 - The MacDoodle.R file (continued)
Programming the Macintosh in Assembly Language

Listing E.14 – The MacDoodle.R file (continued)
1815: FFFE
1816: FFFE
1817: FFFE
1818: FFFE
1819: FFFE
1820: FFFE
1821: FFFE
1822: 0000
1823: *     16 words of cursor mask
1824: 0000
1825: 0000
1826: 0000
1827: 0000
1828: 0000
1829: 0000
1830: 0000
1831: 0000
1832: 0000
1833: 0000
1834: 0000
1835: 0000
1836: 0000
1837: 0000
1838: 0000
1839: 0000
1840: *     Hot spot point
1841: 0000
1842: 0000
1843:
1844: *
1845: *     16 X 16 point pen cursor
1846: *
1847:
1848: Type CURS = GNRL     ;; Cursor type definition
1849: ,47                 ;; Resource ID
1850: .H
1851: *     16 words of cursor pattern
1852: FFFF
1853: FFFF
1854: FFFF
1855: FFFF
1856: FFFF
1857: FFFF
1858: FFFF
1859: FFFF
1860: FFFF
1861: FFFF
1862: FFFF

Listing E.14 – The MacDoodle.R file (continued)
1863: FFFF
1864: FFFF
1865: FFFF
1866: FFFF
1867: FFFF
1868: * 16 words of cursor mask
1869: 0000
1870: 0000
1871: 0000
1872: 0000
1873: 0000
1874: 0000
1875: 0000
1876: 0000
1877: 0000
1878: 0000
1879: 0000
1880: 0000
1881: 0000
1882: 0000
1883: 0000
1884: 0000
1885: * Hot spot point
1886: 0000
1887: 0000

Listing E.14 – The MacDoodle.R file (continued)

1: MacDoodle
2: MacDoodleDraw
3: MacDoodleMenu
4: MacDoodleData
5: MacDoodleRTL
6: PrLink
7: /XXSTART
8: /Bundle
9: /Type 'APPL' 'DOOD'
10: $

Listing E.15 – The MacDoodle.link file
CHAPTER 8

The run-time library has six files:

<table>
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<th>File Name</th>
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<tr>
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<td>E.22</td>
<td>Macro library file</td>
</tr>
</tbody>
</table>

To run the programs in Chapters 4 and 6, you need all of these files. In addition, you must run the RTL.job file to generate the RTL.rel object file and RTL.RSRC resource file. To run a program that uses the run-time library, the MACLIB.ASM file must exist on the same disk as the source file during assembly, and the file RTL.RSRC must exist on some disk in the system.
RTL source file for simplified Macintosh applications

Version 01.01 31-Aug-85

Revision history

Changes for Exercises in Chapter 8.
1. 1 call to XXPRINT from PRINT macro
2. _ExitToShell enhancement

14: Include MacTraps.D ; Traps definition file
15: Include ToolEquX.D ; Tool equates
16: Include FSEqu.D ; File system equates
17: Include QuickEquX.D ; QuickDraw equates
18: Include SysEqux.D ; System equates

19:

20: Resource file equates

21:

22: MENURS EQU 1 ; First menu resource ID
23: DEFMENU EQU 3 ; Three default menus
24: ; -Apple (desk accessory)
25: ; -File
26: ; -Edit
27:

28: WINDOWR EQU 1 ; Standard window resource #
29: Vntop EQU -1 ; Code for on top (GetNewWindow)
30: ScrollW EQU 15 ; Scroll bar width (pixels)
31: TopW EQU 19 ; Top of window width (pixels)
32: VscrID EQU 256 ; Vertical scroll bar resource ID
33: HscrID EQU 257 ; Horizontal scroll bar resource ID
34:

35: APPLE EQU 1 ; Apple menu (desk accessories)
36: ABOUT EQU 1 ; Choice for About
37:

38: EDIT EQU 3 ; Edit menu (Cut/Paste)
39: UNDO EQU 1 ; Choice for Undo
40: CUT EQU 2 ; Choice for Cut
41: COPY EQU 3 ; Choice for Copy
42: PASTE EQU 4 ; Choice for Paste
43:

44: ASCII characters

45:

46: BS EQU 8 ; Backspace character
47: CR EQU $0D ; Carriage return (line terminator)
48: BL EQU $20 ; Space (blank) character
49:

50: Standard file system equates

Listing E.18 – The RTLcode.asm file
Event system masks

-1  ; Get any event
$28 ; Keyboard input (key/autokey)
$228 ; Abort (Command-Period) event

Event system macros

MACRO NEXTEVT Evmask =
MOVE.W {Evmask},DO ; Load mask register
JSR NextEvent ; Get next event

Other event system equates

9  ; Abort event number
1  ; I-beam cursor #
0  ; Bit number for command key down

GETEVENT return codes

16 ; Menu selection; Dl = parameters
17 ; Close window code
18 ; Grow window code; Dl = new size
19 ; Scroll window; Dl = control handle
20 ; Thumb scroll; Dl = control handle
21 ; Thumb scroll; Dl = control handle

Macros

MACRO SAVE = ; Save registers
MOVEM.L DO-D7/A0-A6,SaveRegs(A5)

MACRO RETURN = ; Return to caller with DO
BRA XRETURN ; Branch to exit routine

MACRO RETURNALL = ; Return; restore all
BRA XRETURNALL ; Branch to exit routine

MACRO RETURNP = ; Return D0/D1
BRA XRETURNP

EOFERR EQU -39 ; File system EOF error

Include RTLdata.Asm ; Add data file
XXINIT routine. This routine is called by the PROGRAM macro to perform one-time setup functions.

Calling sequence:

```
JSR XXINIT          ; Call Init routine
DC.B 'Name'         ; Application program name
DC.W Menus          ; Number of menus in resource file
DC.W DEBUG          ; Either $FF01 or $4E71
XXINIT               ; For the linker
```

```
XXINIT:               ; Called by PROGRAM macro
DC.W $FF01           ; For debugging only!!
PES _4(A5)            ; QuickDraw scratch area
_InitGraf             ; Init QuickDraw
_InitFonts            ; Init font package
_InitWindows          ; Init windows package
_InitMenus            ; Init menu package
_PEA DoExit ;<01>    ; Restart procedure
_InitDialogs          ; Init dialog package
_TEInit               ; Init Text Edit package
```

Open the separate resource file. We try it twice: once with the name supplied with the PROGRAM macro, and once with the canned string RTL.RSRC.

```
IF RESFILE = 0        ; Only if resource file separate
MOVE.L (SP),A2       ; A2 -> Name string
LEA Scratch(A5),AO   ; AO -> Target count byte
LEA 1(A0),A1         ; A1 -> Destination
BSR MoveCnt          ; Move in count-delimited string
LEA RSRC,A2          ; A2 -> .RSRC string
BSR MoveCnt          ; Move in this field
ENDIF                 ; Part 1 of resource conditional
MOVE.L (SP),A2       ; Fetch string address again
CLR.L D7             ; Load long
MOVE.B (A2),D7       ; unsigned byte
MOVE.L D7,D6         ; Save this value
ADDQ.L #2,D7         ; Adjust to word boundary
BCRL.L #0,D7         ; A2 -> menu word
ADD.L D7,A2          ; Start part 2 of resource conditional
ADD.W #RSRCLEN,D6    ; Add in .RSRC length
MOVE.B #6,(A0)       ; Update length count
BSR OpenRsrc         ; Try to open file
MOVE.W D0,ResFD(A5)  ; Save it for later
BPL ResOK            ; If > 0, file opened OK
LEA Canned,A0        ; Try default name
BSR OpenRsrc         ; Attempt open
MOVE.W D0,ResFD(A5)  ; Save it for later
BMI ResNFG           ; Couldn't open, quit
ResOK:                ; Resource file open
RESFILE = 0
```

Listing E.18 – The RTLcode.asm file (continued)
For our next trick, we will set up the Macintosh standard menu bar (File Edit ... etc.) as described in the resource file.

Fetch # of menus in resource file

Fetch resource number

Get menu handle

Insert after flag

Insert current menu

Bump resource number

Done?

Not yet, repeat until all inserted

Add desk accessories into first menu (Apple)

Room for menu handle result

Indicate resource type

Menu #1

Fetch menu handle

Accessory type

Add to menu

Paint bar on screen

Now we create the standard window

Room for window handle

Window resource number

-> Window space

Code for on top of others

Create the window

A3 -> Window record

Save window record address

Make window the Q/D current port

Set font to Monaco

Set the window title

Now initialize scroll bars

If window controls

Space for result

Push resource ID

Push window pointer

Add control to window

Save VScroll handle

Listing E.18 – The RTLcode.asm file (continued)
213: CLR.L -(SP) ; Space for result
214: MOVE.W #$HscrID,-(SP) ; Push resource ID
215: MOVE.L A3,-(SP) ; Push window pointer
216: GetNewControl ; Add control to window
217: MOVE.L (SP)+,Hscroll(A5); Save HScroll handle
218: MOVE.L A3,-(SP) ; Push window pointer
219: DrawGRowIcon ; Draw grow box
220: ENDIF ; CONTROL = 0
221: BSR SizeW ; Size the window
222: ; Create Text Edit record
223: ;
224: 225: IF TEXTRTL = 0 ; If no text, don't create TE
226: CLR.L -(SP) ; Space for text handle result
227: PEA DestRect(A5) ; \rightarrow Destination rectangle area
228: PEA ViewRect(A5) ; \rightarrow View rectangle area
229: _TENew ; New text record
230: MOVE.L (SP),A3 ; A3 \rightarrow text record
231: MOVE.L (A3),A3 ; Dereference
232: MOVE.B #-1,teCROnly(A3); Specify no wrap mode
233: MOVE.L (SP),THandle(A5) ; Store text handle
234: TEActivate ; Activate text record
235: ENDIF
236: ; Final initialization
237: ;
238: 239: MOVE.L #$0000FFFF,DO ; Mask for all events
240: _FlushEvents ; Get rid of all events
241: _InitCursor ; Make cursor the arrow
242: CLR.W xCursor(A5) ; Indicate last cursor set
243: MOVE.L (SP)+,EXITAddr(A5); Save Finder's return address
244: MOVE.L SP,ORGSP(A5) ; and stack pointer contents
245: MOVE.W #IBeam,Cursor(A5); Set I-beam cursor
246: MOVE.L WindowPtr(A5),AO; Set return register
247: MOVE.L ViewRect+4(A5),DO; Return window size, also
248: JMP (A2) ; Return to application
249: ;
250: ;
251: This routine is called when we couldn't open a resource file.
252: ; Deep prune yogurt time down south.
253: ;
254: 255: IF RESFILE = 0 ; Only if resource file separate
256: ResNFG MOVE.W WMgrPort,-(SP) ; Push window manager GrafPort @
257: _SetPort ; Set it to our port
258: CLR.L ViewRect(A5) ; Init
259: MOVE.L #$2000200,ViewRect+4(A5); emergency rect
260: PEA ViewRect(A5) ; to stack
261: _EraseRect ; Clears the screen
262: MOVE.L #$00100010,-(SP) ; Position
263: PEA 'Cannot Find Resource File: RTL.RSRC'
264: DrawString ; Write message
265: DC.W -1 ; Bomb
266: ENDIF ; RESFILE = 0

Listing E.18 – The RTLcode.asm file (continued)
MoveCnt routine. This routine moves a Pascal string to another area. The count byte is not moved.

```assembly
272: MOVE.L DO,-(SP) ; Save DO
273: CLR.L DO ; Clear out problem bits
274: MOVE.B (A2)+,DO ; Fetch count byte
275: SUBQ.L #1,DO ; Decrement for DBRA
276: MoveLoop:
277: MOVE.B (A2)+,(A1)+ ; Move a byte
278: DBRA DO,MoveLoop ; Down count
279: MOVE.L (SP)+,DO ; Restore DO
280: RTS ; Return to caller
281: 
282: XXWTitle routine. Called by WTitle macro and by init code.
283: Sets the window title to the string pointed to by AO.
284: 
285: Entry conditions:
286: AO -> New title string (Pascal format)
287: 
288: Exit conditions:
289: 
290: 
291: (none)
292: 
293: XDEF XXWTitle ; For the linker
294: XXWTitle
295: SAVE ; Save the registers
296: MOVE.L WindowPtr(A5),-(SP); Push window address
297: MOVE.L AO,-(SP); and string address
298: SetWTitle ; Set the title
299: RETURNAll ; Return to caller
300: 
301: Menu item Check and Uncheck routines. Called by the CHECK and UNCHECK macros.
302: 
303: Entry conditions:
304: 
305: 
306: DO = Menu number (resource ID)
307: D1 = Item number
308: 
309: Exit conditions:
310: 
311: 
312: 
313: XDEF XXCheck ; For the linker
314: XDEF XXUncheck ; linker
315: XXCheck SAVE ; Save registers
316: MOVE.W #CheckMark,D2 ; Set mark character
317: BRA DoCheck ; Go do it
318: XXUncheck ; Here to undo it
319: SAVE ; Save registers
320: MOVE.W #noMark,D2 ; Set blank (null) mark
```

Listing E.18 – The RTLcode.asm file (continued)
Listing E.18 – The RTLcode.asm file (continued)
375:  MOVE.W D1,D3          ; Preserve item number
376:  MOVE.W D2,D4          ; and style word
377:  BSR DoRsfc            ;<01> Go get resource
378:  MOVE.W D3,-(SP)      ; Push item number
379:  MOVE.W D4,-(SP)      ; Push style word
380:  SetItmStyle          ; Change it
381:  RETURN              ; and return
382:  ;
383:  ; DoRsfc routine. Returns menu handle on top of the stack
384:  ; from resource ID in DO.W.
385:  ;
386:  DoRsfc                ;<01> New with edit <01>
387:  MOVE.L (SP),A3       ;<01> Return address to A3
388:  MOVE.L '#MENU',-SP)  ;<01> Specify resource type
389:  MOVE.W DO,-(SP)  ;<01> Convert
390:  _GetResource         ;<01> ID
391:  -                     ;<01> to handle (SP)
392:  JMP (A3)             ;<01> Return to caller
393:  ;
394:  ; RTL exit routines. Entered from RETURN, RETURNALL, and RETURNP
395:  ; macros. Restore registers and RTS.
396:  ;
397:  XRETURNALL:            ; Here to restore all regs
398:  MOVE.L SaveRegs(A5),DO ; Restore DO
399:  XRETURN:              ; Here to restore all save DO
400:  MOVE.L SaveRegs+4(A5),D1; Restore D1
401:  XRETURNP:             ; Here to restore all save DO and D1
402:  MOVEM.L SaveRegs+8(A5),D2-D7/A0-A6; Restore bulk of registers
403:  RTS                    ; Return to caller
404:  ;
405:  ; XXCURSOR routine. Change cursor to a resource file cursor.
406:  ;
407:  ; Entry conditions:
408:  ;
409:  ;   DO.W = Cursor code:
410:  ;       0 => Arrow
411:  ;       1 => I-beam (Text Edit cursor)
412:  ;       2 => Plus (graphics)
413:  ;       4 => Watch
414:  ;
415:  ; Exit conditions:
416:  ;
417:  ; (none)
418:  ;
419:  ; This routine can be invoked either by the SCURSOR macro or
420:  ; internally in RTL. It does not use SAVE/RETURN.
421:  ;
422:  ; XDEF XXCURSOR
423:  ;
424:  CMP.W xCursor(A5),DO ; Need to do this?
425:  BNE @1                ; Yes
426:  RTS                    ; No
427:  @1:  MOVEM.L DO-D2/A0-A2,-(SP); Save registers
428:  MOVE.W DO,xCursor(A5) ; Remember for next time

Listing E.18 – The RTLcode.asm file (continued)
Listing E.18 – The RTLcode.asm file (continued)
Listing E.18 – The RTLcode.asm file (continued)

483: NextEvent: ; Called internally only
484:    MOVE.L DO,-(SP) ; Save DO for a bit....
485:    IF TEXTRTL = 0 ; If text type RTL
486:    MOVE.L THandle(A5),-(SP); Push text record handle
487:    TEIdle ; Call Text Edit idle proc
488:    ENDIF
489: SystemTask ; Let system tasks run
490:    MOVE.L (SP)+,DO ; Recover mask
491:    CLR.W -(SP) ; Make room for event ID
492:    MOVE.W DO,-(SP) ; Push event mask
493:    PEA EventRecord(A5); Push event record address
494:    GetNextEvent ; Fetch next Mac event
495:    MOVE.W (SP)+,DO ; Event ID to DO
496:    RTS ; Return
497: ;
498: ; XXEVENT routine. Called from GETEVENT macro.
499: ;
500: ; Entry conditions:
501: ;
502: ; DO = Resource ID for cursor (while it's in the window)
503: ;
504: ; Exit conditions:
505: ;
506: ; DO = Event code (0-15)
507: ; DL = Event parameters
508: ;
509: ; XDEF XXEVENT ; External
510: XEVENT: ;
511: ;
512: ; SAVE ;
513: ;
514: ;
515: ;
516: ;
517: ;
518: ;
519: ;
520: ;
521: ;
522: ;
523: ;
524: ;
525: ;
526: ;
527: ;
528: ;
529: ;
530: ;
531: ;
532: ;
533: ;
534: ; Define a macro for event table entries
535: ;
536: MACRO ETAB addr = ; Entry macro
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537:   DC.W  {addr}−XXBASE ; Generate an offset word
538:   |  
539: ;  
540: ;   Define the event table itself
541: ;  
542: EventTab  ; Offset table
543: XXBASE SET * ; Here is the base value
544: ETAB NullEvent ; 0 => Null event, ignore
545: ETABMouseDown ; 1 => Mouse-down event
546: ETABMouseUp ; 2 => Mouse-up event
547: ETABKeyDown ; 3 => Key press (down)
548: ETABKeyUp ; 4 => Key release (up)
549: ETABAutoKey ; 5 => Autokey
550: ETABUpdate ; 6 => Update event
551: ETABDisk ; 7 => Disk
552: ETABActivate ; 8 => Activate
553: ETABAbort ; 9 => Abort
554: ETABNetwork ; A => Network
555: ETABDriver ; B => Driver
556: ETABApp1 ; C => Application #1
557: ETABApp2 ; D => Application #2
558: ETABApp3 ; E => Application #3
559: ETABApp4 ; F => Application #4
560: ;  
561: ;   End of event table
562: ;  
563: Activate  ; Activate window request
564: MOVE.L Message(A5),AO ; AO = Window handle
565: CMP.L WindowPtr(A5),AO ; Is it ours?
566: BNE DoEvent ; No, get next event
567: IF CONTROL = 0 ; Controls?
568: BSR IncControls ; Yes, include them
569: ENDIF ; CONTROL
570: ;  
571: ;   (De)Activate the text window
572: ;  
573: MOVE.W Modify(A5),DO ; Activate or deactivate?
574: BTSP.L #0,DO ; Bit 0 tells us
575: BBQ Deactivate ; Clear => Deactivate
576: IF TEXTCTRL = 0 ; Don't activate TE if not needed
577: MOVE.L THandle(A5),(SP) ; Push text handle
578: TEBActivate ; Activate text window
579: ENDIF ;  
580: MOVE.L Message(A5),(SP) ; Push window pointer
581: _SelectWindow ; Select this window as active
582: MOVE.L Message(A5),(SP) ; Push window pointer
583: _SetPort ; Make the Q/D active port
584: IF CONTROL = 0 ; If window has controls
585: MOVE.L VScroll(A5),(SP) ; Show scroll bars
586: ShowControl ;  
587: MOVE.L HScroll(A5),(SP) ; Show scroll bars
588: ShowControl ;  
589: BRA EndAct ; Do end stuff
590: ELSE ; CONTROL = 0

Listing E.18 – The RTLcode.asm file (continued)
591: BRA DoEvent ; Fetch next event
592: ENDF
593; ; Here if deactivate specified
594: ;
595: ;
596: Deactivate:
597: IF TEXTRTL = 0 ; Don't deactivate TE if no text
598: MOVE.L THandle(A5),-(SP) ; Push text handle
599: _TeDeActivate ; and zero it
600: ENDF
601: IF CONTROL = 0 ; If scroll bars
602: MOVE.L VScroll(A5),-(SP) ; Hide scroll
603: _HideControl ; bars
604: MOVE.L HScroll(A5),-(SP) ;
605: _HideControl ;
606: EndAct: BSR ExcControls ; Exclude controls
607: ENDF ; CONTROL = 0
608: BRA Doevent ; Get next event
609; ;
610: ; Event is an update request
611: ;
612: Update:
613: IF TEXTRTL = 0 ; Just update text part
614: MOVE.L WindowPtr(A5),-(SP) ; If text only
615: _BeginUpdate ; Warn
616: PEA ViewRect ; everyone first
617: MOVE.L THandle(A5),-(SP) ; Warn
618: _TUpdate ; text window
619: MOVE.L WindowPtr(A5),-(SP) ; Thusly
620: _EndUpdate ;
621: BRA Doevent ;
622: ELSE ; Done
623: BSR IncControls ; Graphics mode
624: MOVE.L WindowPtr(A5),-(SP) ; Include controls in window
625: _DrawControls ; Push window pointer
626: MOVE.L WindowPtr(A5),-(SP) ; Draw the controls
627: _DrawGrowIcon ; Push window pointer
628: BSR ExcControls ; Draw grow box
629: BRA UserEvt ; Take controls back out
630: ENDF ; Let user handle
631; ; IncControls and ExcControls routines. Call them to insert
632; and remove controls from the window valid region.
633; ;
634: ; Improper ordering is allowed.
635; ;
636: ;
637: IncControls ; Include controls
638: MOVEM.L DO-D2/AO-A2, -(SP) ; Preserve registers
639: MOVEM.L DestRect(A5),DO/D1; Pick up old rect
640: MOVEM.L DO/D1,ViewRect(A5); Reset to clipped
641: ADD.W #ScrollW,ViewRect+4(A5); Adjust clip
642: ADD.W #ScrollW,ViewRect+6(A5);
643: PEA ViewRect(A5) ;
644: _ClipRect ;

Listing E.18 - The RTLcode.asm file (continued)
645: MOVEM.L (SP)+,DO-D2/A0-A2;  
646: RTS ;  
647:  
648: ExcControls ;  
649: MOVEM.L DO-D2/A0-A2,-(SP);  
650: MOVEM.L DestRect(A5),DO/Dl;  
651: MOVEM.L DO/DL,ViewRect(A5);  
652: PEA ViewRect(A5) ;  
653: _ClipRect ;  
654: MOVEM.L (SP)+,DO-D2/AQ-A2;  
655: RTS ;  
656:  
657: ;  
658: Event is a mouse down  
659: ;  
660: MouseDown  
661: CLR -(SP) ;  
662: MOVE.L Point(A5),-(SP) ;  
663: PEA wWindow(A5) ;  
664: _FindWindow ;  
665: MOVE.W (SP)+,DO ;  
666: AND.W #7,DO ;  
667: ADD.W DO,DO ;  
668: MOVE.W WTable(DO),DO ;  
669: JMP WTable(DO) ;  
670: WTable: ;  
671: XXBASE SET * ;  
672: ETAB Doevent ; 0 Mouse at time of event  
673: ETAB InMenu ; 1 Mouse in menu area  
674: ETAB SystemEvent ; 2 Mouse in system window  
675: ETAB Content ; 3 Window content area  
676: ETAB Drag ; 4 In drag area  
677: ETAB Grow ; 5 In grow box  
678: ETAB GoAway ; 6 In close box  
679: ETAB Doevent ; 7 (Undefined)  
680: ;  
681: Here if key down is indicated. Handle Command-key entries, else  
682: ;  
683: ;  
684: KeyDown  
685: AutoKey  
686: MOVE.W Message+2(A5),Dl;  
687: BTST #ComKey,Modify(A5);  
688: BBEQ UserEvt ;  
689: CLR.L -(SP) ;  
690: MOVE.W Dl,-(SP) ;  
691: _MenuKey ;  
692: BRA DoMenu ;  
693: ;  
694: ;  
695: ;  
696: InMenu: ;  
697: CLR.L -(SP) ;  
698: MOVE.L Point(A5),-(SP) ;  

Listing E.18 - The RTLcode.asm file (continued)
699: _MenuSelect               ; Perform menu selection
700: DoMenu CLR.W -(SP)       ; Unhighlight menus
701: _HLiteMenu               ; This does all
702: MOVE.L (SP),D1           ; Menu number (from _MenuSelect)
703: MOVE.W (SP)+,D6          ; Menu selection (from _MenuSelect)
704: MOVE.W (SP)+,D7          ; Really a choice?
705: TST.L D1                ; No, just kidding
706: BBEQ DoEvent            ; DO = Menu choice return code
707: MOVE.L #MenuChoice,D0   ; Yes, do this one ourselves
708: CMP.W #APPLE,D6         ; Apple menu?
709: BBEQ Inapple            ; No, how about the Edit menu?
710: CMP.W #EDIT,D6          ; Yes, handle this one too
711: BBEQ InEdit             ; Restore registers; return
712: RETURNP                 ; Here if it's a choice we handle ....
713: Inapple:                ; Was it the About choice?
714: CMP.W #ABOUT,D7         ; No, must be a desk accessory
715: BNE DeskAcc             ; Set parameter register
716: MOVE.W D7,D0            ; Do the dialog
717: BSR XDIALOG             ; and do another event
718: BRA DoEvent
719: ;                        ; Here if a desk accessory
720: ;
721: DeskAcc:                ; Clear return space
722: CLR.L -(SP)             ; Indicate menu resource
723: MOVE.L #MENU',-(SP)      ; Push menu ID
724: MOVE.W #APPLE,-(SP)     ; Get menu handle
725: GetResource             ; Push menu selection
726: ;                        ; -> Accessory name area
727: MOVE.W D7,-(SP)         ; Fetch desk accessory name
728: PEA Deskname(A5)        ; Push longword address
729: GetItem                 ; Space for handle
730: PEA GPort(A5)           ; -> Filled-in name area
731: GetPort                 ; Open the accessory
732: CLR.W -(SP)             ; Discard handle
733: PEA Deskname(A5)        ; Push old GrafPort address
734: OpenDeskAcc             ; Restore it
735: TST.W (SP)+             ; And back for another event
736: MOVE.L GPort(A5),-(SP)  ; Here if menu selection was in the Edit menu
737: SetPort                 ; Cut/Copy/Paste
738: BRA Doevent             ; Clear return area
739: ;                        ; Return front window pointer
740: ;                        ; Window handle to AO
741: ;                        ; Our window?
742: InEdit:                 ; No, it's a system window
743: CLR.L -(SP)             ; If TEXT RTL only
744: _FrontWindow            ; Bigger than Paste?
745: MOVE.L (SP)+,AO         ; No, it's OK
746: CMP.L WindowPtr(A5),AO  ; Bigger than Copy value?
747: BNE SystemEdit          ; Restore; return
748: IF TEXITRL = 0
749: CMP.W #PASTE,D7         ; DoEdit: CMP.W #COPY,D7
750: BLE DoEdit              ; Bigger than Paste?
751: RETURNP                 ; No, it's OK
752: DoEdit: CMP.W #COPY,D7

Listing E.18 – The RTLcode.asm file (continued)
753:    BGE DoCopy ; Yes, keep looking
754:    ;
755:    ; Must be a Cut command
756:    ;
757:    MOV.E THandle(A5),-(SP) ; Push text handle
758:    TECut ; Do the cut
759:    BRA Doevent ; Back for more
760:    DoCopy: CMP.W #PASTE,D7 ; Is it a paste?
761:    BBEq DoPaste ; Yes
762:    MOV.E THandle(A5),-(SP) ; Push text handle
763:    _TECopy ; Do the copy
764:    BRA Doevent ; and back for more
765:    DoPaste: ;
766:    MOV.E THandle(A5),-(SP) ; Push text handle
767:    _TEPaste ; Do it
768:    BRA Doevent ; Get next event
769:    ELSE ; Graphics mode
770:    MOV.E #MenuChoice,D0 ; Set return code
771:    MOV.W D6,D1 ; Copy choice words
772:    SNAP D1 ; --to--
773:    MOV.W D7,D1 ; return register
774:    RETURNP ; and return menu choice
775: ENDIF;
776: ;
777: System window edit
778: ;
779: SystemEdit:
780: MOV.W D7,D0 ; DO = menu choice
781: SUBQ.L #1,D0 ; Decrement
782: CLR.W -(SP) ; Space for result
783: MOV.W D0,-(SP) ; Choice word
784: SysEdit ; Do it
785: MOV.W (SP)+,D0 ; Result to DO
786: BRA Doevent ; Back for next event
787: ;
788: Here if mouse in system window
789: ;
790: SystemEvent:
791: PEA EventRecord(A5); ; Event not ours
792: MOV.E WWindow(A5),-(SP); Window handle
793: SystemClick ; Call O/S
794: BRA Doevent ; Back for another event
795: ;
796: Here if mouse in content area of window
797: ;
798: Content:
799: MOV.E WWindow(A5),AO ; AO = window handle
800: CMP.L WindowPtr(A5),AO ; Ours?
801: BNE Doevent ; No, get next event
802: MOV.E AO,-(SP) ; Stack window handle
803: SelectWindow ; Select window
804: PEA Point(A5) ; Stack point address
805: GlobalToLocal ; Convert to window coords
806: IF TEXTRTL = 0 ; If text type RTL

Listing E.18 – The RTLcode.asm file (continued)
807: MOVE.L Point(A5),-(SP); Push point in local coords
808: CLR.W -(SP); No extend flag
809: MOVE.L THandle(A5),-(SP); Stack text handle
810: BRClick; Do Text Edit click
811: BRA Doevent; Get next event
812: ELSE; Graphics mode
813: ;
814: In graphics mode with controls, we must find out if the mouse is in a control. If not, (or if no controls) we return the point to the user program.
815: ;
816: IF CONTROL = 0; Only if we have controls
817: BSR IncControls; Include controls first
818: CLR.W -(SP); Room for result
819: MOVE.L Point(A5),-(SP); Push point
820: MOVE.L WindowPtr(A5),-(SP); Push window address
821: PEA CHandle(A5); Push control handle
822: _FindControl; Fetch the control
823: MOVE.W (SP)+,DO; Get part code
824: BEQ NoControl; None, give point to user
825: MOVE.L CHandle(A5),Dl; Fetch control handle
826: CMP.W #inThumb; Special case?
827: BEQ @2; Yes, go handle
828: SUB.W #inUpButton,DO; Force to range 0-3
829: CMP.L VScroll(AS),Dl; Was it?
830: BEQ @1; Yes, give to user
831: ORI.W #4,DO; Or in horizontal bit
832: SWAP; Set return
833: llDVE.L #ScrollWin,DO register
834: ;
835: MOVE.W #ScrollWin,DO; Back to user
836: BRA @4; If in thumb, we can do the tracking for the user program.
837: ;
838: MOVE.L Dl,D4; Preserve control ID
839: CLR.W -(SP); Room for result
840: MOVE.L Dl,-(SP); Push control ID
841: MOVE.L Point(A5),-(SP); Push original point
842: CLR.L -(SP); No action procedure
843: TrackControl; Track it
844: TST.W (SP)+; For real?
845: BNE @3; Yes, process
846: BSR ExcControls; Reset clip region
847: BRA DoEvent; Get an event
848: ;
849: User changed the value. Fetch new setting.
850: ;
851: CLR.W -(SP); Room for result
852: MOVE.L D4,-(SP); Push control handle
853: GetCtlValue; Fetch the value
854: MOVE.W (SP)+,DO; To
855: SWAP DO; return register
856: MOVE.L D4,Dl; Reset parameter register
857: MOVE.L D4,D1; Assume vertical

Listing E.18 – The RTLcode.asm file (continued)
Listing E.18 – The RTLcode.asm file (continued)

```
861: CMP.L VScroll(A5),D1 ; Good assumption?
862: BEQ @4    ; Yes
863: MOVE.W #TScrollH,DO ; No, fix it
864: @4        BSR ExcControls ; Exclude controls
865: RETURNP   ; Done, return to caller
866: NoControl ; Here if user point
867: BSR ExcControls ; Exclude controls
868: ENDIF     ; CONTROL = 0
869: ;
870: ; Here if mouse is in the REAL content area. Pass the event
871: ; back to the application.
872: ;
873: MOVE.W What(A5),DO ; Set mouse-down return code
874: MOVE.L Point(A5),D1 ; Return point in local coords
875: RETURNP   ; Back to user
876: ENDIF     ;
877: ;
878: ;
879: ; XXTRACK routine. Called from the TRACK macro in response to
880: ; a scroll page or scroll line event. Assumes mouse still down.
881: ;
882: ; Entry conditions:
883: ;
884: ; DO = Control handle
885: ; AO ->User's scroll procedure
886: ;
887: ; Exit conditions:
888: ;
889: ; (None)
890: ;
891: XDEF XXTRACK ; For the linker
892: XTRACK SAVE ; Save the registers
893: BSR IncControls ; Clip to allow drawing controls
894: CLR.W -(SP) ; Room for result
895: MOVE.L DO, -(SP) ; Push control handle
896: MOVE.L Point(A5), -(SP) ; and original mouse point
897: MOVE.L AO, -(SP) ; and user's procedure
898: TrackControl ; Do the track
899: ADDQ.L #2,SP ; Pop return
900: BSR ExcControls ; Reclip for no controls
901: RETURN     ; and return
902: ;
903: ; Here if user wants to drag
904: ;
905: Drag:    ;
906: MOVE.L WWindow(A5), -(SP); Push window handle
907: MOVE.L Point(A5), -(SP); Push mouse point
908: PEA DBounds  ; and bounds rectangle
909: DragWindow ; Do the drag
910: BRA Doevent ; and get a new event
911: ;
912: ; Here if a grow request
913: ;
914: Grow:    ;
```

Programming the Macintosh in Assembly Language
IF \text{CONTROL} = 0 ; Only if controls in place
\text{CLR.L} -(SP) ; Room for result
\text{MOVE.L} \text{Window(A5)},-(SP); Push window handle
\text{MOVE.L} \text{Point(A5)},-(SP); and mouse point
\text{PEA GWBounds} ; and bounds rectangle
\text{GrowWindow} ; Do the grow
\text{MOVE.L} (SP)+,D5 ; D5 = New size
\text{BEQ DoEvent} ; If EQ, didn't change
\text{First, generate an update for the old scroll bar region.}
\text{PEA ViewRect(A5)} ; Convert ViewRect to
\text{LocalToGlobal} ; global coordinates
\text{MOVE.L ViewRect(A5),D3/D4;} ; Fetch rectangle
\text{MOVE.L ViewRect(A5),DO/01;} ; twice
\text{Invalidate VScroll bar}
\text{MOVE.W D1,D0} ; Copy right to left
\text{ADD.W} \#\text{scrollW} ,D1 ; Adjust right for scroll bar width
\text{SWAP} D1 ; Adjust
\text{SUB.W} \#\text{scrollW} ,D1 ; bottom
\text{SWAP} D1 ; for grow box
\text{MOVE.L DO/01,ViewRect(A5)} ; Now
\text{PEA ViewRect(A5)} ; make
\text{IsValidRect} ; invalid
\text{Now, invalidate HScroll bar}
\text{SWAP D3} ; Invert
\text{SWAP D4} ; rectangle
\text{SWAP D4} ; Copy bottom to top
\text{ADD.W} \#\text{scrollW} ,D4 ; Adjust bottom for scroll width
\text{SWAP} D3 ; Re-
\text{SWAP D4} ; swap
\text{ADD.W} \#\text{scrollW} ,D4 ; Adjust right for grow box
\text{MOVE.L D3/D4,ViewRect(A5)} ; Now
\text{PEA ViewRect(A5)} ; make
\text{IsValidRect} ; invalid
\text{Next, actually resize the window on the screen}
\text{MOVE.L} \text{Window(A5)},-(SP); Push window handle
\text{MOVE.L} D5,-(SP); Push size
\text{MOVE.W} #-1,-(SP); Push TRUE value
\text{SizeWindow} ; Update screen to new size
\text{BSR SizeW} ; Size the window
\text{Erase the new window content area}
\text{PEA ViewRect(A5)} ; Push view rectangle address
\text{EraseRect} ; Erase it
\text{Here we move the scroll bars to their new location. First,}
hide both controls.

MOVE.L VScroll(A5),-(SP); Hide VScroll bar

MOVE.L HScroll(A5),-(SP); Hide HScroll bar

Next move and resize VScroll bar

MOVE.L VScroll(A5),-(SP); Move V scroll
MOVE.W ViewRect+6(A5),-(SP); "Right" - scroll width
MOVE.W ViewRect+0(A5),-(SP); "Top"

MoveControl ; Move the scroll bar
MOVE.L VScroll(A5),-(SP); Now resize VScroll bar
MOVE.W #ScrollW, -(SP); Width
MOVE.W ViewRect+4(A5),-(SP); Length
_SizeControl ; Do the size

Now move and resize HScroll bar

MOVE.L HScroll(A5),-(SP); Move H scroll
MOVE.W ViewRect+2(A5),-(SP); Left
MOVE.W ViewRect+4(A5),-(SP); Bottom - scroll width
MoveControl ; Do the move
MOVE.L HScroll(A5),-(SP); Push control handle
MOVE.W ViewRect+6(A5),-(SP); Width
MOVE.W ViewRect+4(A5),-(SP); Length
_SizeControl ; Size it

Now show both controls

MOVE.L VScroll(A5),-(SP); Show VScroll bar
MOVE.L HScroll(A5),-(SP); Show HScroll bar

Now pass the size information to the application.

MOVE.L ViewRect+4(A5),D1; Pick up new size (clipped)
MOVE.W #GrowMin,DO ; Set return code
RETURNP ; Give back to user
ELSE ; CONTROL = 0
BRA DoEvent ; No grows allowed
ENDIF

Determine window size

MOVEM.L DO-D2/A0-A3, -(SP); Save registers we use
MOVEM.L WindowPtr(A5),A3; A3 -> Window structure
MOVEM.L ctrRgn(A3),A0 ; A0 -> Content region (handle)
MOVEM.L (A0),AO ; A0 -> Content region (pointer)
MOVEM.L RgnBoxAO(D0,D1),DO/D1; D0,D1 = GrafPort rectangle
IF CONTROL = 0 ; If doing control stuff
SUB.W #ScrollW,D1 ; Subtract

Listing E.18 – The RTLcode.asm file (continued)
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Listing E.18 – The RTLcode.asm file (continued)

<table>
<thead>
<tr>
<th>Routine</th>
<th>Macro</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>XXSETVMIN</td>
<td>SetVMin</td>
<td>Set upper limit on VScroll bar</td>
</tr>
<tr>
<td>XXSETHMIN</td>
<td>SetHMin</td>
<td>Set left limit on HScroll bar</td>
</tr>
<tr>
<td>XXSETVMAX</td>
<td>SetVMax</td>
<td>Set lower limit on VScroll bar</td>
</tr>
<tr>
<td>XXSETHMAX</td>
<td>SetHMax</td>
<td>Set right limit on HScroll bar</td>
</tr>
</tbody>
</table>

Room for result

Room for result
1077: ; XXSETHVAL  SetHVal  Set thumb value on HScroll bar
1078: ;
1079: ; Entry conditions:
1080: ;
1081: ;   DO.W = Value
1082: ;
1083: ; Exit conditions:
1084: ;
1085: ;   (none)
1086: ;
1087: ; XDEF XXSETVMIN ; Make
1088: ; XDEF XXSETVMAX ; Set upper limit
1089: ; XDEF XXSETVVAL ; all
1090: ; XDEF XXSETHMIN ; external
1091: ; XDEF XXSETHMAX
1092: ; XDEF XXSETHVAL
1093: ; XXSETVMIN ; Set upper limit
1094: ; SAVE ; Save registers
1095: ; MOVE.L VScroll(A5),-(SP) ; Push control handle
1096: ; BRA SetMin ; Do the SetMin
1097: ; XXSETHMIN ; Set left limit
1098: ; SAVE ; Save registers
1099: ; MOVE.L HScroll(A5),-(SP) ; Push control handle
1100: SetMin MOVE.W DO,-(SP) ; and value
1101: _SetMinCtl
1102: RETURNALL ; Set it
1103: ; Back to caller
1104: ; XXSETVMAX ; Set lower limit
1105: ; SAVE ; Save registers
1106: ; MOVE.L VScroll(A5),-(SP) ; Push control handle
1107: ; BRA SetMax ; Do set max
1108: ; XXSETHMAX ; Set right limit
1109: ; SAVE ; Save registers
1110: ; MOVE.L HScroll(A5),-(SP) ; Push control handle
1111: SetMax MOVE.W DO,-(SP) ; Push value
1112: _SetMaxCtl ; Set it
1113: RETURNALL ; Done
1114: ;
1115: ; XXSETVVAL ; Set vertical thumb
1116: ; SAVE ; Save the registers
1117: ; MOVE.L VScroll(A5),-(SP) ; Push control handle
1118: ; BRA SetVal ; Do set val
1119: ; XXSETHVAL ; Set horizontal thumb
1120: ; SAVE ; Save registers
1121: ; MOVE.L HScroll(A5),-(SP) ; Push control handle
1122: SetVal MOVE.W DO,-(SP) ; Push value
1123: _SetCtlValue ; Set value
1124: ; RETURNALL
1125: ; Exit
1126: ;
1127: ;
1128: ; XXDIALOG routine. Handles DIALOG macro. (Also used for
1129: ; the "About ..." box in Apple menu.)
1130: ;

Listing E.18 – The RTLcode.asm file (continued)
XDEF XXDIALOG ; For the linker
MOVEM.L D1/D6/A0-AL,-(SP); Push volatile registers
CLR.L -(SP); Dialog pointer return area
MOVE.W D0,-(SP); Dialog box resource ID
CLR.L -(SP); No dialog storage
MOVE.L #ONTOP,-(SP); On top of all
GetNewDialog ; Create a new dialog box
MOVE.L (SP),D6 ; Handle to D6
SetPort ; Make it QuickDraw port
IF TEXTRTL = 0 ; If text style RTL
  MOVE.L THandle(A5),- (SP); Deactivate text window
  _TEDeActivate ;
ENDIF ;
CLR.L -(SP); No filter procedure
PFA ItemHit(A5) ; -> Item hit data
ModalDialog ; Wait for "OK" button
MOVE.L D6,-(SP); Push dialog box handle
DisposeDialog ; and close it
MOVE.W ItemHit(A5),DO ; Load return register
MOVE.L WindowPtr(A5),-(SP); Reset
SetPort ; port address
MOVE.L (SP)+,D1/D6/A0-AL; Restore registers
RTS ; Back to caller

XXPRINT routine. Handles the PRINT macro.
Entry conditions:
A4 -> Pascal string to print
Exit conditions:
(None)

IF TEXTRTL = 0 ; Junk whole routine if graphics
XDEF XXPRINT ; Define for linker
XXPRINT SAVE ; Save registers
MOVE.W DO,-(SP);<01> Place DO on stack temporarily
BSR DoPrint;<01> Print original string
TST.W (SP)+;<01> Need carriage return?
BEQ @l;<01> No, quit now
LEA XXCR,A4;<01> A4 -> Carriage-return string
BSR DoPrint;<01> Go print that
@l RETURNALL ;<01> All done, go away
DoPrint CLR.L D6 ; Clear a temporary
MOVE.L (A4)+,D6 ; Fetch count byte
MOVE.L A4,AL ; A1 -> Text
MOVE.L D6,DO ; DO = Count
SUBQ.L #1,DO ; Adjust for DBRA count
BLT TYPEDone ; Done if < 0
CLR.L D7 ; Initialize counter
LookCR: CMPIL.B #CR,(AL)+ ; Is it a <CR>?

Listing E.18 - The RTLcode.asm file (continued)
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Listing E.18 – The RTLcode.asm file (continued)

1185:    BNE    TYPEDBR ; No, don't bump count
1186:    ADDQ.L #1, D7 ; Bump count
1187:    TYPEDBR DBRA D0, LookCR ; Repeat till count exhausted
1188:    TST.W D7 ; Any line control chars?
1189:    BNE    DoType ; No, skip next
1190:    MOVE.L THandle(A5), Al ; A1 -> Text handle
1191:    MOVE.L (Al), Al ; A1 -> Actual text record
1192:    CLR.L D5 ; Clear out D5 long
1193:    MOVE.L WindowPtr(A5), AO ; AO -> Window record
1194:    MOVE.W PortRect+4(AO), D5 ; D5 = Rectangle size (vertical)
1195:    DIVS telineHite(Al), D5 ; D5 = # lines in dest rectangle
1196:    SUB.W PortRect+4(A0), D5 ; How many already?
1197:    BGT    GotSane ; Still some left at bottom
1198:    CLR.L D5 ; Correct for none left
1199:    SUB.W 07, o5 ; How many lines do we need?
1200:    BGE    DoType ; None
1201:    SUB.W D7, D5 ; Copy to scratch register
1202:    MOVE.W D5, D0 ; Multiply to convert to pixels
1203:    MULS.W telineHite(Al), D5 ; No horizontal scroll
1204:    CLR.W -(SP) ; Push vertical scroll
1205:    MOVE.W D5, -(SP) ; Push text handle
1206:    MOVE.L THandle(A5), -(SP) ; Scroll it
1207:    _TEScroll ; A1 -> Text handle
1208:    MOVE.L THandle(A5), Al ; A1 -> Actual text record
1209:    MOVE.L (Al), Al ; A1 -> Actual text record
1210:    MOVE.L tviewRect(Al), tDestRect(Al); Adjust vertical view for deletion
1211:    MOVE.L tviewRect+4(Al), tDestRect+4(Al);" ;
1212:    NBG.W D5 ; D5 = # lines to delete
1213:    SUB.W D5, tlNlines(Al) ; Mark as deleted
1214:    ADD.W D5, D5 ; Convert to index
1215:    MOVE.W tlNlines(Al, D5, W), DO; First character to remain
1216:    MOVE.L ttext(Al), A2 ; A2 = Text handle
1217:    MOVE.L (A2), A2 ; A2 -> Text start (destination)
1218:    LEA (A2, D0, W), A3 ; A3 -> Source
1219:    MOVE.W tlength(Al), D1 ; Count of characters to move
1220:    SUB.W D0, D1 ; Fix for deletion
1221:    EXT.L D1 ; Out to long
1222:    MOVE.W D1, D0 ; Adjust
1223:    SUBQ.W #1, D0 ; for DBRA
1224:    MOVE.L A2, A0 ; Save address in AO
1225:    TypeDel MOVE.B (A3)+, (AO)+ ; Move a byte
1226:    DBRA D0, TypeDel ; Until done
1227:    MOVE.L A2, -(SP) ; -> Text
1228:    MOVE.L D1, -(SP) ; = Character count
1229:    MOVE.L THandle(A5), -(SP); ; -> -> Text record
1230:    _TSetText ; "Replace" text in TE record
1231:    DoType: ; Here to begin output
1232:    MOVE.L A4, -(SP) ; Push character pointer
1233:    MOVE.L D6, -(SP) ; Push length
1234:    MOVE.L THandle(A5), -(SP); ; and text handle
1235:    _TEInsert ; Output the text
1236:    TYPEDone: ; Here when done
1237:    RETURNALL ; Restore registers
1238:    ENDP entity...
XXINPUT routine. Called by INPUT macro.

Entry conditions:
- AO -> User buffer
- DO = Count of bytes available

Exit conditions:
- (none)

IF TEXTRTL = 0

IF text style RTL

Save user's registers

DO > 1 byte?

No, count is OK

Use only 255

Preserve in nonvolatile reg

Save buffer pointer

in nonvolatile registers

First character position

= Character count so far...

Here to get next character

Get next keyboard event

No, just ignore

Yes, ignore

Character to DO

Backspace?

Invalid character

Check for control chars.

Any characters?

No, invalid character

Decrement count

Remove from buffer

Do TEKey for screen update

Here to see if control character

Was it carriage return?

Yes, store count and return

Less than space?

Yes, error

Room in buffer?

No, don't do anything

Store in buffer

Increment count

Now put on screen

and in TE buffer

Here when CR typed

Store the count byte
1293:    SUB.W  D3,D4 ; How many bytes remain?
1294:    BLE   PrintCR ; None, bail out
1295:    SUB.W  #1,D4 ; Adjust for DBRA
1296:    ZapBuf: CLR.B (A3)+ ; Clean out
1297:    DBRA  D4,ZapBuf ; rest of buffer
1298:    PrintCR LEA    XXCR,A4 ; A4 -> CR sequence
1299:    JMP DoPrint ; Print CR, then return
1300:    ENDIF ; TEXTRTL
1301:    ;
1302:    ; XXOPENR routine. Called by OPENR macro.
1303:    ;
1304:    ; Entry conditions:
1305:    ;
1306:    ;    AO -> filename
1307:    ;
1308:    ; Exit conditions:
1309:    ;
1310:    ;    DO = File handle or error code
1311:    ;
1312:    ; This routine performs a volume search if the default open
1313:    ; fails.
1314:    ;
1315:    ; XDEF XXOPENR
1316:    XXOPENR:    ; Entry point
1317:    SAVE    ; Save the registers
1318:    LEA   TRYRopen,A6 ; A6 -> Open function
1319:    CLR.L Filebuf(A5) ; No special file buffer
1320:    BRA   Gopen ; Go to general open function
1321:    ;
1322:    ; This routine is called internally to do the OpenResFile trap, instead
1323:    ; of the generalized resource file open.
1324:    ;
1325:    ; OpenRsrc:    ; Entry point
1326:    ;
1327:    ; Entry conditions:
1328:    ;
1329:    ;    AO -> File name
1330:    ;
1331:    ; Exit conditions:
1332:    ;
1333:    ; This routine is called by OPEN macro.
1334:    ;
1335:    ; Entry conditions:
1336:    ;
1337:    ; Exit conditions:
1338:    ;
1339:    ; DO = File handle or error code
1340:    ; DL = Volume reference number or zero
1341:    ;
1342:    ; XDEF XXOPENEND
1343:    XXOPENEND SAVE  ; Entry point
1344:    LEA   TRYDopen,A6 ; A6 -> Open function
1345:    MOVE.L Al,Filebuf(A5) ; Save buffer address

Listing E.18 - The RTLcode.asm file (continued)
General Open function. Called by resource and data open front ends.

A6 -> Routine for open
AO -> File name

```
1347: ;
1348: ;
1349: ;
1350: ;
1351: ;
1352: ;
1353: ;
1354: Gopen: MOVE.L AO,A4 ; Save file name pointer
1355: JSR (A6) ; Try to open as is
1356: TST.W D0 ; Success?
1357: BGT RQuit ; Yes, return
1358: TST.W D1 ; Volume specified?
1359: BNE RQuit ; Yes, fail
1360: CLR.L D6 ; Load
1361: MOVE.B (A4),D6 ; length byte
1362: MOVE.L VCBHdrt+2,A3 ; A3 -> VCB entry
1363: RVScan: TST.W VCBdrVNum(A3) ; Is volume on line?
1364: BBE RNexitV ; No, get next
1365: LEA FScratcht+1(A5),A1; A1 -> Scratch area
1366: LEA VCBN(A3),A2 ; A2 -> Volume name
1367: CLR.L D7 ; Fetch
1368: MOVE.B (A2),D7 ; count byte
1369: ADD.L #1,D7 ; Increment for ":" character
1370: ADD.W D6,D7 ; Compute total string length
1371: BSR MoveCnt ; Move in volume name
1372: MOVE.L #':',(A1)+ ; Move in separator
1373: MOVE.L A4,A2 ; A2 -> File name
1374: BSR MoveCnt ; Move file name in, too
1375: LEA FScratch(A5),AO ; AO -> Composite name
1376: MOVE.B D7,(A0) ; Plunk down length byte
1377: CLR.W D1 ; Default volume number
1378: JSR (A6) ; Try to open that
1379: MOVE.W VCBtRERefNum(A3),D1; Return volume ref number in D1
1380: TST.W D0 ; Success?
1381: BGT RQuit ; Yes, stop
1382: RNexitV: ; No, chain to next volume
1383: MOVE.L (A3),A3 ; A3 -> Next in chain
1384: MOVE.L A3,D1 ; Move to D reg
1385: BNE RVScan ; Try again
1386: MOVE.L #-1,D0 ; Failed utterly
1387: RQuit: RETURNP ; Restore registers; return
1388: ;
1389: ; TRYRESOP routine. Try to open resource fork of a file, for use
1390: ; as the program's resource file.
1391: ;
1392: TRYRESOP: ; AO -> File name
1393: CLR.W -(SP) ; Clear out room
1394: MOVE.L AO,-(SP) ; Push file name
1395: OpenResFile ; Open
1396: MOVE.W (SP)+,D0 ; Fetch file handle/error code
1397: RTS ; Return to caller
1398: ;
1399: ; TRYDopen routine. Try to open data fork of a file.
1400: ;
```

Listing E.18 - The RTLcode.asm file (continued)
1401: TRYDopen: ; AO -> File name
1402: MOVE.L AO,ioFileName+IOPB(A5); Put in file name
1403: LEA IOPB(A5),AO ; AO -> Parameter block
1404: CLR.L ioCompletion(AO); No completion routine
1405: MOVE.W D1,ioRefNum(AO); Set volume ID
1406: CLR.W ioFileType(AO); Default version
1407: CLR.B ioPermissions(AO); Whatever we can get
1408: MOVE.L Filebuf(A5),ioOwnBuf(AO); Special access buffer
1409: Open ; Try it
1410: LEA IOPB(A5),AO ; AO -> Parameter block again
1411: MOVE.W ioResult(AO),DO ; Fetch error code
1412: BNE OpenFail ; IF NE, back to caller
1413: MOVE.W ioRefNum(AO),DO ; Get return parameter
1414: OpenFail: ; Common exit point
1415: EXT.L DO ; Convert to long
1416: RTS ; and back to caller
1417: ;
1418: ; TRYRopen routine. Try to open Resource fork of a file.
1419: ;
1420: TRYRopen: ; AO -> File name
1421: MOVE.L AO,ioFileName+IOPB(A5); Put in file name
1422: LEA IOPB(A5),AO ; AO -> Parameter block
1423: CLR.L ioCompletion(AO); No completion routine
1424: MOVE.W D1,ioRefNum(AO); Set volume ID
1425: CLR.W ioFileType(AO); Default version
1426: CLR.B ioPermissions(AO); Whatever we can get
1427: MOVE.L Filebuf(A5),ioOwnBuf(AO); No special access buffer
1428: OpenRF ; Try it
1429: LEA IOPB(A5),AO ; AO -> Parameter block again
1430: MOVE.W ioResult(AO),DO ; Fetch error code
1431: BNE ROpenFail ; IF NE, back to caller
1432: MOVE.W ioRefNum(AO),DO ; Get return parameter
1433: ROpenFail: ; Common exit point
1434: EXT.L DO ; Convert to long
1435: RTS ; and back to caller
1436: ;
1437: ; XXPOPEN routine. Opens a file using the Mac standard file package.
1438: ;
1439: ; Entry conditions:
1440: ;
1441: ; AO -> Extension string
1442: ; A1 -> Buffer
1443: ; A2 -> Return buffer for name
1444: ; A3 -> Table of allowable file types
1445: ;
1446: ; Exit conditions:
1447: ;
1448: ; DO = File reference number
1449: ; D1 = Volume reference number
1450: ;
1451: ; XDEF XXPOPEN ; For linker
1452: XXPOPEN: ; Entry point
1453: ;
1454: SAVE ; Save caller's registers

Listing E.18 - The RTLcode.asm file (continued)
Listing E.18 – The RTLcode.asm file (continued)
1509: MOVE.B (Al)+,D1 ; Fetch character
1510: CMPI.B 'a',D1 ; Lower-
1511: BLT DoCompare ; case?
1512: CMPI.B 'z',D1 ;
1513: BGT DoCompare ;
1514: BCLR $5,D1 ; Convert to uppercase
1515: DoCompare: ; Here to compare
1516: CMP.B (AO)+,D1 ; Compare next
1517: BNE Failure ; If NE, quit
1518: DBRA DO,ExtLoop ; Repeat for count
1519: Success: ; Here if match
1520: MOVE.W #0,8(SP) ; Load Boolean TRUE
1521: MOVE.L (SP)+,(SP) ; Move return -> parameter
1522: RTS ; Exit
1523: Failure: ; Here if no match
1524: MOVE.W #-1,8(SP) ; Load Boolean FALSE
1525: MOVE.L (SP)+,(SP) ; Move return -> parameter
1526: RTS ; Exit
1527: ;
1529: ;
1530: ; Entry conditions:
1531: ;
1532: ; AO -> File name
1533: ;
1534: ; Exit conditions:
1535: ;
1536: ; DO = Error code/file handle
1537: ;
1538: XDEF XXCREATE ; For the linker
1539: XXCREATE: ;
1540: SAVE ; Save caller's registers
1541: JSR TryCreate ; Call internal routine
1542: RETURNP ; Restore all but DO/Dl
1543: ;
1544: TryCreate: ; Here if locally called
1545: MOVE.L AO,ioFileName+IOPB(A5); Set file name
1546: MOVE.L Al,A3 ; Save Al
1547: LEA IOPB(A5),AO ; AO -> IOPB
1548: CLR.L ioCompletion(AO); No completion routine
1549: MOVE.W DI,ioRefNum(AO); Specified volume
1550: CLR.W ioFileType(AO); Default version
1551: CLR.B ioPermsn(AO); Whatever we can get
1552: CLR.L ioOwnBuf(AO); No special access buffer
1553: _Delete ; Get rid of existing version
1554: _Create ; Do it
1555: _GetFileInfo ; Get file information
1556: MOVE.L 'TEXT',ioFileType(AO); Set file type
1557: MOVE.L 'EDIT',ioFileType+4(AO); Set application
1558: _SetFileInfo ; Set the info
1559: MOVE.L A3,ioOwnBuf(AO); Set buffer address
1560: _Open ;
1561: MOVE.W ioResult(AO),DO ; Get error code
1562: EXT.L DO ; Extend to long

Listing E.18 - The RTLcode.asm file (continued)
1563: BNE CreateNFG ; Failed if nonzero
1564: MOVE.W ioRefNum(A0),DO ; Get reference number
1565: MOVE.W ioVRefNum(A1),D1; Return volume reference number
1566: CreateNFG: ; Common exit point
1567: RTS ; Return to caller
1568: ;
1569: ;
1570: ; XXPCREATE routine. This routine calls the standard file package
1571: ; to create an output file.
1572: ;
1573: ; Entry conditions:
1574: ;
1575: ; AO -> Prompt string
1576: ; Al -> 522 byte buffer for use by file system
1577: ; A2 -> Name buffer return area (64 bytes)
1578: ; A3 -> Default name
1579: ;
1580: ; Exit conditions:
1581: ;
1582: ; D0 = File reference number
1583: ; D1 = Volume reference number
1584: ;
1585: ; XDEF XXPCREATE ; Entry point
1586: XXPCREATE: ; Save registers
1587: MOVE.L A1,Filebuf(A5) ; Save buffer address
1588: MOVE.L SPoint,-(SP) ; Point for dialog box
1589: MOVE.L A0,-(SP) ; Prompt string
1590: MOVE.L A3,-(SP) ; Default name
1591: CLR.L -(SP) ; No dialog hook procedure
1592: PEA SFReply(A5) ; -> Reply area
1593: MOVE.W #$FPut,-(SP) ; Routine selector
1594: Pack3 ; Invoke package
1595: _Pack3 ;
1596: TST.B Good(A5) ; Test return code
1597: BNE NoCancel ; NE => Not cancelled
1598: MOVE.L #Cancel,D0 ; Return
1599: BRA XXPFail ; Failed, return
1600: ; NoCancel:
1601: MOVE.W VolRef(A5),D1 ; Set volume ID
1602: LEA FName(A5),A0 ; AO -> File name
1603: Movebuf(A5),A1 ; Restore Al
1604: JSR TryCreate ; Try to create it
1605: TST.W D0 ; Worked?
1606: BMI XXPFail ; No, quit now
1607: MOVE.B FName(A5),(A2)+ ; Move in count byte
1608: MOVE.L A2,A1 ; A1 -> Destination
1609: LEA FName(A5),A2 ; A2 -> Source
1610: JSR MoveCnt ; Move in name
1611: MOVE.W ioVRefNum(A0),D1; Set volume ref number
1612: BRA XXPFail ; Go exit
1613: ;
1614: ;
1615: ; XXGETF routine. Gets file info and returns to the user.
1616: ;

Listing E.18 – The RTLcode.asm file (continued)
Entry:
AO -> File name
Al -> Information buffer
Dl = Volume reference number or 0 for scan

XDEF XXGETF
Entry point
SAVE
TryGetF,A6
Do volume scan for file
MOVE.L Al,FileBuf(A5)
Save Al in global area
BRA Gopen

TryGetF routine. Attempts to get file info for file.

MOVE.L AO,IOPB+ioFileName(A5); Stuff file name
LEA IOPB(A5),AO ; AO -> IOPB now
MOVE.W Dl,ioRefNum(A0); Clear vol ref field
CLR.W ioFDirIndex(A0); Clear directory index field
GetFileInfo
Try it
MOVE.W ioResult(A0),DO ; Error?
BNE GETNFG
; Yes, return error
MOVE.W #ioFQElSize-1,DO;
LEA IOPB(A5),A2 ; A2 -> IOPB
MOVE.L FileBuf(A5),A1 ; Al -> User's buffer
GetMove:
MOVE.B (A2)+,(Al)+ ; Stuff a byte
DBRA DO,GetMove ; Until done
MOVE.W ioRefNum(A0),DO ; Load ref number
GETNFG: RTS
; and bail out

SETF Routine. Sets file info for named file.

Entry conditions:
AO -> File name
Al -> Buffer area

Exit conditions:
DO = ioResult

XDEF XXSETF ; For linker
SAVE
LEA IOPB(A5),A2 ; A2 -> IOPB
MOVE.W #ioFQElSize-1,DO; DO = Count
SetMove:
MOVE.B (A2)+,(Al)+ ; Move a byte
DBRA DO,SetMove ; Loop till done
MOVE.L AO,IOPB+ioFileName(A5); Stuff file name
LEA IOPB(A5),AO ; AO -> IOPB now

Listing E.18 – The RTLcode.asm file (continued)
1671:    MOVE.W D1,ioVRefNum(AO);       ; Set volume reference number
1672:    _SetFileInfo                      ; Try it
1673:    MOVE.W ioResult(AO),D0;        ; Get result code
1674:    EXT.L DO                         ; Extend to long
1675:    RETURN                          ; and bail out
1676:    
1677:    
1678:    XXREAD routine. Reads from an open file.
1679:    
1680:    Entry conditions:
1681:    
1682:    DO = File handle
1683:    D1 = Byte count
1684:    AO -> Buffer
1685:    D2 = End-of-line character
1686:    
1687:    Exit conditions:
1688:    
1689:    DO = # bytes actually read
1690:    
1691:    XDEF XXREAD                      ; For the linker
1692:    XXREAD: SAVE                    ; Save caller's registers
1693:    LEA IOPB(A5),Al                  ; Al -> Parameter block
1694:    MOVE.W DO,ioRefNum(Al);        ; Store file reference number
1695:    MOVE.L D1,ioByteCount(Al);      ; Store byte count
1696:    MOVE.L AO,ioBuffer(Al);        ; and buffer address
1697:    MOVE.W D2,ioPosMode(Al);       ; Specify sequential read
1698:    MOVE.L Al,AO                    ; AO -> Parameter block
1699:    Read:                           ; Issue the read
1700:    LEA IOPB(A5),AO                 ; AO -> Parameter block again
1701:    MOVE.W ioResult(AO),DO;       ; Fetch result code
1702:    EXT.L DO                       ; Extend to long
1703:    BBQ Noerr                       ; No error
1704:    CMP.L #eofE:RR,D0              ; End of file error?
1705:    BNE ReadDone                   ; No, return error
1706:    TST.L ioNumDone(AO)            ; Any bytes read?
1707:    BBQ ReadDone                   ; No, return error
1708:    Noerr: MOVE.L ioNumDone(AO),DO; Not (really) an error, return byte count
1709:    ReadDone:                       ; Here when done
1710:    RETURN                         ; Restore the registers
1711:    
1712:    XXWRITE routine. Writes to an open file.
1713:    
1714:    Entry conditions:
1715:    
1716:    DO = File handle
1717:    D1 = Byte count
1718:    AO -> Buffer
1719:    D2 = End-of-line character
1720:    
1721:    Exit conditions:
1722:    
1723:    DO = # bytes actually written/error count
1724:    

Listing E.18 – The RTLcode.asm file (continued)
1725: XDEF XXWRITE ; For the linker
1726: XXWRITE SAVE ; Save caller's registers
1727: LEA IOPB(A5),Al ; Al -> Parameter block
1728: MOVE.W DO,iORefNum(Al) ; Store file reference number
1729: MOVE.L D1,iOByteCount(Al) ; Store byte count
1730: MOVE.L AO,iBuffer(Al) ; and buffer address
1731: CLR.W ioPosMode(Al) ; Indicate sequential
1732: MOVE.L Al,AO ; AO -> Parameter block
1733: Write ; Issue the write
1734: LEA IOPB(A5),AO ; AO -> Parameter block again
1735: MOVE.W ioResult(AO),DO ; Fetch result code
1736: EXT.L DO ; Extend to long
1737: BNE WriteDone ; NE => Error, done
1738: MOVE.L ioNumDone(AO),DO; No error, return actual byte count
1739: WriteDone: ; Here when done
1740: RETURN ; Restore the registers
1741: ; XXSEEK routine. Called by SEEK macro.
1742: ; Entry conditions:
1743: ; DO = I/O reference number
1744: ; D1 = File offset
1745: ; D2 = Sense word
1746: ; XDEF XXSEEK
1747: XXSEEK: SAVE ; Seek on an open file
1748: LEA IOPB(A5),AO ; Al -> Parameter block
1749: MOVE.W DO,iORefNum(AO) ; Store file reference number
1750: MOVE.L D1,iOPosOffset(AO); Store offset
1751: ANDI.W #3,D2 ; Insure proper range
1752: MOVE.B SeekTab(D2),D2 ; Translate to Macintosh code
1753: MOVE.W D2,iOPosMode(AO); Set proper field
1754: _SetFPos ; Do the set
1755: LEA IOPB(A5),AO ; AO -> Parameter block
1756: MOVE.W ioResult(AO),DO ; Fetch error code
1757: EXT.L DO ; Out to long
1758: BMI SeekDone ; < 0 means error
1759: _GetFPos ; Fetch new pointer
1760: LEA IOPB(A5),AO ; AO -> Parameter block
1761: MOVE.L ioPosOffset(AO),DO; Load return value
1762: SeekDone: ; Here to return to caller
1763: RETURN ; Restore caller's registers
1764: SeekTab DC.B 1,3,2 ; Seek translation table
1765: .ALIGN 2 ; Force word boundary
1766: ; XXDELETE routine. Deletes a file by name.
1767: ; Entry conditions:
1768: ; AO -> File name string
1769: ; D1 = Volume reference number or zero for scan.
1770: ;

Listing E.18 – The RTLcode.asm file (continued)
1779:  XDEF  XXDELETE
1780:  XXDELETE:
1781:    SAVE
1782:    LEA  TryDel,A6
1783:    BRA  Gopen
1784:    TryDel routine. Attempts to delete a file.
1785:    :  
1786:  
1787:  TryDel:
1788:    MOVE.L AO,IOPB+ioFileName(A5); Stuff file name
1789:    LEA  IOPB(A5),AO
1790:    MOVE.W Dl,ioVRefNum(AO); Clear vol ref field
1791:    CLR.W ioDirIndex(AO); Clear directory index field
1792:    _Delete
1793:    MOVE.W ioResult(A0),DO; Load return code
1794:    EXT.L DO; Extend to longword
1795:    RTS; and bail out
1796:    
1797:  XXCLOSE routine. Called by CLOSE macro.
1798:  
1799:    Entry conditions:
1800:    
1801:    DO.W = File number to close
1802:    
1803:    XDEF  XXCLOSE
1804:    SAVE
1805:    LEA  IOPB(A5),AO
1806:    MOVE.W DO,ioRefNum(AO); Set reference number
1807:    _Close
1808:    BSR  DoFlush
1809:    RETURNALL
1810:    
1811:  XXEXIT routine. Called by EXIT macro.
1812:  
1813:    Entry conditions:
1814:    
1815:    (None)
1816:    
1817:    Exit conditions:
1818:    
1819:    (Doesn't return)
1820:    
1821:    XDEF  XXEXIT
1822:    BSR  DoFlush
1823:    MOVE.L EXITAddr(A5),AO; AO -> Exit routine
1824:    MOVE.L ORGSP(A5),SP
1825:    JMP  (AO); Quit
1826:    
1827:  DoExit routine. Called from dialog manager when BOMB dialog appears.
1828:    
1829:  DoExit
1830:    BSR  DoFlush
1831:    _ExitToShell
1832:  

Listing E.18 – The RTLcode.asm file (continued)
1833: ; DoFlush routine. Flushes all volumes.
1834: ;
1835: ;
1836: DoFlush MOVE.L VCBHdrc+2,A3 ; A3 -> VCB entry
1837: EVScan: TST.W VCBDrvNum(A3) ; Is volume online?
1838: LEA IOPB(A5),A0 ; No, get next
1839: MOV.L VCBWSn(A3),ioVEntry(IO); Set volume name
1840: CLR.W ioVDrvNum(A0) ; Specify no drive number
1841: _FlushVol ; Flush the volume
1842: _NextV: ; No, chain to next volume
1843: MOVE.L (A3),A3 ; A3 -> Next in chain
1844: MOVE.L A3,D1 ; Move to D reg
1845: BNE EVScan ; Try again
1846: RTS ; Back to caller

Listing E.18 – The RTLcode.asm file (continued)

1: ; RTL data area
2: ; Initialized data
3: ;
4: ; STRING FORMAT 3 ; All strings are Pascal strings
5: ;
6: DWBounds: DC.W 28,4,338,508 ; DragWindow bounds rectangle
7: IF CONTROL = 0 ; Only for controls
8: GWBounds: DC.W 28,50,300,508 ; GrowWindow bounds rectangle
9: ENDIF ; CONTROL = 0
10: SPoint: DC.W 100,100 ; Point for standard file window
11: IF RESFILE = 0 ; Resource file separate
12: Canned: DC.B 'RTL,RSRC' ; Default resource file name
13: RSRC: DC.B '.RSRC' ; Resource extension
14: RSRCLEN EQU *-RSRC-1 ; Adjusted byte count
15: ENDIF ; RESFILE = 0
16: XDEF XXCR ; Newline sequence for TYPE macro
17: XXCR DC.B 1,13 ; Carriage return
18: ALIGN 2 ; Align to next word
19: ;
20: ; Uninitialized data
21: ;
22: ; EXITAddr: DS.L 1 ; Exit address to Finder
23: ORGSP: DS.L 1 ; Stack pointer from Finder
24: FileBuf: DS.L 1 ; File buffer address for open
25: Scratch: DS.B 32 ; 32-byte resource name scratch area
26: Pscratch: DS.B 32 ; 32-byte file name scratch area
27: IF RESFILE = 0 ; Only if separate resource file
28: RESFILE = 0
29: ResFD: DS.W 1 ; Resource file descriptor
30: ENDIF ; RESFILE = 0

Listing E.19 – The RTLdata.asm file
31: WindowPtr DS.L 1 ; Returned window pointer
32: ViewRect: DS.W 4 ; Text record's view rectangle
33: DestRect: DS.W 4 ; Text record's destination rectangle
34: IF TEXTRgL = 0 ; If text RTL
35: THandle: DS.L 1 ; Text record handle
36: ENDIF
37: GPort: DS.L 1 ; Current GrafPort
38: WArea: DS.W WindowSize ; Window storage area
39: ItemHit: DS.W 1 ; Modal dialog result
40: DeskName: DS.W 16 ; Desk accessory name
41: Cursor: DS.W 1 ; Cursor code for window
42: xCursor: DS.W 1 ; Last cursor code for window
43: ;
44: ; Event record for get next event
45: ;
46: ;
47: EventRecord DS.W 0 ; 0
48: What: DS.W 1 ; 2 Event type
49: Message: DS.L 1 ; 4 Event message
50: When: DS.L 1 ; 8 Event time
51: Point: DS.L 1 ; 12 Mouse position
52: Modify: DS.W 1 ; 14 Modifiers
53: ;
54: WWindow: DS.L 1 ; Input to FindWindow
55: SaveRegs: DS.L 15 ; Register save area
56: ;
57: ; I/O parameter block for use with file I/O
58: ;
59: IOPB: DS.W 0 ; Global tag
60: DS.B ioPQELSize; Define area
61: ;
62: ; Reply area for standard file package
63: ;
64: ;
65: SPReply: DS.W 0 ; Structure tag
66: Good: DS.B 1 ; Boolean TRUE => not cancelled by user
67: Copy: DS.B 1 ; Currently unused
68: fType: DS.L 1 ; O/S file type
69: VolRef: DS.W 1 ; Volume reference number
70: version: DS.W 1 ; File version number
71: FName: DS.B 64 ; Returned file name
72: ExtPtr: DS.L 1 ; -> User-specified file extension string
73: ;
74: ; Memory area for window controls
75: ;
76: VScroll: DS.L 1 ; Handle for vertical scroll bar
77: HScroll: DS.L 1 ; Handle for horizontal scroll bar
78:CHandle: DS.L 1 ; Handle for FindControl

Listing E.19 – The RTLData.asm file (continued)
1: *
2: * This is the resource file for the Mac run-time library
3: *
4:
5: RTL.RSRC
6:
7:
8:
9: Type MENU
10: ,1
11: \14
12: RTL Programs
13: (-
14:
15: ,2
16: File
17: Quit
18:
19: ,3
20: Edit
21: Cut/X
22: Copy/C
23: Paste/V
24:
25:
26: Type DLOG
27: ,1
28:
29: 100 100 190 500
30: Visible NoGoAway
31: 1
32: 0
33: 1
34:
35:
36: Type DITL
37: ,1
38: 3
39:
40: StaticText
41: 15 20 36 400
42: This Program uses the special Mac Run Time Library
43:
44: StaticText
45: 35 20 56 400
46: By Steve Williams
47:
48: Button
49: 60 260 80 320
50: OK
51:
52:
53: Type WIND

Listing E.20 – The RTL.R file
Listing E.20 – The RTL.R file (continued)

```
54: ,1
55:
56: 40 5 300 500
57: Visible NcGoAway
58: 0
59: 0
60:
61:
62: *
63: * Scroll bar controls for main window
64: *
65:
66: Type CNTL
67: ,256(4)
68: x
69: 40 485 300 500
70: Visible
71: 16
72: 0
73: 0 720 0
74:
75: Type CNTL
76: ,257(4)
77: x
78: 285 5 300 500
79: Visible
80: 16
81: 0
82: 0 576 0
```

Listing E.21 – The RTL.job file

```
1; Asm RTL.Asm Exec Edit
2; Rmaker RTL.R Exec Edit
```

Listing E.22 – The MACLIB.ASM file

```
1; ;
2; ; Macro library file for simplified Macintosh applications
3; ;
4; ; Version 01.01 31-Aug-85
5; ;
```
Revision history:

<01> 31-Aug-85 Revision for Exercise 8.2

PROGRAM macro. This macro is used to define an application.
It must be the first code-generating statement in the program.

Usage:

PROGRAM name,debug,menus

Where name is the applications name (used to find the
resource file, for instance).

Debug is either DEBUGON or DEBUGOFF, to make the program's
first instruction an illegal instruction ($FF01) or a NOP.
This can later be patched.

Menus is the number of menus in the main menu bar, or the
DEFAULT token.

STRING \FORMAT 3 ; Set all strings to Pascal standard

.MACRO PROGRAM ; name,menus,debug =
XDEF XXSTART ; Entry point name
XREF XXINIT ; Initializer

XXSTART JSR XXINIT ; Call init routine
IF ' %1' <> '' ; Name specified
DC.B ' %1' ; Yes
ELSE
DC.B 'No Name' ; Default
ENDIF

.ALIGN 2 ; Force word alignment
IF ' %3' <> '' ; Menus?
DC.W %3 ; Do specified number
ELSE ; Not specified
DC.W 0 ; Use default
ENDIF
IF ' %2' <> '' ; Debug specified?
DC.W %2 ; Yes
ELSE ; Not specified
DC.W $4E71 ; Use NOP instruction
ENDIF

DEFAULT EQU 0 ; Default parameter
DEBUGON EQU $FF01 ; Debug option
DEBUGOFF EQU $4E71 ; No debug option

Listing E.22 - The MACLIB.ASM file (continued)
PRINT macro. Prints a Pascal string on the main window.

Usage:

- PRINT 'String',[,crflag]
- or-

PRINT address[,crflag]

The second form allows use of a resource file, or an arbitrary
addressing mode. "crflag", if nonblank, specifies no newline.

```
.MACRO PRINT ;string,crflag =
XREF XXPRINT ;Define for linker
MOVEM.L DO/A4,-(SP) ;<Ol> Save DO + A4
LEA $1,A4 ;A4 -> Output string
IF '82' <> '' ;Is carriage return desired?
CLR.W DO ;<Ol> For no carriage return
ELSE ;<Ol> If not blank
MOVE.W #-1 DO ;<Ol> For carriage return
ENDIF
JSR XXPRINT ;Call output string
MOVEM.L (SP)+,DO/A4 ;<Ol> Restore DO + A4
.ENDM
```

INPUT macro. Accepts a line of keyboard input.

```
.MACRO INPUT ;address,length =
XREF XXINPUT ;Define for linker
MOVEM.L AO/D0,-(SP) ;Save parameter registers
LEA $1,A0 ;-> Return buffer
IF '82' = '' ;Not specified?
MOVEQ.L #80,D0 ;Default to 80
ELSE ;Use specified
MOVE.L %2,D0 ;
ENDIF
JSR XXINPUT ;Call RTL routine
MOVEM.L (SP)+,AO/D0 ;Restore registers
.ENDM
```

ENDPROGRAM macro. This macro must be the last line in the source file.
Usage:

ENDPROGRAM

MACRO ENDPROGRAM =
STRING_FORMAT 1
|

OPEN macro. This macro opens the data fork of a file. The file handle is returned in DO.W.

Usage:

OPEN filename,filebuff,volref

Filename is the address of a Pascal string containing the name of the file to be opened. Filebuff is the address of a 522-byte buffer to be used by the file system. This can be 0 if only one file is open at a time.

Volref is the volume reference number, or blank for a volume scan.

OPENR macro. This macro opens the resource fork of a file.

Usage:

OPENR filename,buffer,volref

Filename is the address of a Pascal string containing the name of the file to be opened. Buffer is the address of a 522-byte buffer to be used by the file system.

Listing E.22 – The MACLIB.ASM file (continued)
POPEN macro. This macro opens the data fork of a file using
the Macintosh standard file name prompt.

Usage:

PO PEN types, ext, namebuf, buffer

Types is the address of a type array:

```
DC.W #Types
DC.L Typel
DC.L Type2
< Etc.>
```

Namebuf is the address of a 63-byte array to receive the file name
selected by the user. Ext is the file extension. Zero
means all extensions. Buffer is the optional 522-byte buffer.

```
MACRO POPEN
    moves, ext, namebuf, buffer
    =
    MOVEM.L AO-A3,-(SP)
    LEA %1,A3
    LEA %2,AO
    LEA %3,A2
    LEA %4,Al
    XREF XXOPEN
    JSR XXOPEN
    J.IDVF.L (SP)+,AO-A3
-ENDM
```

CREATE macro. This macro creates a new file. The file is left open for
access to the data fork. The file handle is returned in DO.W.

```
MACRO CREATE
    filename, buffer, volref =
    MOVEM.L AO-Al,-(SP)
    LEA %1, AO
    IF ' %2' <> ''
        Buffer specified?
    ELSE
        No buffer
    ENDIF
    IF ' %3' = ''
        VolRef specified?
    ELSE
        Specified,
    IF ' %3' = 'DEFAULT'
        Take the default?
    ELSE
        Do vol scan
    ELSE
        Don't
```
213:   MOVE.W %3,D1 ; Use specified
214:   ENDF         ; = DEFAULT
215:   ENDF         ; Specified
216:   XREF XXCREATE ; RTL routine name
217:   JSR XXCREATE  ; Do the create
218:   MOVEM.L (SP)+,AO-A1 ; Restore the registers
219: .ENDM
220: ; PCREATE macro. This macro creates a new file, using the Macintosh prompt
221: ; feature.
222: ; Usage:
223: ; PCREATE prompt,defname,namebuf,buffer
224: ; Prompt is the prompt string.
225: ; Defname is the default name string.
226: ; Namebuf is the buffer for the returned file name.
227: ; Buffer is the optional 522-byte buffer.
228: ;
229: MACRO PCREATE prompt,defname,namebuf,buffer =
230: MOVEM.L AO-A3,-(SP) ; Save registers
231: LEA {prompt},AO ; AO -> Prompt string
232: LEA {defname},A3 ; A3 -> Default Name
233: LEA {namebuf},A2 ; A2 -> Name buffer area
234: LEA {buffer},A1 ; A1 -> 522-byte buffer
235: XREF XXPCREATE ; For the linker
236: JSR XXPCREATE  ; Call RTL routine
237: MOVEM.L (SP)+,AO-A3 ; Restore registers
238:|
239: ; SEEK macro. This macro moves the file pointer on an open file.
240: ; Usage:
241: ; SEEK ioref,offset,sense
242: ; Ioref is the I/O reference number, offset is the offset longword, and
243: ; sense is a word parameter giving the meaning of offset.
244: ;
245: MACRO SEEK ioref,offset,sense =
246: MOVEM.L D1-D2,-(SP) ; Save input registers
247: MOVE.W {ioref},D0 ; Load ioref #
248: MOVE.L {offset},D1 ; Load offset
249: MOVE.W {sense},D2 ; and sense word
250: XREF XXSEEK ; For the linker
251: JSR XXSEEK ; Call RTL routine
252: MOVEM.L (SP)+,D1-D2 ; Restore input registers
253:|
254: ; DELETE macro. Deletes a file by name.
255: ;
256: MACRO DELETE ioref,offset,sense =
257: MOVEM.L D1-D2,-(SP) ; Save input registers
258: MOVE.W {ioref},D0 ; Load ioref #
259: MOVE.L {offset},D1 ; Load offset
260: MOVE.W {sense},D2 ; and sense word
261: XREF XXDELETE ; For the linker
262: JSR XXDELETE ; Call RTL routine
263: MOVEM.L (SP)+,D1-D2 ; Restore input registers
264: |
265: ;
Usage:
DELETE Filename[,volref]

Filename is the address of a file-name string. Volref is a volume reference number.

.MACRO DELETE
MOVEM.L AO/D1,(SP) ; Save input registers
LEA %1,AO ; Load file name address
IF '\02' <> '' ; Is name null?
MOVE.W %2,D1 ; Load volume reference
ELSE ; Not null,
CLR.W D1 ; make it zero
ENDIF ;
XREF XXDELETE ; For the linker
JSR XXDELETE ; Call RTL routine
MOVEM.L (SP)+,AO/D1 ; Restore registers
.ENDM

GETINFO macro. This macro gets the file information block for a named file.
Usage:
GETINFO filename,buffer,volref

Filename is the address of a Pascal string containing the name of the file to be queried. Filebuffer is the address of an 80-byte buffer to receive the file info.

.MACRO GETINFO
MOVEM.L AO/A1/D1,(SP) ; Save registers
LEA %1,AO ; AO -> File name
LEA %2,A1 ; AI -> Buffer area
IF '\03' <> '' ; Volref specified?
IF '\03' = 'DEFAULT'
CLR.W D1 ; Do vol scan
ELSE ; Don't
MOVE.W %3,D1 ; Do specific vol
ENDIF ; DEFAULT
ELSE
CLR.W D1 ; Not specified
ENDIF ; Specified
XREF XXGETF ; RTL routine name
JSR XXGETF ; Call RTL
MOVEM.L (SP)+,AO/A1/D1 ; Restore registers
.ENDM

SETPINFO macro. This macro sets the file information block for a named file.
Usage:
SETPINFO filename,buffer,volref
Filename is the address of a Pascal string containing the name of the file to be set. Filebuff is the address of an 80-byte buffer containing the file info.

```assembly
.MACRO SETINFO
    ; filename,buffer,volref =
    MOVEM.L AO/Al/Dl,-(SP) ; Save registers
    LEA %1,AO            ; AO -> File name
    LEA %2,Al            ; Al -> Buffer area
    IF '%3' <> '
        ; Volref specified?
        IF '%3' = 'DEFAULT'
            CLR.W Dl    ; Do vol scan
        ELSE
            ENDIF
        ELSE
            CLR.W Dl    ; Not specified
        ENDIF
        XREF XXSETF
        JSR XXSETF
        IDVEM.L (SP)+,AO/Al/Dl ; Restore registers
    ENDM

READ macro. Reads data from an open file.

Usage:

READ filename,buffer,count

Filename is a word, buffer is an address, and count is a longword.

```assembly
.MACRO READ filename,buffer,count =
    MOVEM.L Dl-D2/AO,-(SP) ; Save registers
    LEA {filename},DO     ; Load file number
    MOVE.W {buffer},AO    ; AO -> Buffer address
    MOVE.L {count},Dl     ; Dl = Byte count
    CLR.W D2              ; Indicate no newline
    XREF XXREAD
    JSR XXREAD
    MOVEM.L (SP)+,Dl-D2/AO ; Restore registers

READLN macro. Reads a line of data from an open file.

Usage:

READLN filename,buffer,count

Filename is a word, buffer is an address, and count is a longword.

```assembly
.MACRO READLN filename,buffer,count =
    MOVEM.L Dl-D2/AO,-(SP) ; Save registers
    MOVE.W {filename},DO  ; Load file number
    LEA {buffer},AO       ; AO -> Buffer address
```
WRITE macro. Writes data to an open file.

Usage:

WRITE filenum,buffer,count

Filenum is a word, buffer is an address, and count is a longword.

CLOSE macro. Closes an open file.

Usage:

CLOSE filenum

EXIT macro. Flushes volumes, returns to Finder.

USAGE:

EXIT

GETEVENT macro. This macro returns in DO.W the event number
of an event obtained from the system's event queue.

Listing E.22 - The MACLIB.ASM file (continued)
Programming the Macintosh in Assembly Language

Listing E.22 – The MACLIB.ASM file (continued)
StopAlert  #id[,filterproc]

#id is a resource ID, and filterproc is an event filter address. Returns # of the item hit in D0.W.

.MACRO  StopAlert
MOVEM.L D1-D2/AO-Al,-(SP);  ; Save registers
CLR.W -(SP) ; Room for result
MOVE.W %1,-(SP) ; Push resource ID
IF '%2' <> '' ; If proc specified
PEA %2 ; Load pointer
ELSE
CLR.L -(SP) ; No proc
ENDF
DC.W $A986 ; _StopAlert trap
MOVE.W (SP)+,DO ; Result to DO
MOVEM.L (SP)+,D1-D2/AO-Al; ; Unsave registers
.ENDM

NoteAlert macro. Calls Macintosh NoteAlert facility.

Usage:

NoteAlert  #id[,filterproc]

#id is a resource ID, and filterproc is an event filter address. Returns # of the item hit in D0.W.

.MACRO  NoteAlert
MOVEM.L D1-D2/AO-Al,-(SP);  ; Save registers
CLR.W -(SP) ; Room for result
MOVE.W %1,-(SP) ; Push resource ID
IF '%2' <> '' ; If proc specified
PEA %2 ; Load pointer
ELSE
CLR.L -(SP) ; No proc
ENDF
DC.W $A987 ; _NoteAlert trap
MOVE.W (SP)+,DO ; Result to DO
MOVEM.L (SP)+,D1-D2/AO-Al; ; Unsave registers
.ENDM

CautionAlert macro. Calls Macintosh CautionAlert facility.

Usage:

CautionAlert  #id[,filterproc]

#id is a resource ID, and filterproc is an event filter address. Returns # of the item hit in D0.W.
Listing E.22 – The MACLIB.ASM file (continued)

`533: .MACRO CautionAlert
534: MOVEM.L D1-D2/AO-Al,-(SP); ; Save registers
535: CLR.W -(SP); ; Room for result
536: MOVE.W %1,-(SP) ; Push resource ID
537: IF '％2' <> '' ; If proc specified
538: PEA %2 ; Load pointer
539: ELSE ; No proc
540: CLR.L -(SP) ; Push 0 long
541: ENDIF ;
542: DC.W $A988 ; CautionAlert trap
543: MOVE.W (SP)+,DO ; Result to DO
544: MOVEM.L (SP)+,D1-D2/AO-Al; ; Unsave registers
545: .ENDM
546: ;
547: ; SCURSOR macro. Change the cursor to one of the standard
548: ; values.
549: ;
550: ; SCURSOR #ID
551: ;
552: ; #ID is 0-5 (cursor ID)
553: ;
554: .MACRO SCURSOR
555: MOVE.L D0,-(SP) ; ; Save register
556: MOVE.W %1,DO ; Set ID
557: XREF XXCURSOR ; RTL routine
558: JSR XXCURSOR ; Call RTL
559: MOVE.L (SP)+,DO ; Restore register
560: .ENDM
561: ;
562: ; DIALOO macro. Performs a Macintosh _ModalDialog function.
563: ;
564: ; Usage:
565: ;
566: ; DIALOO #ID
567: ; #ID is the resource ID of the dialog template in the resource file.
568: ; D0 has the item number selected by the user.
569: ;
570: ;
571: .MACRO DIALOO
572: MOVE.W %1,DO ; ; Load ID
573: XREF XXDIALOO ; For the linker
574: JSR XXDIALOO ; Call RTL routine
575: .ENDM
576: ;
577: ; CHECK macro. Checks an item in a menu.
578: ;
579: ; Usage:
580: ;
581: ; CHECK menu,item
582: ; Where menu is the menu resource number and item
583: ; is the item number.
584: ;
585: ;
MACRO CHECK

MOVEM.L DO-DL,-(SP) ; Push registers
MOVE.W %1,DO ; Menu to DO
MOVE.W %2,DL ; Item to DL
XREF XXCHECK ; For the linker
JSR XXCHECK ; Call RTL
MOVEM.L (SP)+,DO-DL ; Restore registers
.ENDM

UNCHECK macro. Unchecks an item in a menu.

Usage:
UNCHECK menu,item

Where menu is the menu resource number and item
is the item number.

MACRO UNCHECK

MOVEM.L DO-DL,-(SP) ; Push registers
MOVE.W %1,DO ; Menu to DO
MOVE.W %2,DL ; Item to DL
XREF XXUNCHECK ; For the linker
JSR XXUNCHECK ; Call RTL
MOVEM.L (SP)+,DO-DL ; Restore registers
.ENDM

ENABLE macro. Enables an item in a menu.

Usage:
ENABLE menu,item

Where menu is the menu resource number and item
is the item number.

MACRO ENABLE

MOVEM.L DO-DL,-(SP) ; Push registers
MOVE.W %1,DO ; Menu to DO
MOVE.W %2,DL ; Item to DL
XREF XXENABLE ; For the linker
JSR XXENABLE ; Call RTL
MOVEM.L (SP)+,DO-DL ; Restore registers
.ENDM

DISABLE macro. Disables an item in a menu.

Usage:
DISABLE menu,item

Where menu is the menu resource number and item
is the item number.
Listing E.22 - The MACLIB.ASM file (continued)
Calling sequence:

SETVMIN value

Where value is the desired value.

SETVMAX Macro. Sets the lower limit on a window's vertical scroll bar.

Calling sequence:

SETVMAX value

Where value is the desired value.

SETVVAL macro. Sets the thumb value on a window's vertical scroll bar.

Calling sequence:

SETVVAL value

Where value is the desired value.
745: ;
746: ; SETHMIN macro. Sets the left limit on a window's horizontal scroll bar.
747: ;
748: ; Calling sequence:
749: ;
750: ; SETHMIN value
751: ; Where value is the desired value.
752: ;
753: ;
754: ;
755: ;
756: ;
757:;
758: ; .MACRO SETHMIN 
759: ; MOVEM.L DO,-(SP) ; Push registers
760: ; MOVE.W %1,DO ; DO = Value
761: ; XREF XXSETHMIN ; For the linker
762: ; JSR XXSETHMIN ; Call RTL routine
763: ; MOVEM.L (SP)+,DO ; Pop registers
764: ;
765: ; SETHMAX macro. Sets the right limit on a window's horizontal scroll bar.
766: ;
767: ; Calling sequence:
768: ;
769: ; SETHMAX value
770: ;
771: ; Where value is the desired value.
772: ;
773: ;
774: ;
775: ;
776:;
777: ; .MACRO SETHMAX 
778: ; MOVEM.L DO,-(SP) ; Push registers
779: ; MOVE.W %1,DO ; DO = Value
780: ; XREF XXSETHMAX ; For the linker
781: ; JSR XXSETHMAX ; Call RTL routine
782: ; MOVEM.L (SP)+,DO ; Pop registers
783: ;
784: ; SETHVAL macro. Sets the thumb value on a window's horizontal scroll bar.
785: ;
786: ; Calling sequence:
787: ;
788: ; SETHVAL value
789: ;
790: ; Where value is the desired value.
791: ;
792: ;
793: ;
794: ;
795:;
796: ; .MACRO SETHVAL 
797: ; MOVEM.L DO,-(SP) ; Push registers
798: ; MOVE.W %1,DO ; DO = Value

Listing E.22 – The MACLIB.ASM file (continued)
XREF XXSETHVAL ; For the linker
JSR XXSETHVAL ; Call RTL routine
MOVE.L (SP)+,AO ; Pop registers
.ENDM

WTitle macro. Sets the title bar to a specified string.
Usage:
WTitle string
Where string is the address of the new string (Pascal format).

.MACRO WTitle
MOVE.L AO,-(SP) ; Save AO
LEA %1,AO ; AO -> New string
XREF XXWTITLE ; Call RTL routine
JSR XXWTITLE
MOVE.L (SP)+,AO ; Pop AO
.ENDM

Listing E.22 – The MACLIB.ASM file (continued)
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