By the author of "Assembly Lines: The Book"

IIGS

COMPUTE!'s

APPLE IIGS MACHINE LANGUAGE FOR BEGINNERS

Roger Wagner

The understandable guide to
learning 65816 machine language
on the Apple IIGS.

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Roger Wagner

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Dedication

Once upon a time, a man was called upon to write a book to teach others the things he had spent a lifetime learning. His wife and child waited patiently for the dream to become real. I know one of my father's greatest joys was the accomplishment of that book. The wheel has turned, and now I dedicate this book to the most patient people I know, and the three most important and loved women in my life: my mother, Bea, my wife, Pam, and my daughter, Marta.

Contents

Foreword

This is the definitive guide to programming in 65816 machine language on the Apple IIGS. It's a thorough introduction to machine language programming on the newest Apple II, a comprehensive tutorial for beginning machine language programmers, and an invaluable reference guide for the most experienced software developer.

Roger Wagner's name is well known to Apple users and programmers. He is a popular columnist, a software developer with his own publishing company, and the author of the bestselling *Assembly Lines: The Book*. He has used his years of Apple II experience to put together *COMPUTE!'s Apple IIGS Machine Language for Beginners,* a book for both experienced and beginning machine language programmers.

Clearly written, with dozens of practical examples to show the way, this book includes more than the basics of machine language programming—it's a specific reference and guide to programming in 65816 machine language on the Apple IIGS. For instance, you'll find complete chapters on using the built-in assembler and on how to write and assemble source code with two popular assemblers, the *Merlin 8/16* and the *APW*.

Other topics covered include ProDOS 8 and 16, Menu Manager, the Toolbox, the Memory Manager, QuickDraw, the Event Manager, the Window Manager, and how to add machine language to Applesoft BASIC programs. *COMPUTE!'s Apple IIGS Machine Language for Beginners* also contains exhaustive appendices that you can refer to in an instant. Among the appendices is a comprehensive 65816 instruction set.

Written for Apple IIGS programmers of every level of experience, *COMPUTE!'s Apple IIGS Machine Language for Beginners* is the most complete guide and reference to 65816 programming around. If you want to learn how to program in machine language on the IIGS, or if you're already creating software masterpieces in machine language, you need *COMPUTE!'s Apple II Machine Language for Beginners*.

All the programs in this book are ready to type in and use. There is also a disk available from COMPUTE! Books which includes all the source code from the book. An assembler is required to use the disk. To purchase the disk, use the coupon in the back of the book.

Introduction

Some BASIC programmers believe that machine language is some very difficult and obscure language used only by advanced programmers. As it happens, it's just *different,* and if you have successfully used Applesoft BASIC to write some of your own programs, there's no reason why you should have any difficulty learning to write machine language programs.

This book will meet you at your current understanding of Applesoft BASIC and will introduce you to the fundamental principles of machine language programming. Your knowledge of BASIC will provide a valuable foundation for learning, and you'll even notice some similarities between BASIC and machine language programs. This is no accident. Part of BASIC's original purpose was to be an educational tool in the teaching of machine language programming.

Using the BASIC environment as a starting point, you'll learn about memory organization and use, and you'll learn how to add simple machine language routines to your existing BASIC programs. Each new concept will be introduced as an extension to ideas already presented, making the learning process as absolutely clear and simple as possible. By the time you're done, you'll be able to write your own Apple IIGS machine language programs—ones completely independent of BASIC—and you'll be able to use many advanced Apple IIGS features such as super hi-res graphics, the mouse, menus, and windows.

Because the Apple IIGS is an amazingly complex machine, it's impossible for one book to provide every last detail of its operation. There are very large books written on just some of the many topics covered in this book. For example, the 700-page *Apple IIGS Technical Reference,* by Michael Fischer, is about the IIGS Tools only; and the 600-page *Programming the 65816,* by David Eyes and Ron Lichty, is an encyclopedic reference dealing with just the 65816 instructions. The goal of this book is not to provide the last word about each 65816 instruction, or on every GS Tool call. Instead, the goal is to provide information that will build the foundation essential for your own further efforts.

When you've completed this book, you'll have gained the knowledge and confidence necessary to write your own programs. The many examples of executable programs included will provide valuable subroutines and procedures that you can incorporate in your own programs.

What You Need

Like any creative process, having the right tools and materials can make all the difference in the world. We're going to make some assumptions about what materials you have as you read this book.

Obviously, having an Apple IIGS on hand while you work through the examples is important. You'll also need to have a disk drive to save your programs, although it doesn't matter whether you have a floppy disk of any particular brand or capacity—in fact, even a hard disk is OK. Apple Computer's ProDOS will be used in those chapters that deal with file operations.

When a person writes a letter or report on a computer, a word processor is the right tool for the job. When writing machine language programming, a good *assembler* is what you need. An assembler is essentially a word processor specifically designed for writing machine language programs. It also does many other things, so you'll need one to follow the examples in this book. Most of the examples use the *Merlin 8/16* assembler, but there is also information on the *APW (Apple Programmer's Workshop)* assembler. I prefer the *Merlin 8/16* in terms of ease of use, speed of assembly, and minimum explanation required for a beginning programmer; but you may use any assembler capable of assembling 65816 instructions.

It's also important, especially as you do more programming, to have a solid reference library. For beginners, this book has all the information necessary to complete the examples, but you may wish to look at books listed in the bibliography for further reading material.

Program Library

In the early days of programming, programmers had to write programs that were completely self-contained, ones in which every operation of the program was covered by instructions the programmer had specifically written into the program.

It soon became apparent, however, that time could be saved in program development if the most frequently used routines were available in a library that could be incorporated as the program was being written. That way, things like disk access, printing to the screen, reading the keyboard, and so forth, didn't have to be rewritten every time a new program was started—programmers no longer have to "reinvent the wheel."

In the Apple IIGS, a great number of useful routines and operations are not only already written for you, but are also built right into the machine, much the same way that Applesoft BASIC is already there. Thus, your library is right in the machine. You don't have to add hundreds of lines of program instructions from a disk file when you write a program; a simple call to a subroutine in the computer does the trick. Your program is smaller, development time is shorter, and writing a program is in general much more satisfying.

One of the most valuable lessons you can learn from this book, beyond the simple commands that make up machine language, is how to use the routines already existing in the machine that make writing your programs much easier. You should also make a point of saving every program you write, so you can build your own collection of program operations for use in later programs as you create them.

Just for the Fun of It

One last warning before you start: Don't be discouraged if you're not an overnight expert in assembly language programming.

Many people are discouraged when learning a new skill because they expect instant results. Perhaps you know someone who got interested in art or music, and then became disappointed when their first attempts weren't beautiful works of art or they weren't able to play their favorite melody by just picking up the instrument.

Even some schools lose sight of the fact that not everything has to be justified by monetary or productivity standards. They teach only word processing and spreadsheets because these are the "practical" uses for a computer, and downplay the value of programming or using the computer for fun. Yet these same schools have no problem offering shop and art classes, even though very few students will go on to become professional carpenters or artists.

The key to your own success is to set achievable goals, and to do things that you find personally rewarding. Don't worry that the first program you write isn't likely to be immediately publishable as a commercial product, or that it isn't big enough to do something "really important." By starting with a small project like drawing a single line on the screen, you'll have chosen a project that will teach you something, and in completing it, you'll gain the confidence and sense of satisfaction that will make you want to start your next project. As your experience grows, one day you'll suddenly realize that you've learned how to write all sorts of great programs and that programming has become more fun than work.

The bottom line is this: The most important rule in programming is that you enjoy it. As in learning any subject, motivation and taking the time to experiment are more important than genius or prior experience. If you have the former, everyone will think you have the latter.

Chapter 1

Applesoft BASIC and Beyond

Chapter 1

Applesoft BASIC and Beyond

A good starting point for learning machine language is to take a look at something you're already familiar with, namely Applesoft BASIC. As it happens, Applesoft BASIC is a machine language program. When your program executes the command PRINT "HELLO", it's a machine language program that puts the characters on the screen. It is also possible to call custom-made machine language routines from within an Applesoft BASIC program. If this is all true, why learn machine language in the first place?

What Is Machine Language and Why Bother Learning It?

As discussed earlier, the primary reason for learning machine language is that you'll find the subject interesting and fun to experiment with. There are some more tangible reasons, though, that will make learning machine language more useful than, say, learning ancient Latin. One of the main reasons is speed. The Apple IIGS can execute about 100,000 machine language instructions per second, far more than Applesoft BASIC can execute, even when it's running in fast mode.

Another reason to learn machine language is flexibility. Applesoft BASIC is an artificial environment that stands between you and the most fundamental level of your computer. When you type PRINT "HELLO" in a BASIC program, you really don't have any idea what causes the letters to appear on the screen. In machine language, you do. In addition, BASIC is limited to the different kinds of information, called *data structures*, that it can easily deal with. For example, in BASIC you can have string variables with lengths up to 255 characters. Suppose you want to store a paragraph with 1000 characters in it—Applesoft BASIC has no direct variable defined for paragraph. Or suppose you want your program to handle graphics objects like points, rectangles, ovals, and so forth. Again, no variable types exist for these.

In machine language, there is not specifically any data type; you still have to create these. But you do have the flexibility to create any kind of data structures you want.

On the Apple IIGS, another good reason to program in machine language is to have access to all those features, such as super hi-res graphics, that are built into the machine, but are not directly accessible from Applesoft BASIC. With machine language, these are relatively easy to use. In fact, an interesting first application of your machine language programming skills can be using them to create a bridge between Applesoft BASIC and the IIGS Tools.

Finally, one of the best reasons to learn machine language is to gain a better idea of how a computer actually works. In machine language, you're dealing with the most fundamental levels of operation in the computer. You'll see how the microprocessor actually runs a program, how memory is used, how the hardware interacts with a program, and more. This knowledge will also make you more flexible as the hardware evolves and changes in the future, and it provides an excellent foundation should you ever wish to program on other computers.

A World of Languages

Programming is just a word to describe the process of telling your computer what *you* want it to do. In fact, this is the real power of a computer as a modern device. The beauty of a computer is that you can tell it how to help you solve problems that are unique to your own life, on your own terms, and at your convenience.

How hard is it to program a computer? Not as hard as you might think. The only requirement is a *language* with which you can communicate with your computer. It doesn't understand English directly, but it's also not always necessary to use BASIC, PASCAL, or other formal computer languages. Some of the most successful commercial programs for the computer are just well-disguised programming languages.

As an example, consider the classic spreadsheet program. It's always fun to hear someone say "Oh, I don't program. I just use programs like the Acme Spreadsheet." With a little thought, you realize that using a spreadsheet is much like programming. The user creates a set of numbers, variables and equations that are used in a predictable order by the computer. Some more advanced spreadsheet programs have enhancements like search and sort functions, IF-THEN testing, and more. It's programming all right—just in a different language than we usually think of.

Any language consists of a collection of words with specific meanings. In programming, these words are usually commands that make the computer do something in particular, such as add numbers, clear the screen, and so on.

In Applesoft BASIC, there are just over 100 different commands to learn, expressions like PRINT, VTAB, INPUT. Once you've learned the commands, you can put them together in a certain order and create a program.

In machine language, there are still only about 100 commands to learn, and many fall into groups of similar functions that make learning them easier still.

How It Really Works

Lesson #1 starts with Wagner's Paradox:
"Everything complex can be broken down into simple elements (and nothing is as simple as it seems)."

Although sometimes it feels like life is an endless case of discovering the fine print, it's true that most things in life are quite simple when you consider the fundamental things that make them up. The computer is an excellent example.

Even though the engineering required to build a computer is awe-inspiring, the underlying principle of their operation is almost trivial.

The heart of your Apple IIGS is something called the 65816 microprocessor. Another important part is its *memory*—thousands of places in the computer where a simple number can be stored. Each memory location can store an arbitrary number value in the range of 0 to 255. Number values larger than 255 must use a combination of bytes to store the number value. That's why, in Applesoft BASIC, you get an "ILLEGAL QUANTITY ERROR" if you try to use the POKE statement with a value larger than 255, such as in POKE 768,1000. (Try this if you've never done it.)

The 65816, like its cousins in other computers, works on the idea of scanning through memory, one location at a time, and performing some action depending on what number value it finds stored there.

If it finds a 27 in one place, perhaps it will add some numbers; if it finds a 32, it will subtract them. In the 65816, as was mentioned earlier, there are about 100 general operations that the microprocessor will do, depending on what number it finds in a given memory location. A program is created by putting the possible commands in a certain meaningful order to tell the computer how to do a certain task.

Obviously, the more memory a computer has, the more instructions (and information) it can hold. In the world of Applesoft BASIC, which was designed for an earlier microprocessor called the 6502, there are about 65000 memory locations in which various numbers can be stored. Each memory location is called a *byte* of memory by most programmers. When you hear someone talk about 1 *megabyte*, they're talking about one million separate memory locations in the computer. The 65816, a newer descendant of that original 6502, can address up to *16 million bytes* of memory (16 megabytes).

In Applesoft BASIC, however, which was created for the Apple IIs, we can only talk to 64K at a given time. (There are actually 65,536 locations in the computer. In the metric system, *K* is used as an abbreviation for thousand, but in computer jargon *K* refers to 1024 bytes.)

BASIC vs. Machine Language

The 65816 can directly interpret the numbers stored in memory as a program—a sequence of instructions. This sequence of number-instructions is called *machine language*. Machine language, or ML, is the actual series of numbers in memory that the microprocessor can directly act on. There are no handy words like PRINT or HOME to make life easier for the human creating the program. Machine language programming in its literal sense is the process of placing numbers in memory, one at a time, to create a program that the computer can understand and carry out. *Assembly language*, as we'll see shortly, is actually what most people mean when they say they program in machine language. Assembly language itself is an extension beyond true machine language—but more on that later.

BASIC is sometimes called a *high-level* language. One way of looking at this term is that BASIC commands, like PRINT, are closer to English than more simplistic languages (like machine language). What it really means, though, is that a new command has been created, behind the scenes, from the primary 100 commands at the machine language level, to do something fairly complex.

An interesting analogy might be to consider that all the words you know are created with the 26 letters of the alphabet. As with human language, an infinite number of specific high-level computer commands can be created from the 100 fundamental commands that are built into the computer.

In its native mode, just the 65816 and some memory, the computer doesn't really understand words like PRINT. That's where the idea of Applesoft BASIC as language in itself comes in.

When you type in RUN to start an Applesoft BASIC program, you're actually triggering a machine language program in the computer that acts as a middleman between the lines of BASIC that you typed in and those 100 commands that the 65816 understands.

When your program says PRINT "HELLO", this intermediate program looks up the word PRINT in a list of commands, and then executes a short, built-in ML program that prints HELLO on the screen.

So, actually, Applesoft BASIC really is machine language. Each time a statement in your Applesoft BASIC program is executed, the computer carries out a short machine language program (or more properly, a *subroutine*).

The main reason Applesoft BASIC runs more slowly than a pure machine language program is that it takes the Applesoft BASIC interpreter (the middleman) time to decide which routine to execute for each command in the various lines of BASIC.

Peeking at Maps and Addresses

If you know how to write even a simple program in Applesoft BASIC, you're well on your way to knowing how to write a program in machine language.

For starters, we mentioned earlier that there are 65,536 locations in the original Apple II computers to store the parts of a machine language program. What a coincidence—line numbers in BASIC cover the same range.

In BASIC you identify a place in your program with a line number. For example, to jump to a given routine, you might use the statement GOSUB 1000.

In machine language, each location is identified with an *address*. Computer people start counting with zero for the first item, so the addresses of those locations count 0, 1, 2, 3—up to 65,535. (65,535 + the 0 byte = 65536).

Just like the addresses of the houses on a street, each address of a location in memory lets you find one and only one spot in the computer to look at or store a number in.

A useful chart can be made to show a diagram of the various memory locations in your Apple, and to show what different parts of memory are used for. Such a chart is called a *memory map*. Figure 1-1 is a simple memory map that represents the memory that Applesoft BASIC uses in the Apple IIGS.

This memory map represents each single available memory location in the first 64K (65536) of memory. The zero byte is shown at the bottom, but this is arbitrary. It's also important not to confuse the *contents* of a memory location with its address. We've already said that the value of a number stored in a byte of memory cannot be larger than 255. However, the *address* of a given byte can be virtually any number at all, as shown by the memory map.

Figure 1-1.
A Simple Apple IIGS
Memory Map

```
65535
65534
65533
  .
  .
  .
32768
32767
32766
  .
  .
  .
 255
 254
 253
  .
  .
  .
  3
  2
  1
  0
```

Another common way of drawing a memory map is horizontally, with low address values on the left, and the *top* of memory on the right, such as the one shown in Figure 1-2.

Figure 1-2. Horizonal Memory Map

0	1	2	. . .	32768		65535

In normal Applesoft BASIC, there are two commands in particular, POKE and PEEK, that let you look at, and usually change, the contents of any of the first 64K of memory in your computer. These commands are the first links to the world of machine language.

Many times, a machine language program will use the contents of some particular memory location to store a meaningful value or to look at the contents of a location to see what action should be taken.

The Applesoft BASIC PEEK command is used to determine the contents of a given memory location in the Apple.

By using the PEEK command to examine different memory locations, you can find out some useful things not normally accessible by the usual BASIC commands. For example, memory location 33 holds the width of the screen. Suppose you wanted to write a general-purpose program which would work on anybody's computer, in either 40 or 80 columns. By examining memory location 33, your program could tell which mode is active when it is run. For example:

```
10 TEXT: HOME
20 CW = PEEK(33): REM DETERMINE COLUMN WIDTH
30 T$ = “TITLE OF THIS PROGRAM”
40 HTAB CW/2 — LEN(T$)/2: REM CENTER TITLE
50 PRINT T$: REM PRINT CENTERED TITLE
```

This program will always print a centered title on the screen, no matter what the video display mode.

Another useful PEEK is at memory locations 218, 219, and 222. In an Applesoft BASIC program, errors can be trapped by the statement ONERR GOTO early in the program. Using this command, for example, Control-C can appear to be ignored by the running program. Usually, Control-C will stop a running program, but with ONERR, you can trap the error and continue program execution. Program 1-1 is a short example.

Program 1-1. ONERR Example 1

```
5 HOME
10 ONERR GOTO 100
20 X = 1
30 VTAB 1:HTAB 1: PRINT X
40 X = X + 1
50 IF X < 10000 THEN 30
60 END
100 EC = PEEK (222) : REM ERROR CODE
110 EL = PEEK (218) + 256 * PEEK (219) : REM ERR LINE #
120 IF EC = 255 THEN VTAB 12: HTAB 1: PRINT "I'M NOT DONE YET!"
130 VTAB 1:HTAB 1:RESUME
```

In this program, line 10 tells Applesoft BASIC to jump to line 100 if any error occurs. Whenever any error occurs in a running program, Applesoft BASIC always stores a code value for the error in location 222. It also stores the value for the line number.

Storing the line number, however, creates a new problem. We mentioned earlier that a single byte of memory could only store a value in the range of 0 to 255. Since line numbers can have any value from 0 to 65535, how can Applesoft BASIC store the number? It uses two bytes. The system is a little strange, though. First, Applesoft BASIC divides the line number the error occurred in by 256 (a number you'll see a lot in machine language programming). It stores the remainder in the first memory location—218—and then stores the result in the next memory location, 219.

For example, if you press Control-C while the sample program is on line 40, Applesoft BASIC stores 40 (the remainder) in location 218, and it stores 0 (40 divided by 256 = 0, remainder 40) in location 219.

If you had a large program, and an error occurred when the program was executing line 600, then locations 218 and 219 would hold the values 88 and 2, respectively (600 divided by 256 equals 2, remainder 88).

You may wonder why we divide by 256. The main reason is that dividing a large line number like 63000 by any other number produces results or remainders larger than 255, and we couldn't store the result or remainder in a single byte. Using 256 as the divisor makes everything work smoothly. And one byte can hold any one of 256 different numbers (0–255).

Now, back to the error handling routine. To reconstruct the line number that the error occurred on, the program needs to multiply the value at location 219 by 256, and then add the result to the remainder value at 218. Line 110 does this for purposes of illustration, although our program in particular doesn't use the result.

Finally, line 120 tests the error code to see if the error was caused by pressing Control-C (255 is the error code for Control-C). Any other error, such as a syntax error, generates a different code.

When trying out this program press Control-C several times in a row. You'll notice the value for X at a given point is sometimes printed below the error message when you press Control-C. This is because RESUME re-executes the last statement executed, not the last complete line.

POKEing Around in Memory

In Applesoft BASIC, a POKE is used to put a particular number value (always in the range of 0 to 255) into a particular memory location (in the range of 0 to 65535).

For example, the sample program just presented has a drawback: It ignores all errors, even typographical errors in the listing. If a syntax error due to a typing mistake occurs, the program gets stuck in an endless loop—resuming the line with the error, going to the ONERR routine, and resuming again. Try it—retype line 50 as

```
50 IF X PRINT 10000 THEN 30 : REM DELIBERATE ERROR
```

Line 100 can tell the kind of error, but just how can we turn off the ONERR trap?

The answer is to change memory location 216. This location is set with a certain number value when the ONERR GOTO statement is executed, and Applesoft BASIC uses this value as a *flag*, or indicator, of when to trap errors. If our program could reset location 216 to 0 (the ONERR off value), errors other than Control-C would be properly handled—the program would stop and a message would be printed. While we're at it, let's add the instruction GOTO 30 to line 120 so as to re-execute the entire line when Control-C is pressed.

Program 1-2 is the revised listing.

Program 1-2. ONERR Example 2

```
5. HOME
10 ONERR GOTO 100
20 X = 1
30 VTAB 1:HTAB 1: PRINT X
40 X = X + 1
50 IF X < 10000 THEN 30
60 END

100 EC = PEEK (222) : REM ERROR CODE
110 EL = PEEK (218) + 256 * PEEK (219) : REM ERR LINE #
120 IF EC = 255 THEN VTAB 12: HTAB 1: PRINT "I'M NOT DONE YET!": GOTO 30
```

```
125 POKE 216,0 : REM TURN OFF "ONERR"
130 VTAB 1:HTAB 1:RESUME
```

First, try this program as shown to verify that it works the way the first sample listing did. Then retype line 50 incorrectly as

```
50 IF X PRINT 10000 THEN 30 : REM DELIBERATE ERROR
```

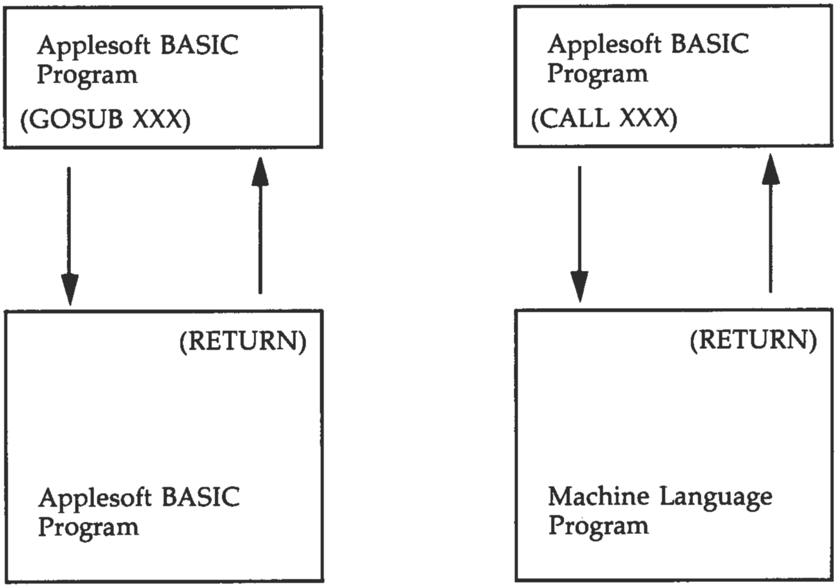
and verify that the improved listing can distinguish between Control-C and other errors. By expanding the list of IF-THEN tests for different error codes, you can make your programs selectively respond to a wide variety of errors at different parts in your program.

Using Applesoft BASIC's CALLs

The other, and most important, link to machine language programming from Applesoft BASIC is the CALL command.

If you've ever used a CALL statement in Applesoft BASIC, you've already done the machine language equivalent to BASIC's GOSUB command. For example, a CALL 32768 from BASIC tells the computer to start running a machine language program at a certain location in memory (location number 32768). As long as there is a machine language program there—and that program eventually ends with the usual RETURN code (or more accurately, its ML equivalent)—then, when the routine is finished, program control will return to your Applesoft BASIC program (Figure 1-3).

Figure 1-3. GOSUB vs. CALL



For now, it's important to understand that *where* a machine language program is located in the computer (its address) is as important as the line numbers in a BASIC Program.

Instant Machine Language Programming

One of the first, and best ways to start using machine language programming techniques in your own programs is to just use Applesoft BASIC's CALL command to execute short machine language routines that either already exist in the computer or that you have written yourself.

We mentioned already that there were quite a number of preprogrammed routines built into your Apple computer that Applesoft BASIC uses for its own commands. Knowing some of these, like knowing some of the special memory locations to PEEK and POKE, can enhance your existing Applesoft BASIC programs.

For instance, did you wonder why the sample ONERR program didn't use a FOR-NEXT loop? To find out, try running the program written using a FOR-NEXT loop (Program 1-3) and pressing Control-C.

Program 1-3. ONERR Example 3

```
5 HOME
10 ONERR GOTO 100
20 FOR X = 1 TO 10000
30 VTAB 1:HTAB 1: PRINT X
40 NEXT X
60 END

100 EC = PEEK (222) : REM ERROR CODE
110 EL = PEEK (218) + 256 * PEEK (219) : REM ERR LINE #
120 IF EC = 255 THEN VTAB 12: HTAB 1: PRINT "I'M NOT DONE YET!": GOTO 30
125 POKE 216,0 : REM TURN OFF "ONERR"
130 VTAB 1:HTAB 1:RESUME
```

When you press Control-C in this program, you'll find that, although the code for handling the Control-C works OK, when the program tries to continue the FOR-NEXT loop, you get a NEXT WITHOUT FOR error. That's because Applesoft BASIC forgets where it's up to in the FOR-NEXT loop when the error occurs. Does this mean you can never have an ONERR trap with a GOTO in a program that uses FOR-NEXT loops? It does—if you don't know a special CALL that you can do to fix the problem. Program 1-4 is the revised program.

Program 1-4. ONERR Example 4

```
5 HOME
10 ONERR GOTO 100
20 FOR X = 1 TO 10000
30 VTAB 1:HTAB 1: PRINT X
40 NEXT X
60 END

100 EC = PEEK (222) : REM ERROR CODE
110 EL = PEEK (218) + 256 * PEEK (219) : REM ERR LINE #
115 CALL 62248: REM FIX ONERR HANDLING
120 IF EC = 255 THEN VTAB 12: HTAB 1: PRINT "I'M NOT DONE YET!": GOTO 30
125 POKE 216,0: REM TURN OFF "ONERR"
130 VTAB 1:HTAB 1:RESUME
```

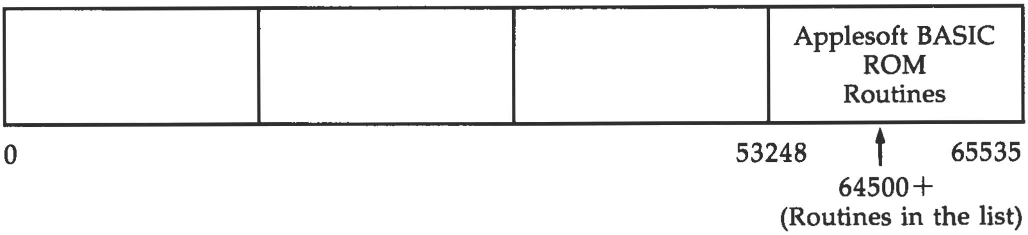
The added line, 115, does a CALL 62248 that restores Applesoft BASIC's memory (so to speak) about where in the FOR-NEXT loop it was when the error occurred. CALL 62248 calls a part of the Applesoft RESUME routine that fixes the internal Applesoft information about any pending FOR-NEXT loops. If the error doesn't occur in a FOR-NEXT loop, the CALL 62248 doesn't hurt anything.

There are a number of useful CALLs that you can do in an Applesoft BASIC program to routines already present in your computer. Here's a short list of some of those ML routines that you can call right from Applesoft BASIC.

Address to Call	**Effect**
64538	Move cursor up.
64614	Move cursor down.
64528	Move cursor left.
64500	Move cursor right.
64780	Wait for a keypress.
64858	Wait for a RETURN keypress.
64668	Clear to end of line from cursor.
64578	Clear to bottom of screen from cursor.

Looking at the list, you'll notice all the addresses have rather high values. That's because Applesoft BASIC uses a large number of machine language routines starting at location 53248. The particular routines in this list start at 64500 and above, but you'll recall the ONERR fix was a CALL to location 62248. Figure 1-4 is a memory map that shows where Applesoft BASIC ROM is located.

Figure 1-4. The Location of Applesoft BASIC ROM



The illustration indicates that the Applesoft BASIC routines are ROM routines. You've probably heard the terms *RAM* and *ROM* before. (ROM stands for *Read Only Memory;* RAM stands for *Random Access Memory.*) Your computer has both RAM and ROM in it. The difference is that RAM not only stores a number value, but the number value can be changed by *writing* a new value to that location at any time. That's what a POKE in Applesoft BASIC does: It writes a new number value to a given memory location. ROM memory, on the other hand, can only be *read.* That is, you can PEEK to see what's there, but a POKE will not change the contents.

As an example, try this short BASIC program:

```
10 PRINT PEEK (62000): REM SHOW WHAT'S AT LOC. 62000
20 POKE 62000,0 : REM TRY TO CHANGE IT
30 PRINT PEEK (62000): REM SEE IF IT CHANGED.
40 END
```

What you should find is that, no matter how hard you try to change the contents of memory location 62000, it always holds the same value.

The problem with RAM is that, generally speaking, when you turn off the computer's power, the contents of RAM are erased; therefore, you can't store anything permanent there. But there are some things, like Applesoft BASIC, that the computer designers wanted to keep in the machine while the power is off; these are stored in ROM.

As a side-note: If we explain this much further, the latter part of Wagner's Paradox will rear its ugly head. You've probably already noticed that both RAM and ROM can access any given byte at a time, so ROM is technically random access memory, too (as opposed to sequential access memory, where you have to look at each byte in a series before you can examine each successive byte). Also, when the power is off, your Apple IIGS remembers changeable things like the clock time and your Control Panel settings, and these have to be written somewhere to be stored. If you can't write to ROM, it must be RAM that they are written to. But we just said RAM lost its contents when the power is turned off. The designers cheated by hooking up a battery to a small (256) number of bytes of memory to keep a few things, like the time and the Control Panel settings, on hand while the power is turned off.

Since ROM routines are always in the machine at the same place all the time, you can CALL them from your Applesoft BASIC program, just like the ONERR fix. To see how these might be used, let's consider some more short examples.

Waiting for a keypress. Usually, in an Applesoft BASIC program, when you want the program to wait for a keypress you must use GET A$ or something similar to get the character from the keyboard. The only disadvantage is that a flashing cursor appears on the screen. Suppose you want to write a program that waits for a keypress, but doesn't put a flashing cursor on the screen. Using CALL 64780 from the previous chart, you could write a program like Program 1-5.

Program 1-5. Waiting for Keypress

```
10 HOME
15 PRINT "WAIT FOR KEYPRESS DEMO"
20 VTAB 12: PRINT "PRESS A KEY TO CONTINUE..."
25 CALL 64780
30 HOME
35 VTAB 12: PRINT "THANK YOU!"
40 END
```

Moving around. This next program, Program 1-6, demonstrates how to move the cursor around on the screen, depending on what key is pressed. (These calls only work from 40-column mode.)

Program 1-6. Moving the Cursor

```
10 HOME: PRINT CHR$(17): REM 40-COLUMN MODE
20 HTAB 20:VTAB 12:REM CENTER CURSOR
30 GET A$
40 IF A$="U" THEN CALL 64538
50 IF A$="D" THEN CALL 64614
60 IF A$="L" THEN CALL 64528
70 IF A$="R" THEN CALL 64500
80 IF A$="Q" THEN END
90 GOTO 30
```

Calling them by name. Another trick we can add to an Applesoft BASIC program to make the CALLs more understandable is to set Applesoft BASIC variables equal to the address you want to call. By making the names of the variables a clue to the function of the routine itself, your program becomes more understandable.

For example, let's take that last program, and change it just a bit (Program 1-7).

Program 1-7. Using Meaningful Variable Names

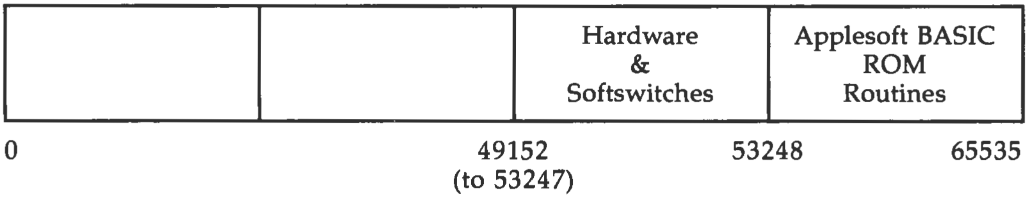
```
 5 UP=64538: DOWN=64614:LEFT=64528:RIGHT=64500
10 HOME: PRINT CHR$(17): REM 40-COLUMN MODE
20 HTAB 20:VTAB 12:REM CENTER CURSOR
30 GET A$
40 IF A$="U" THEN CALL UP
50 IF A$="D" THEN CALL DOWN
60 IF A$="L" THEN CALL LEFT
70 IF A$="R" THEN CALL RIGHT
80 IF A$="Q" THEN END
90 GOTO 30
```

In naming the routines in Applesoft BASIC, remember that only the first two letters of the name are really used by Applesoft BASIC. This means you can't use two different routines called MOVEUP and MOVEDOWN, for example. Also, you have to use legal variable names, and you must avoid the use of Applesoft BASIC keywords. You can't create a variable called PRINT, for example.

Hardware Locations and Softswitches

There is one other area of memory you should be aware of, the range from 49152 to 53247. This area of memory contains addressable locations that are not necessarily either ROM or RAM. Instead, many of the memory locations in this area are direct electrical connections to part of your computer's hardware. The computer is designed so a program can examine certain of these locations to determine the status of physical parts of the computer, such as the keyboard, and to also change other parts that are hardware controlled, such as the speaker, text and graphics display, and other functions. Figure 1-5 shows the location in memory of hardware and softswitches.

Figure 1-5. Memory Locations of Softswitches



For example, suppose you want to know if someone were pressing the Open Apple key on the keyboard. Since a GET A$ and an INPUT A$ (the usual methods of getting characters from the keyboard) won't work, you need some other alternative. Fortunately, memory location 49249 is directly connected to the Open Apple key. In this case, we use the term *memory location* in a very general sense. Although we can gain information with a PEEK (49249), there really isn't any RAM or ROM there—just a wire to the keyboard.

To see how to use this in a program, try this sample program:

```
10 PRINT "PRESS THE OPEN APPLE KEY..."
20 IF PEEK (49249) < 128 THEN 20
30 PRINT "THANK YOU!"
40 END
```

You'll notice that what we're looking for is for the apparent "contents" of location 49249 to reach a value greater than 127. If you were to print the contents on a continuous basis (say in a program loop), you'd see all kinds of different values. The important change that takes place when the Open Apple key is pressed is that although a wide range of different values will still be seen, all of them will have a value greater than 127. Later on, you'll see what's so special about the values 127 and 128.

There is also another group of these apparent memory locations that are called *softswitches.* A softswitch is an addressable switch that will change the state of something in the computer just by accessing the location.

For example, if you want to switch from the text display to a view of whatever is on the hi-res page, the steps in Program 1-8 will do the trick.

Program 1-8. Switching to Hi-Res

```
10 PRINT "PRESS A KEY FOR THE HI-RES DISPLAY..."
20 GET A$
30 POKE 49239,0: REM HI-RES SWITCH
40 POKE 49232,0: REM GRAPHICS DISPLAY
50 POKE 49235,0 : REM MIXED DISPLAY
60 VTAB 22: PRINT "PRESS A KEY FOR TEXT AGAIN..."
70 GET A$
80 POKE 49233,0: REM BACK TO TEXT
90 END
```

There are two separate softswitches that are used to control hi-res graphics. The first, 49239, is a control switch that tells the computer that you want hi-res (as opposed to lo-res) graphics. However, setting this switch doesn't actually change the display. It's the other location, 49232, that switches the display from text to graphics.

Line 80 uses location 49233 to switch back to text. Many programs that let you switch between text and graphics views use POKEs (or an equivalent) to switch the display.

It is important to note that it's the *accessing* of the location that does the switch, not any actual manipulation of the data there, because there is no RAM to be changed. You could just as easily use a POKE 49233,157 on line 80—it wouldn't make any difference. Zero is used just to keep things simple in the listing, but the computer doesn't care what you use.

What You've Learned So Far

The important thing so far is to understand that there are many levels of programs in your Apple computer. You're familiar with Applesoft BASIC, but ultimately, the computer actually runs series of number values stored in memory, called a machine language program.

A machine language program is called by jumping to a given address, rather than a line number as in BASIC. Most machine language routines are like BASIC subroutines, and they eventually return control back to the point from where they are called. This means that they can be used with a CALL statement from within an Applesoft BASIC program, just like BASIC subroutines, to enhance the programs you are writing today.

Not every memory location has to contain an actual program, however. Some locations store *flags* to indicate the status of something. Others contain data, such as the words to print on the screen, and some may not be "real" memory at all, but instead are hardware locations that control certain computer functions or tell you something about what's going on in the system.

The Applesoft BASIC commands POKE and PEEK can be used to both alter the contents of memory and to examine any given memory location to see what's already there. POKE can also be used to access hardware *softswitches* to change things like the screen display.

You may want to go back to programs you've seen in magazines, or on your local user group program disks, and look for POKEs, PEEKs, and CALLs to see how these are used in many different Applesoft BASIC programs for a variety of results.

Secret #1

You can use POKEs to change the screen, background, and text colors on your Apple IIGS right from within an Applesoft BASIC program.

Here's a program that asks for new color screen values, and then changes the system accordingly.

```
0 REM SCREEN COLOR DEMO
5 DIM C$(15): FOR I = 0 TO 15: READ C$(I): NEXT I
10 SV = PEEK (49186): REM SCREEN VALUE
15 TX = INT (SV / 16): REM TEXT COLOR VALUE
20 BK = SV - (TX * 16): REM BACKGROUND COLOR VALUE
25 REM
30 BV = PEEK (49204): REM BORDER VALUE
35 HV = INT (BV / 16): REM OTHER HARDWARE VALUES
40 BC = BV - (HV * 16): REM BORDER COLOR VALUE
45 OS = SV:OB = BV: REM SAVE ORIG. VALUES
50 TEXT : HOME
55 PRINT “BACKGROUND COLOR IS: ”;C$(BK)
60 PRINT “TEXT COLOR IS: ”;C$(TX)
65 PRINT “BORDER COLOR IS: ”;C$(BC)
100 REM GET NEW COLORS
105 PRINT
110 INPUT “ENTER VALUE FOR BACKGROUND: (0-15)”;BK$:BK = VAL (BK$): IF BK < 0 OR BK
    > 15 THEN 110
115 INPUT “ENTER VALUE FOR TEXT: (0-15) ”;TX$:TX = VAL (TX$): IF TX < 0 OR TX > 15
    THEN 115
120 IF BK = TX THEN PRINT : PRINT CHR$ (7);“YOU WON’T BE ABLE TO SEE WHAT”: PRINT
    “YOU ARE TYPING!”: GET A$: GOTO 100
125 INPUT “ENTER VALUE FOR BORDER: (0-15) ”;BC$:BC = VAL (BC$): IF BC < 0 OR BC >
    15 THEN 120
200 REM RESET VALUES
210 SV = TX * 16 + BK: POKE 49186,SV: REM SET BACKGROUND & TEXT
220 BV = HV * 16 + BC: POKE 49204,BV: REM SET BORDER COLOR
230 PRINT : INPUT “TRY AGAIN? (Y/N)”;I$
235 IF I$ = “Y” OR I$ = “y” THEN 100
290 POKE 49186,OS: POKE 49204,OB: REM RESTORE SCREEN
299 END
999 DATA BLACK,DEEP RED,DARK BLUE,PURPLE,DARK GREEN,DARK GRAY,MEDIUM BLUE,LIGHT
    BLUE,BROWN,ORANGE,LIGHT GRAY,PINK,GREEN,YELLOW,AQUAMARINE,WHITE
```

Although it may seem a little long, the basic principles are quite simple. The softswitch at location 49186 contains both the background color and the text color. Dividing by 16 separates text color value. Subtracting this value from the total value then yields the background color. Since each color range can only be in the range of 0 to 15, it is possible to pack both values into a single byte.

Location 49204 holds the value for the border color, along with some other system values. The designers of the Apple IIGS probably didn’t want to waste half a byte. The array C$( ) has been set up with the words for each color value in the interest of making the program user-friendly. After inputting the new values, the new values are recombined by multiplying the text color by 16 and then adding the background color (the reverse of the decoding process). When this value is POKEd back to location 49186, the background and text colors immediately change. The screen border byte is recalculated in a similar manner and is likewise updated with a POKE.

The program saves the original contents of both locations so things can be restored when the program is finished. If you make a mistake entering the program and suddenly find yourself with black text on a black background, or something similarly unreadable, just press RESET to restore the colors you've already chosen in the Apple IIGS Control Panel.

Chapter 2

Real Machine Language Programming

Chapter 2

Real Machine Language Programming

Machine language programming is the process of storing the exact number values in memory that the 65816 will be able to understand to carry out a set of instructions.

In the last chapter, you saw how to CALL machine language program from Applesoft BASIC in much the same way as you would do a GOSUB to a BASIC subroutine.

To see how a BASIC program can create and then run a short ML program, enter Program 2-1.

Program 2-1. ML Programming Using BASIC POKEs

```
10 HOME
20 POKE 768,32
30 POKE 769,12:POKE 770,253
40 POKE 771,96
50 PRINT "PRESS A KEY..."
60 CALL 768
70 PRINT "THANKS!"
80 END
```

When you RUN this program, the screen should clear, and the PRESS A KEY prompt and a flashing cursor should appear on the screen. When you do press a key, THANKS! should appear and the program will end.

Functionally, this program is equivalent to the "Waiting for Keypress" demo program in Chapter 1. In that program, a call to a built-in routine at 64780 was done to wait for a keypress. How can the program above accomplish the same function by calling location 768? And what are all those POKEs for?

If you examine the program closely, you can see that four memory locations, starting at location 768, are being POKEd to hold various number values. The number series 32, 12, 253, 96 is understandable by the 65816 microprocessor in your Apple to mean "wait for a keypress."

This is a true machine language program, which is placed in memory starting at location (address) 768. Line 60 of the Applesoft BASIC program then uses a CALL statement to execute the routine. Remember that a CALL is very much like a GOSUB, except that instead of going to a line number in your BASIC program, it jumps to a memory location, expecting to find a machine language program there.

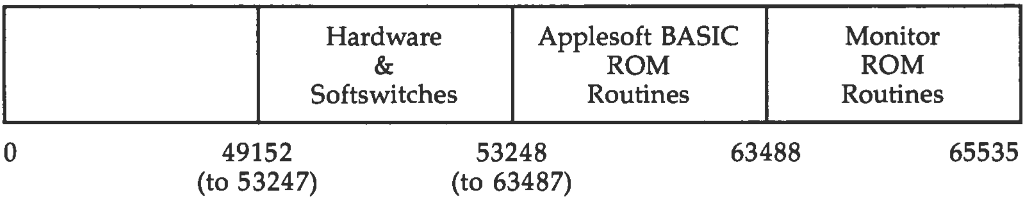
You know that every subroutine in BASIC must end with a RETURN to properly return to the main program. The same principle applies to machine language subroutines. Can you guess which number code in our machine language program is equivalent to the RETURN in an Applesoft BASIC program? If you guessed the last value, 96, you're right.

You could look in a technical reference manual (or at the back of this book) to determine the meaning behind the other values, but there is an easier way—use the built-in Monitor that is present in every Apple IIGS computer. The word *Monitor* is used on many microcomputers to mean a sort of mini-language that is used at a lower level than BASIC to make life easier when dealing with machine language programs and data.

The Monitor, like Applesoft BASIC, is itself a group of machine language routines. These routines start at memory location 63488 and go up to 65535. In fact, earlier, when we said that the Applesoft BASIC routines were in the range of 53248 to 65535, it wasn't quite the whole picture. Actually, the Applesoft BASIC routines start at 53248 but end at 63487. The next byte is then where the Monitor routines actually start. As it happens, Applesoft BASIC does call the Monitor routines to do many functions like cursor handling, keyboard input, and so on. That's why the cursor routines in Chapter 1 were in the Monitor memory range from 63488 to 65535.

Figure 2-1 is a more complete memory map.

Figure 2-1. Memory Map Showing the Location of the Monitor



The Monitor is useful for examining any portion of the computer's memory and has a number of other handy features as well, including a small assembler and the ability to list ML programs in an understandable way.

One of the most common uses of the Monitor is to look at the contents of a range of memory locations. To examine the part of memory that holds the machine language program POKEd into memory by the BASIC program, you need to first change to the Monitor command mode. To enter the Monitor voluntarily,* type in:

```
CALL −151
```

and press RETURN.

The Applesoft BASIC prompt ( ]) should change to an asterisk (*), which indicates you are officially in the Monitor. That is to say, Applesoft BASIC commands are no longer recognized, and instead, Monitor commands are. You can try typing HOME at this point to confirm this (your computer should just beep at you), but don't try randomly typing anything else just yet. Now, to look at those numbers that make up our program, type in

```
300.303 (and press RETURN)
```

The screen should display

```
*300.303
00/0300:20 0C FD 60- .}‘
```

At this point, you may justifiably say "Wait a minute—this doesn't look like the same numbers my BASIC program used. And I thought it started at location 768, not 300."

You're almost right. The numbers don't *look* the same, but—believe it or not—they do represent the *same* values.

Hexadecimal Numbers

In explaining the numbering systems used in computers, people who write books and columns on machine language programming often talk about how we count by sets of 10 because we have 10 fingers. Ten is called the *base* of our numbering system because it's the foundation for how we count: We group quantities by tens.

Regardless of why you think we count by 10's, it is true that in a mathematical sense, the base for a counting system can be any number you want. In the computer, for various electrical and logical reasons that we won't discuss

* As opposed to the surprise visits, usually accompanied by a beep, program crash, and a message something like:

```
00/0320: 00 D8     BRK D8
 A=0000 X=0000 Y=0000 S=01DD D=0000 P=30
 B=00 K=00 M=0C Q=80 L=1 m=1 x=1 e=1
```

here, your Apple computer likes to count by 2's at the machine level of operation.

This brings us back to the Monitor. Applesoft BASIC is written using 12K of machine language routines to support the roughly 100 BASIC commands. The Monitor also has a limited space in which to create its commands, and it has to take care of things like reading the keyboard and managing the screen. Therefore, when they went to create the routines to print the numbers stored in a given memory location (or to decode numbers typed in by the user), it was much easier to deal with routines in a number system based on 16 (a power of 2) than it was 10. This number system, based on groups of 16, is called the *hexadecimal* number system, called *hex* for short.

It really isn't necessary for you to be an expert in counting in base 16 to be able to use the hex numbers on your screen, but a brief explanation will make things a little easier.

When counting in base 10, you count from 0 to 9, and then use a second position (for the 1) to create the next number (10). In a sense, we're just putting a limit on how many symbols are legal in a given digit position. When counting from 10 to 99, we again limit ourselves to the digits 0 through 9, and thus have to move over another position for the value after 99.

When the counting system for hex numbers was created, the mathematicians asked why they couldn't count past 9 by using other nonnumerical symbols. Seeing no reason to quit at nine, they began using letters to continue counting.

When you count in hex, you start just like you did before:

0, 1, 2, 3, 4, 5, 6, 7, 8, 9

but, when you get to 9, you begin using letters of the alphabet:

. . . 8, 9, A, B, C, D, E, F

Allowing characters up to the letter *F* lets us use just one digit position (now called a hexit) to count to what would normally be 15. In any case, when you continue, you now do just what you did to mark a group of 10 in base 10—add a 1 to the left to mark a set of 16—and keep counting:

. . . 8, 9, A, B, C, D, E, F, 10, 11, 12 . . .

Like before, when you use up the characters on the right, you just repeat the pattern:

. . . 19, 1A, 1B, 1C, 1D, 1E, 1F, 20, 21, 22 . . .

Remember: Don't worry about being a math whiz at this point. All you need to do is to believe that the symbol 1B is a legitimate way of writing the number quantity denoted as 27 in base 10.

1B (hex) = (1 × 16) + 11 = 27 (decimal)

If you count high enough in hex numbers, the symbols run out again, and you'll have to add another number position:

. . . 99, 9B, 9C, 9D, 9E, 9F, A0, A1 . . .
. . . F9, FA, FB, FC, FD, FE, FF, 100, 101 . . .

Some people get nervous at this point because they're not used to saying 1A as a number, or they're not sure that 100 means one hundred anymore. Actually, as long as the other person knows that you're talking hex addresses or numbers, saying one hundred, or even B-hundred (for B00) is just fine.

To avoid confusion in written text, however, a dollar sign is usually put in front of hex numbers (example: $B00), so someone can tell at a glance which numbering system you're using.

Now, back to that list of numbers you were looking at in the Monitor.

```
00/0300:20 0C FD 60- .}'
```

The screen display shows that location $300 holds the value $20, 32 decimal, our first POKE in the Applesoft BASIC program. Each value that follows is a number in hexadecimal notation that indicates the value stored at the successive memory locations ($301, $302, and so forth).

Note that no dollar sign is used in the Monitor. The Monitor only expects hex values, so no dollar sign is needed.

The Monitor also provides some extra information, to the right of the hex numbers, starting with the dash (–) character. We'll explain that a little later, so you can ignore whatever's printed there for the time being.

To verify that these numbers are the same values as POKEd in by the BASIC program, you need to be able to convert a hexadecimal number back to a decimal. Actually, that's not too difficult. You just need to remember a few special tricks. The first is that the last six letters when counting in hex (A, B, C, D, E, F) stand for 10, 11, 12, 13, 14, and 15 in decimal. The second is that when you have more than one digit in a number, you multiply by either 16, 256, or 4096 for numbers in the second, third, or fourth positions, respectively.

$A = 10
$B = 11
$C = 12
$D = 13
$E = 14
$F = 15

Example of converting a multidigit number:

$$\begin{array}{lllr}
\$4321 & = 4 \times 4096 & = & 16384 \\
 & + 3 \times 256 & = & 758 \\
 & + 2 \times 16 & = & 32 \\
 & + 1 \times 1 & = & 1 \\
\hline
 & & = & \mathbf{17185}
\end{array}$$

It's actually more confusing to explain than to do. Let's just look at a few examples. To convert the starting address, $300, you just need to know that the third number position gets multiplied by 256 to convert it to base 10: 3 × 256 = 768. (For the time being, you can ignore the 00 in front of the / character in the address).

For 20, remember that numbers in the second position get multiplied by 16 to convert them to base 10: 2 × 16 = 32; that checks with the first number POKEd into memory on line 20 of the program. For the second value, $0C, the C is equivalent to 12 in base 10. For the next number, $FD, multiply 15 ($F = 15) by 16; then add 13 ($D = 13). That's (15 × 16) + 13 = 253, which agrees with the third POKE. At the very end, 60 represents 6 × 16 = 96, the value which instructs the 65816 to return from the machine language program.

Don't worry about needing to convert back and forth between decimal and hex in order to program in machine language. Usually, your assembler will do the necessary math for you. The Monitor also has a built-in converter that will assist you. It's important to have a general idea of what's going on when the computer does the conversion for you. To see how the Monitor does the conversion, type in:

```
20=
```

and press Return. The screen will display:

```
*20=
Decimal-> 32 {+32}
```

The Monitor has translated $20 to decimal 32 for you. That's a good feature. Try typing the other hex numbers followed by an equal sign, and see if you get the decimal values calculated by hand, above.

The Monitor can convert decimal to hex, also. Just put the equal sign at the beginning of the number instead of the end. For example, type in

```
=32
```

and press Return. The screen will display

```
*=32
Hex-> $00000020
```

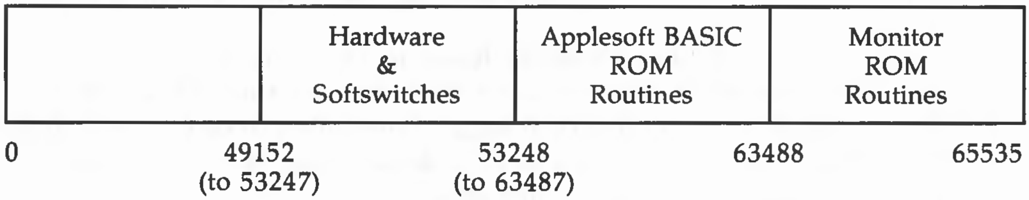
Try the other decimal numbers used in the BASIC program, and verify that they agree with the hex values shown when you typed in 300–303.

Why Bother with Hex Numbers?

You may be wondering why you even need to bother with hexadecimal notation. Couldn't the computer do all the translations automatically? It could, but it turns out that hex numbers are actually easier to work with in many cases.

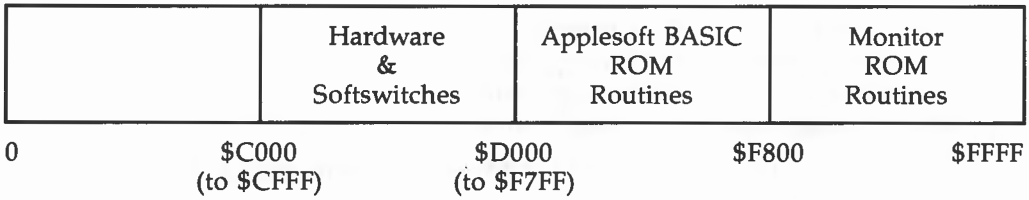
For example, you probably don't remember all the decimal addresses given as the boundaries between the hardware locations, Applesoft BASIC, and the Monitor ROM routines. That's understandable, especially considering how arbitrary the values seem. To refresh your memory, Figure 2-2 is the same memory map as Figure 2-1. Trying to remember all these addresses is difficult because there's no apparent pattern.

Figure 2-2. Memory Map in Decimal



Next, look at the same chart using hex numbers, Figure 2-3.

Figure 2-3. Memory Map in Hex



Addresses like $2000, $4000 and even $F800 are much easier to remember than 8192, 16384, and 63488.

This may seem like a lot to absorb right away, but be patient. These concepts will be covered again many times throughout the book. It will become clear to you later. So, be patient, allow yourself some breaks in between topics, and you'll find that learning hex is almost effortless.

It's Culture That Counts

Many people have remarked that our choice of ten as a number base is related to the fact that we have ten fingers on our hands. One can only guess how a different set of circumstances would have profoundly changed our lives. Speculating, for instance, on which two commandments would have been omitted had we only eight fingers is enough to keep you awake at night.

A living example of this arbitrary nature of number bases was recently brought to light by the discovery of a long lost tribe living in the remote jungles of South America. The tribe had been isolated from the rest of the world for at least 7000 years. An important aspect of their life was a huge population of dogs living among the people. In fact, dogs so out-numbered the people (so to speak) that the people had evolved a counting system based on the number of legs on a dog, as opposed to our decimal system. They counted in the equivalent of base four.

In counting, they would be heard to say, "one, two, three. . . . " For the next number, they just used what seemed a natural whole unit. They wrote it as *10* and called it *doggy.* Continuing to count they would say, "doggy-one (11), doggy-two (12), doggy-three (13). . . . " Quite practical really, 13 = 1 dog, three legs.

This system worked quite well, and they only needed four symbols to count with (0, 1, 2, 3). When they got to the number after doggy-three, they wrote it as 20 and called it *twoggy.* A similar procedure was used for 30.

20 = twoggy	30 = troggy
21 = twoggy-one	31 = troggy-one
22 = twoggy-two	32 = troggy-two
23 = twoggy-three	33 = troggy-three

Now, upon reaching 33, adding one more meant writing the new number with three digits.

You're probably wondering what they called it. The digits are naturally 100. Oh, the name. Why, of course, it's *one houndred.*

POKEs, PEEKs, and CALLs in the Monitor

World sociology is just amazing, isn't it? Speaking of languages, you know how BASIC lets you change and examine memory locations using POKE and PEEK, and you now know how to run a machine language program from BASIC.

These operations are also present in the Monitor.

You've seen how to examine a range of memory locations: Type in the addresses separated by a period and press RETURN. This is equivalent to BASIC's PEEK command. If you want to look at a single location, just type in the single hex address. To examine location $300, for example, just type

```
300
```

The screen should print

```
*300
00/0300:20-
```

You can also examine a set of different addresses, which are not necessarily continous in memory by typing the addresses to examine separated by spaces. For instance, type

```
300 302
```

and you should see

```
*300 302
00/0300:20-
00/0302:FD-}
```

To do the equivalent of BASIC's POKE, type the address followed by a colon. For example, let's use a part of memory not currently used by our program, say location $30A.

First, see what's there by typing

```
30A
```

and press Return. Make a note of what number value you find there.

To change the value of the contents of location $30A from its current value, to $FF (or pick any number you want), type in

```
30A: FF
```

Now type

```
30A
```

The screen should print

```
00/030A:FF-.
```

The value has been changed. Typing an address followed by a colon and a number value is the equivalent of BASIC's POKE command.

Now, what about the equivalent of a CALL statement? In the Monitor, all commands are single letters, rather than complete words, and they follow the address of interest. To run your program from the Monitor, type in

```
300G
```

A blinking box should appear on the screen, waiting for you to press a key. When you do, the asterisk Monitor prompt should return. The letter G that followed the address 300 stands for *Go* and tells the Monitor to run a machine language program at the specified address.

The Monitor LIST Command

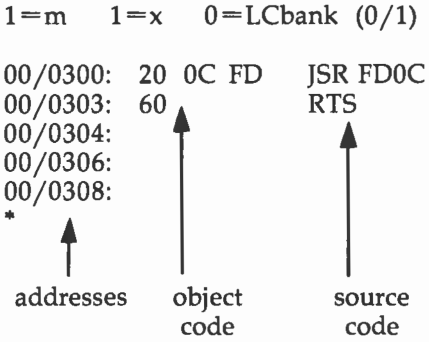
You're probably thinking by now that if you have to deal entirely with numbers to do machine language programming, it's going to get old very fast—and you're right. Fortunately, few people program using soley the number values, and the Monitor has some features to do things a little easier.

To list a machine language program, the monitor has a nifty command, just like BASIC does. Type in

```
300L
```

The screen should now list 20 lines on the screen that look like the example shown in Figure 2-4.

Figure 2-4. A Monitor Listing



```
1=m    1=x    0=LCbank  (0/1)

00/0300:  20  0C  FD     JSR FD0C
00/0303:  60             RTS
00/0304:
00/0306:
00/0308:
*
```

L is the Monitor LIST command, and it tells the Monitor to display the contents of memory as an *assembly language* program.

Now, since we keep tossing around both *assembly language* and *machine language*, you might well ask what's the difference?

Once, programmers programmed their computers by entering pure numbers to tell the microprocessor what to do for a given program. (That's probably when programming got a bad name.)

Then one day, someone asked why letter codes couldn't represent the commands, with the computer figuring out which numbers are represented by the character strings. Others thought it a good idea, so began searching for a way to do it.

Since they were very-memory conscious at the time (in 1978, 16K of RAM for an Apple cost $300), they used short abbreviations for words, called *mnemonics* (pronounced neh-monics). Mnemonics are memory aids; programmers use them to remember the code word for a given operation. The term *code* when talking about object code and source code probably originated then, too.

Thus, at $303, you see that the Monitor has translated the $60 to **RTS**. This stands for **ReTurn from Subroutine**, and sounds a little like the RETURN that you'd put at the end of a BASIC subroutine.

It's much easier to remember RTS when creating a program than it is to remember $60.

A program that takes a list of mnemonic codes and then translates them into the proper series of numbers in memory is called an *assembler*. The listing that is typed in by the programmer is call a *source listing*, and it corresponds to the text in the rightmost column of the Monitor listing.

The numbers that are put in memory by the assembler are called the *object code*, and they correspond to the numbers in the columns that were shown in Figure 2-1. The numbers at the far left are the *addresses* (or memory locations) of the numbers that make up the object code and are displayed for convenience only.

When you BLOAD or BSAVE a binary file that is a machine language program, you're loading or saving just a series of numbers that makes up the object code to a machine language program.

In the technical sense then, assembly language is the programming of the computer by typing in the mnemonic codes, which are then assembled by an assembler. Machine language programming involves putting pure numbers directly into memory without the aid of an assembler. The end result is the same though, a machine language program.

As it happens, most people use the two terms interchangeably. Few people write pure machine language programs of any size anymore. Assembly language and machine language really mean two different things, but, anymore, in general conversation the distinction is not that important.

Imagine writing programs by POKEing each value into memory.

From now on, we'll try to be somewhat consistent, and correct, in using the terms, but this means you may see both words in the same sentence, apparently referring to the same thing. There will be a difference though. What you'll write will be an assembly language program, using the mnemonics like

JSR and RTS. What you load and run in the computer is a machine language subroutine, made up of pure numbers. Therefore, you can expect to see a passage something like: "After you've finished your assembly language program, save it to the disk. Your Applesoft BASIC program can then BLOAD and CALL the machine language subroutine as it's needed."

Using Subroutines

Now, back to our program in progress. In the listing, the first group of numbers in memory (20 0C FD) are translated as JSR FD0C. **JSR** is a mnemonic that stands for **Jump to SubRoutine.** A JSR in assembly language is very much like a GOSUB in BASIC. However, instead of jumping to a line number, a JSR goes to an address in memory. As long as the routine there ends with an RTS (like a RETURN in BASIC), control will eventually return to the calling program.

In the case of the JSR, $FD0C has a decimal equivalent of 64780. Sound familiar? When we said that this sample program was functionally equivalent to the Waiting sample, the similarity was closer than you might have guessed. All we did in this program was put the CALL 64780 in our own machine language program at location 780 ($300). See Figure 2-5.

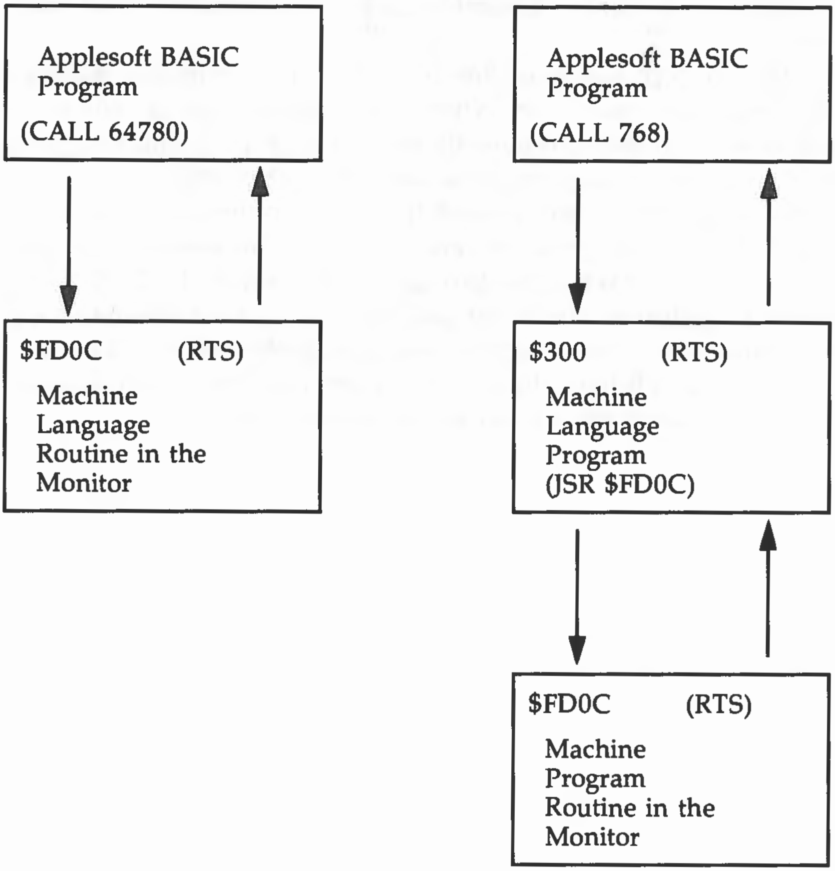
Another incidental fact to note is that the address $FD0C is stored in memory at locations $301 and $302—in reverse order. That is, $0C comes first at $301, and $FD is stored at $302. This is similar to how the line number of an Applesoft BASIC error was stored by the ONERR routine in the demo program in Chapter 1.

It turns out that this is the standard way microprocessors store, and expect to find, address values in memory. The first stored value is sometimes called the *low-order byte,* and the second is the *high-order byte.* As a further example, for the address $2000 (the beginning of the first hi-res page), the low-order byte is 0, and the high-order byte is $20. This would be stored in memory as $0,$20.

An important tip here is that the high- and low-order bytes for any hex number can be quickly determined by just visually splitting the number: $FD0C has a high-order byte of $FD, and a low-order byte of $0C. In decimal notation you have to divide by 256 to obtain the high-order byte, and use the remainder as the low-order byte. For example, 64780 ($FD0C) divided by 256 equals 253 ($FD = high-order byte) with a remainder of 12 ($0C = low-order byte).

Finally, the program ends with a RTS, which returns control to either the Applesoft BASIC program that called it, or, if you did a 300G from the Monitor, back to the Monitor prompt. Generally speaking, all ML routines called from Applesoft BASIC should always end with RTS, so that control properly

Figure 2-5. CALLing an ML Program



returns to the calling program. RTS in assembly language is very much like a RETURN in Applesoft BASIC—every subroutine should end with one.

The remainder of the listing will vary from time to time and computer to computer, depending on a number of factors.

By the way, any time you want to return to Applesoft BASIC from the Monitor, just press Control-C and press Return. This will get you back to Applesoft BASIC with any program you had there still intact.

The Simplest ML Program

The program just presented is almost the simplest machine language program possible. The only thing simpler could be RTS by itself. However, it has helped illustrate some of the key elements to machine language programming.

In this chapter you've learned about hex numbering, assemblers, the Monitor, Monitor commands, two assembly language commands (JSR and RTS), and more.

Another key concept is that of *flow of control.* The computer is always executing some program somewhere. When you write a program, you're merely redirecting that flow of control temporarily to your own program. One program can pass control to another program, or to another part of itself.

In our final example, control passed from the Applesoft BASIC program to our own machine language program, and from there to another routine at another location, and then back again through each level to the BASIC program. Mastering the ability to direct this process, and to control what happens along the way, is the essence of machine language programming. As you progress in this book, you'll learn how to make the computer do just about anything you want by using the proper set of instructions.

Chapter 3

The Apple IIGS Mini-Assembler

Chapter 3

The Apple IIGS Mini-Assembler

As you move through this book, you'll notice that each chapter builds on the material from previous chapters. In the last chapter, you saw how to create a machine language program by POKEing the appropriate values into memory, and then either CALLing it from BASIC, or using the Monitor GO command.

In this chapter, you'll be introduced to your first assembler, the one that's built right into your Apple IIGS. Along the way, we'll also take a better look at the 65816 microprocessor and get a feel for how it manipulates data in the computer.

Although there are a number of Applesoft BASIC programs available that create short subroutines with the POKE and CALL method, most programs are written using an assembler. You'll recall that an assembler is a programmer's tool that lets you type in easy-to-remember abbreviations for microprocessor instructions. Then the assembler program translates these abbreviations into the proper number values.

Full-featured assemblers, like word processors, are usually commercial software products that you buy as an addition to the computer itself. However, for short programs, and occasional corrections to an existing program, the Apple IIGS has a built-in *mini-assembler* you can use without purchasing any separate software at all. Let's see how it could be used to create the same program that our BASIC program did.

Starting and Using the Mini-Assembler

From the Applesoft BASIC prompt, type CALL −151 to get to the Monitor. When the Monitor prompt appears, type an exclamation mark (!) and press Return. The prompt should change to an exclamation mark. This indicates that you are in the mini-assembler.

The first thing to remember is that in assembly language, the addresses of each instruction take the place of line numbers in BASIC. To start a new program, you need to first tell the computer where you want the program to begin, much the same as you would start with some line number when beginning a new BASIC program.

We want our program to start at $300. To begin, type

```
300:
```

but don't press Return yet. Now type the first instruction for the program in *assembly language*

```
300: JSR FDOC
```

and press Return. Be sure that the 300 is at the very beginning of the line. You don't have to put a space between the 300: and the JSR, but you'll need a space after the JSR. The easiest way to keep things straight is to type them in so they look the best. (You don't need a dollar sign in front of any of the numbers since the mini-assembler assumes everything will be in hex.)

When you press Return, the text you've entered will be rewritten, and the screen should display

```
00/0300:  20   0C   FD      JSR FD0C
!
```

A new ! prompt will await your next command. Notice how the mini-assembler has automatically translated the JSR FD0C into the proper machine language values and has placed them in memory for you.

If you make a mistake, and, for example, type the letter *O* instead of a zero, the mini-assembler will try to help out with a beep and a ˆ marker under where the error occurred. Unfortunately, it doesn't always put it in the right spot, and you'll usually get and something like

```
*!
!300:JSR FDOC
          ^
```

If you do get the error display, retype the line carefully.

Now you've successfully typed your first line of a true assembly language program. You might think that you'll have to now know the address for the next instruction ($303), but that's not so. The mini-assembler is keeping track of the current memory location for you. To continue the program, just type a single space and RTS, and then press Return. The space is very important here—a space must precede each instruction that you want added to the current program location. The screen should display

```
00/0300:  20   0C   FD      JSR FD0C
00/0303:  60                RTS
!
```

That's the whole program. To turn off the mini-assembler, press Return at the beginning of the line, and the Monitor prompt (*) should return. Now, to verify that the program is there, type in

```
300L
```

You should get a listing exactly like that in Chapter 2 (at least for the first two lines that make up our program). To test the program, type

```
300G
```

from the Monitor as you did before.

Now, let's write a BASIC program to call the routine. Press Control-C and Return to go back to Applesoft BASIC. Then type NEW and enter this program:

```
10 HOME
20 PRINT "PRESS A KEY . . . "
30 CALL 768
40 PRINT "THANKS!"
50 END
```

After typing this in, enter RUN and press Return. The program should work exactly like the BASIC program in Chapter 2, except that you can see it didn't put the machine language program in memory itself—that was created by you using the mini-assembler.

Saving a machine language program. The next question is, how can you save your work? Saving the BASIC program is easy—just save it like any other BASIC program. But what about the machine language part?

To save a binary file under ProDOS, you must know the starting address and the length (number of bytes) to save. The starting address is $300. The length is four bytes. As a tip, you can always look at the number value immediately *after* the RTS at the end of your program and subtract the starting address from that to determine the length ($304−$300 = 4). Thus, to save this program, you would type in

```
BSAVE BINARY.1,A$300,L$4
```

This is usually done from the immediate mode of Applesoft BASIC, but you can also do it right from the Monitor. You'll notice we use BSAVE (not SAVE) to save a machine language program (or any block of memory for that matter).

When you want to run the program again, you'll have to get that binary file back in memory. The whole sequence for this would be:

```
BLOAD BINARY.1
LOAD MYPROGRAM
RUN
```

BLOAD is used to load the binary file back into memory. You don't need to give the starting address, since ProDOS will remember where it came from. The second command loads your BASIC program, after which RUN gets everything going. I'm using the names BINARY.1 and MYPROGRAM as examples for the binary and BASIC programs, respectively, but you can use any names you'd prefer.

As a side note, it really doesn't matter what order you do the BLOAD and LOAD in, as long as both files are in memory by the time you type RUN. As a matter of fact, the best approach is to have the BASIC program load the binary file itself.

```
10 HOME
15 PRINT CHR$(4);"BLOAD BINARY.1"
20 PRINT "PRESS A KEY . . . "
30 CALL 768
40 PRINT "THANKS!"
50 END
```

In this revised program, line 15 loads the binary file into memory automatically. This is the preferred arrangement, because then you (or the ultimate user) can just type in RUN MYPROGRAM to run the program right from the disk, without having to know which files to load.

Storing Data in Memory with the 65816

So far, we've been letting someone else do all the work, namely that routine at $FD0C. All our program did was tell the microprocessor where to go after it got to us via the Applesoft BASIC program.

The first step to writing a true program is to learn how to control the memory contents of the computer. In fact, this is really all any program, no matter how complicated it is, ever does. When you type on a word processor, the program in the background just watches the keyboard as you type each key, and then it stores an appropriate value in memory. With 64K of memory just for Applesoft BASIC, we can store a lot of letters, even though we're using up one byte of memory for each character.

With that inspiration, let's see how to write a program that prints a letter on the screen. Before we start though, you'll have to learn a little bit more about the 65816.

You already know that the 65816 microprocessor works by just scanning through memory one byte at a time, and carrying out some instruction depending on what it finds at each new location. To accomplish this, and many other important tasks, the microprocessor has the equivalent of built-in memory locations, called *registers* that are used to keep track of things.

The most important of these is the *Program Counter.* The Program Counter (sometimes abbreviated PC) is a two-byte register, whose contents point to wherever in memory the microprocessor is currently operating.

A byte associated with the Program Counter called the *Program Bank Register,* or PBR. Although Applesoft BASIC can only use the first 64K of memory in the computer, remember that there can be up to 16 million bytes of memory. Counting in hex, the first 64K of addresses go from $0000 to $FFFF. It takes two bytes to store the pair of FFs for the last address. To count further, starting at $010000, you need a third byte.

The 65816 can run programs and access data anywhere in the computer, so a third byte is needed to make a complete address. To make things easier to read, you can write the address $010000 like this: $01/0000. The first byte, stored in the Program Bank Register, tells us which group of 64K bytes, called a *bank,* we're talking about. The next four characters, representing two bytes, give the address in that bank. An address that uses all three bytes is called a *long address,* as opposed to a *short address* that only uses two bytes to give an address in a given bank, usually bank 0.

When the Monitor lists the contents of address $300 as

```
00/0300: 20
```

it's giving the entire address, bank $00, address $300.

To make things a little more visual, we'll make a model of the 65816 that we'll add to as we introduce new facts about how it works. Our model is shown in Figure 3-1.

Figure 3-1. The 65816 Microprocessor Model 1

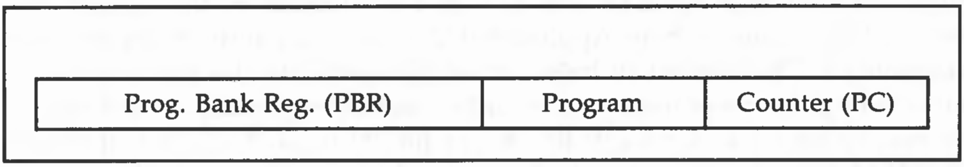
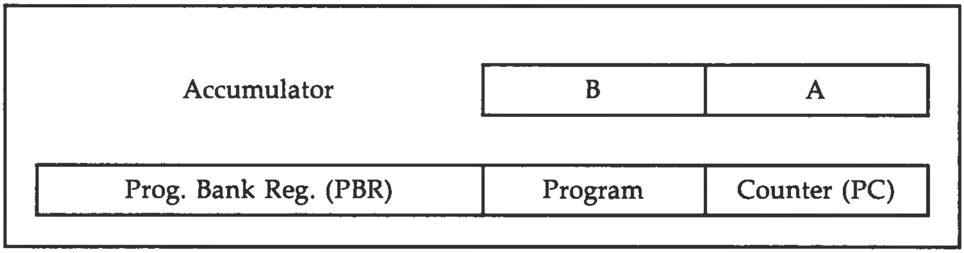


Figure 3-1 shows the Program Bank Register and the Program Counter with their three bytes internal to the 65816. This means that the 65816 doesn't need to use any memory in the computer itself to store any of its "personal" information. The contents of both registers continually change as the 65816 accesses different parts of memory in different banks. The registers are like RAM in that they lose their contents if the power is turned off.

The Busy Accumulator

To make things easier, the designers also put in a number of other internal registers that the 65816 can use. The most often-used is called the *Accumulator* (usually abbreviated as the A register). It's called the Accumulator because the result of each successive math operation is left in this register, and is used as the basis for each successive operation, thus letting the result accumulate.

Figure 3-2. The 65816 Microprocessor Model 2



Like the Program Counter, the Accumulator is made up of two bytes (see Figure 3-2). Sometimes programmers say the Accumulator is two bytes wide. When calling 65816 routines from Applesoft BASIC, only the first byte of the Accumulator is usually used. The second byte of the Accumulator is labeled B, to distinguish it from the first byte.

The Accumulator can be loaded with either a specific number value, or the microprocessor can be instructed to use the *contents* of a given memory location as the value. The assembly language code for loading the Accumulator is **LDA**, which stands for **LoaD Accumulator**. Although the 65816 can be instructed to load both bytes (A and B) with one instruction, the default mode when calling a routine from Applesoft BASIC is to use only the A part of the Accumulator. The number of bytes actually loaded into the Accumulator can be controlled by the programmer to be either one or two bytes, as desired. Routines called from Applesoft BASIC, or BRUN from ProDOS 8 or ProDOS 8.SYSTEM files all default to one-byte operations and use only the A part of the Accumulator. Chapter 7 discusses how to control this in your own programs. For the time being, assume that all registers operations involve only one byte unless otherwise noted.

For example, if you wanted to load the Accumulator with the value $05, you could enter

```
LDA #05
```

as the instruction in the mini-assembler. Notice the number sign (#) in front of the 5. This tells the mini-assembler to use the specific value 5.

An interesting alternative is to tell the computer to look in a memory location and place whatever value is stored there in the Accumulator. That instruction looks like this:

```
LDA 05
```

This second form is used the most often; it lets you move a piece of data from one location in the computer to another.

Using the Accumulator

The text screen display in Applesoft BASIC (or any text-based program for that matter) is controlled by manipulating the contents of a specific part of memory, namely the range from $400 to $7FF. By putting a given value in the appropriate spot in memory, any character can be made to appear at any location on the screen.

You've seen how to load the Accumulator with a given value or the contents of a memory location. To store that value somewhere, you use the instruction **STA (STore Accumulator)**. In a program, it looks like this:

```
STA $06
```

This instruction stores whatever was in the Accumulator in memory location $06. This can be combined with the LDA instruction to store a given value anywhere in memory. As an example, let's use the mini-assembler to write a program that prints the letter *A* in the center of the screen. If you're not already there, go the the Monitor, and then to the mini-assembler, and enter this program:

```
300: LDA #C1
 STA 5BC
 RTS
```

When you're finished entering the program (remember to press Return alone to exit the mini-assembler), the screen should display

```
*!
00/0300:  A9  C1         LDA #C1
00/0302:  8D  BC  05     STA 05BC
00/0305:  60             RTS
!
*
```

Although you can type 300G to run this program, let's keep BASIC around a little longer, even if just to clear the screen. Press Return to exit the mini-assembler. Type Control-C, Return to go to Applesoft BASIC, and then enter this program:

```
10 HOME
20 CALL 768
30 END
```

When you run this program, the screen should clear, and the letter *A* will appear in the middle of the screen.

The program works by first loading the Accumulator with the value $C1, the code value for the letter *A*. Memory location $5BC is the byte assigned to the middle of the screen. By putting the value $C1 there, the *A* is instantly displayed on the screen.

For truly inquiring minds, suffice it to say that the final magic is accomplished by electrical hardware that is constantly scanning memory from $400 to $7FF and using the contents of each memory location to control the video display. If you're really interested in this, try to find a copy of one of Jim Sather's books on the Apple, particularly *Understanding the Apple IIe,* listed in the bibliography of this book. Although his book was based on the IIe, much of it still applies to how the Apple IIGS behaves with an Applesoft BASIC program, and is interesting reading.

The only remaining problem is that our program still needs the Applesoft BASIC program to clear the screen. If only there were a way to clear the screen from machine language.

There is. In fact, we can call the same routine, located at $FC58 that Applesoft BASIC uses to clear the screen. Try retyping the program like this:

```
300: JSR FC58
 LDA #C1
 STA 5BC
 RTS
```

When you're done, the screen should look like this:

```
*!
00/0300: 20  58  FC     JSR  FC58
00/0303: A9  C1         LDA  #C1
00/0305: 8D  BC  05     STA  05BC
00/0308: 60             RTS
!
*
```

If you type 300G now, the screen will clear without the Applesoft BASIC program. This complete program can be saved to the disk by typing

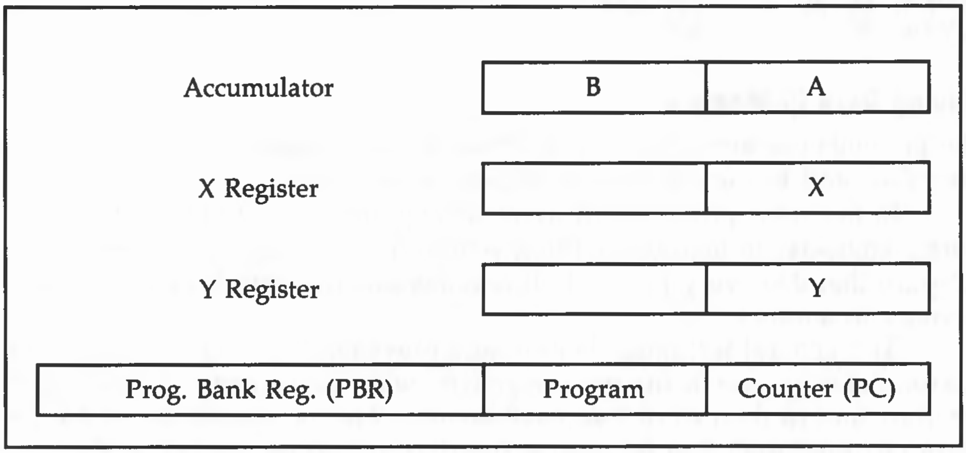
```
BSAVE HOME.A,A$300,L$09
```

You've just written your own self-contained machine language program. This program can even be BRUN from the immediate mode of Applesoft BASIC.

The X and Y Registers

As long as we're talking about the various registers in the 65816, we might as well mention two more: the X and Y registers. (See Figure 3-3.)

Figure 3-3. The 65816 Microprocessor Model 3



Having only one internal register in the microprocessor would make things rather limited, so they added two more, the X and Y registers, that you can use to hold data with. There are also some special tricks you can do with these registers that you can't do with the Accumulator, but more on that later.

Like the Accumulator, the X and Y registers are two bytes wide. Just as you can use LDA and STA to load and store data using the Accumulator, there are equivalents, **LDX, LDY** and **STX** and **STY** for the X and Y registers. Like the Accumulator, you can also use the number sign (#) in front of a number value to load either register with a specific value. The number of bytes loaded and stored defaults to 1 when calling a routine from Applesoft BASIC, but this also can be changed if desired. There is no separate name for the second bytes in the X and Y registers.

As an exercise, try rewriting our HOME.A program using the X and Y registers instead of the Accumulator. You can BSAVE them to your disk with the names HOME.X and HOME.Y. When correctly entered, the programs should look like this:

HOME.X

```
00/0300: 20  58  FC     JSR  FC58
00/0303: A2  C1         LDX  #C1
00/0305: 8E  BC  05     STX  05BC
00/0308: 60             RTS
```

HOME.Y

```
00/0300: 20  58  FC     JSR  FC58
00/0303: A0  C1         LDY  #C1
00/0305: 8C  BC  05     STY  05BC
00/0308: 60             RTS
```

Moving Data in Memory

The previous examples have shown how to load a register with a specific number value, and to then store it in memory somewhere.

In the word processor we were talking about, if all you could do was store a character in memory, editing would be pretty difficult. To write any program that does very much at all requires moving data from one place in memory to another.

The general technique behind any movement of data is to first load the Accumulator, or one of the other registers, with the contents of some memory location, and to then store it somewhere else. Here's a variation on the program just presented that first stores the character to be printed on the screen in one location, and then uses a different register to pick that value up and move it to the special screen display location:

```
00/0300: A9  C1         LDA  #C1
00/0302: 85  06         STA  06
00/0304: A6  06         LDX  06
00/0306: 8E  BC  05     STX  05BC
00/0309: 60             RTS
```

In this program, we first load the Accumulator with the code value for the letter *A*, and then temporarily store it in memory location 6. Choosing $06, by the way, is fairly arbitrary. It was chosen only because it happens to be a memory location that is never used by Applesoft BASIC, so it's a safe place, rather like the range from $300 to $3CF, where you can put machine language data without hurting anything. In fact, the bytes $06 through $09 are all available for programs you write in assembly language.

The next part of the program is the part that actually moves a byte of data from one place to another. First, it loads the X register with the value

#$C1 that we just stored, and then moves it to location $5BC, where it becomes visible on the screen. This LDX/STX combination (or you can use LDA/STA or LDY/STY) is typical of how to move data from one place to another.

There is also a special command for storing a zero in memory: **STZ, STore Zero**. Without this command, you would have to have these steps in a program to put a zero in location $06:

```
LDA #$00
STA $06
```

With the STZ command, you only need

```
STZ $06
```

This takes fewer bytes, and doesn't require you to change the contents of the Accumulator. Because zeroing memory is done quite often, this is a very useful instruction.

Moving Data Between Registers

You've seen how to move data between one memory location and another, but suppose you want to move a byte from one register to another? To do that you just use the *transfer* instructions of the microprocessor. There are six transfer instructions of immediate interest:

```
TAX     TAY     TXY
TXA     TYA     TYX
```

TAX stands for **Tranfer Accumulator to X**, and does just that, it copies the value in the Accumulator into the X register. **TXA** is for **Transfer X to Accumulator**, and provides the transfer in the reverse direction. There is also a set for transferring between the Accumulator and the Y register (**TAY, TYA**), and also for transferring between the X and Y registers directly (**TXY, TYX**). here's a list of these six transfer instructions:

TAX	Transfer Accumulator to X
TXA	Transfer X to Accumulator
TAY	Transfer Accumulator to Y
TYA	Transfer Y to Accumulator
TXY	Transfer X to Y
TYX	Transfer Y to X

As an example, here's a variation on that last program that loads the value for the letter *A* into the Accumulator first, and then transfers it to the X register for storage at $5BC:

```
00/0300: A9  C1       LDA  #C1
00/0302: AA           TAX
00/0303: 8E  BC  05   STX  05BC
00/0306: 60           RTS
```

You can also use the B part of the Accumulator to store a byte temporarily, by using another transfer instruction, **XBA**. This swaps the A and B parts of the Accumulator. You could use it in a program like this:

```
00/0300: A9  C2       LDA  #C2
00/0302: EB           XBA
00/0303: A9  C1       LDA  #C1
00/0305: 8D  BC  05   STA  05BC
00/0308: EB           XBA
00/0309: 8D  BD  05   STA  05BD
00/030C: 60           RTS
```

In this program we first load the Accumulator with the code value for the letter *B*, and then use the XBA swap command to move it to the B part of the Accumulator. The value for A is then loaded and stored on the screen as before. Finally, we use XBA again to retrieve the value for the letter *B*, and store it on the screen right next to the letter *A*.

Long Addressing

The use of JSR, LDA, and STA so far have been limited to simple two byte addresses. When a routine is called from Applesoft, is BRUN, or is part of a ProDOS 8 System file (filetype SYS), it's assumed that the program, and any associated data is in the first bank of 64K of memory. Although occasional use may be made of the second bank by routines such as the 80-column drivers or ProDOS itself, access in these routines is done by switching banks using a *softswitch*, as was described in Chapter 1.

The 65816, however, does allow direct access to any part of the 16-megabyte address space ($00/0000 to $FF/FFFF). This is done by using the *long* addressing mode, in which *three* bytes are used to determine the address. The long addressing mode is signified in the mini-assembler by just typing a three byte address after the LDA or STA, including any leading zeroes as needed. For example, if your program wanted to load a byte from bank 5, location $300, and then store it in bank 6, location $1A00, the following lines could be typed in using the mini-assembler:

```
!
!300: LDA 050300
! STA 061A00
```

This would show on the screen as

```
*!
00/0300:  AF  00  03  05  LDA  050300
00/0304:  8F  00  1A  06  STA  061A00
!
```

Try typing the lines again using only the two-byte addresses $0300 and $1A00, and compare this with the mini-assembler output from the previous example.

```
!
!300: LDA 0300
! STA 1A00
```

This will show on the screen as

```
*!
00/0300:  AD  00  03      LDA  0300
00/0303:  8D  00  1A      STA  1A00
!
```

You can see that in the long address form, three bytes instead of two follow the opcodes for the LDA and STA instuctions. Notice also that the opcode values are different ($AF = LDA long; $AD = LDA short).

You can also do the equivalent to a JSR to anywhere in memory, but this requires a new instruction, **JSL (Jump Subroutine Long)**. A JSR will only jump to a two-byte address in the bank that a program is currently executing in (bank 0 for Applesoft, for instance). A JSL, however, has a three-byte operand, and can be used to jump to a subroutine anywhere. For example, you can use the mini-assembler to type in this instruction to jump to a subroutine at $05/0300:

```
!
!300: JSL 050300
```

The screen will display

```
00/0300:  22  00  03  05      JSL   050300
!
```

A routine must know whether it is being called with a JSR or a JSL, because all routines called by a JSL must end with the instruction **RTL (ReTurn from subroutine Long)**, *not* an RTS. If a routine does not end with the proper return instruction, the computer will not return to he proper place in memory. Thus, it's up to you, the programmer, to keep track of which routines you're calling, and how you are calling them. For the time being, we'll only be using the JSR instruction for Monitor subroutines, which all end in an RTS.

Using the Monitor to Debug a Program

Before we leave the mini-assembler, there is one other technique that is very important to learn early on, and that is how to find out what's wrong with a program that isn't working the way you want it to.

This process is called *debugging* a program. The term's origin goes back to the early days of computers, and consisted of *very* large machines that used electromechanical relays for memory. The story goes that one day a computer wasn't working properly. When some technicians went inside (ah, those were the days, when you *really could* get inside your computer), they found a poor moth caught in one of the relays. When they came out, and someone asked them what the problem was, one said "Oh, just a bug in the computer." Well, expressions have a way of sticking around, and pretty soon everybody was blaming everything on a bug somewhere.

The result is that programmer's use the term *bug* to mean any error in the programming logic (or just plain typing error) that causes the program to not work the way they intended. Debugging a program is the process of tracking down the cause of the problem, and, hopefully, correcting it. One of the easiest ways to fix a bug in a program is to describe it in the documentation, and give a good reason why it's there. Best of all is to describe the bug in a really creative way, and tell everyone it's a feature!

For your programs, though, you'll probably just want them to work the way you intended, and so a few tips on how to track down these critters is in order.

For starters, use the mini-assembler to enter this program:

```
300: JSR FC58
 LDA C1
 STA 5BC
 RTS
```

This should list as:

```
00/0300: 20  58  FC     JSR  FC58
00/0303: A5  C1         LDA  C1
00/0305: 8D  BC  05     STA  05BC
00/0308: 60             RTS
```

When you run this program, either with a CALL 768 from Applesoft BASIC, or a 300G from the Monitor, the letter *o* should appear in the middle of the screen, instead of the expected *A*. What could the problem be? Generally speaking, the program looks pretty good.

This is where debugging comes in. Usually the first step is to logically think through the part of the program that seems to be causing the problem.

The screen is clearing OK, so the JSR FC58 is probably not the problem. Since the letter *o* is appearing in the middle of the screen, maybe the Accumulator isn't holding what we think it is. The second line does say LDA C1, but let's make sure.

The way to check this is with a *breakpoint.* A breakpoint is a place in the program where you force the computer to stop executing the program. It's very much like a STOP instruction in BASIC, except that in the Apple, the break-handling function prints out some extra helpful information that you usually don't get with Applesoft BASIC's STOP command.

The number code for a break is 0, pretty easy to remember. (The mnemonic is **BRK**, but this is probably the only machine language command that gets typed in more often directly by hand than with an assembler.)

To put a break in our program, you just need to type 0 at the point at which you want to see what the system status is. In our case, let's replace the RTS with a BRK. To do this type

```
308: 00
```

Now, type 300G to run the program. In the wink of an eye (and a quick wink at that), the screen should clear, the letter *o* will be placed on the screen, you'll hear a beep, and the top of the screen will show

```
00/0308:    00 00          BRK 00
 A=00EF X=0000 Y=0000 S=01DD D=0000 P=B0
 B=00 K=00 M=0C Q=80 L=1 m=1 x=1 e=1
*
```

The beep happens whenever a break occurs. The computer then prints a display of the contents of all the registers, and the address at which the break occurred.

Our break instruction was at $308, and this checks out with the display. You can also see the contents of the A, X, and Y registers, including both bytes in each (plus a whole lot more we haven't quite gotten to).

You'll notice that the Accumulator holds the value $EF, *not* $C1 as we had intended. Just for fun, type in

```
C1
```

and press Return.
You should see

```
00/00C1: EF -o
```

Aha—because the number sign was missing in front of the C1 in our program, the microprocessor loaded the Accumulator with the *contents* of location $C1, rather than the specific value $C1. This is confirmed by examining the contents of location $C1, which just happens to be $EF, consistent with what the break display showed.

You'll also notice that the monitor shows the letter *o* to the right of the display of the contents of $C1. That's the significance of these characters to the right of every memory display: If the number value shown were printed on the screen, the Monitor shows what text character would appear. This character is the character associated with the number in memory according to something called the ASCII value. ASCII character codes are explained in greater detail in Chapter 6.

Even if you suspected earlier that the missing number sign was the culprit, this example still demonstrates one of the fundamental principles of debugging—placing a break point at a critical point in the program and observing whether the registers contain what you think they should.

Debugging a program can be one of the most challenging (and frustrating) parts of programming, but sooner or later everyone has to do it. Taking the time to carefully think through your programs as you're writing them, and thinking carefully about them again when problems occur, will make the process much easier. The secret is to try to narrow down the precise instant at which the program has deviated from the way you think it should be running, and to then look at what's not right at that particular spot. From there you can usually figure out what's gone wrong.

There are commercial software programs (called debuggers) that let you step through a program one line at a time, with all the registers displayed for each step. These can be helpful sometimes, but for most of what's in this book, and in fact many of the problems you'll encounter even in large programs, the judicious use of just one or two BRK instructions can quickly solve most programming mysteries.

Nineteen Instructions

With the completion of this chapter you've learned 19 assembly language commands:

```
BRK   JSL   JSR   LDA   LDX
LDY   RTL   RTS   STA   STX
STY   STZ   TAX   TAY   TXY
TXA   TYA   TYX   XBA
```

and a little bit about trouble-shooting a program. You've also written, run, and saved a self-contained assembly language program. In the next two chapters we'll discuss how to assemble programs using two popular assemblers.

Secret #2

Turn on your Apple IIGS but don't put a disk in the drive. You should get a bouncing Apple with the message, **No Startup Device!**

Hold down the Control, Option, and Apple keys and press the N key. You should get a list of all the people that worked on the Apple IIGS.

Chapter 4

Assembling a Program with *Merlin 8/16*

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The next two chapters will provide specific information on writing assembly language programs with the two most common assemblers for the Apple IIGS, *Merlin 8/16* and *APW (Apple Programmer's Workshop).*

There are at least two other assemblers that will create 65816 programs, namely the *SC Assembler,* from SC Software, and the assembler that comes with the book by William Sanders called *Elementary Assembly Languge: Apple IIGS.* Each of these has advantages, especially Sander's price, but, as of the date this book was written, they didn't have the ability to create the special kind of files that we'll ultimately need to run some of the built-in IIGS tools like the pull-down menus and windows.

If you only have the *APW,* you should still read this chapter because all of the listings throughout the remainder of the book use the *Merlin 16* assembler. This chapter may help you understand the differences between the two systems and aid in the few changes that need to be made to a *Merlin 16* source listing to assemble it using the *APW.* If you only have *Merlin 8/16,* you may wish to skip Chapter 5.

The specific technical facts presented in this chapter, such as assembler fields, labels, and so forth are repeated in Chapter 5, so you don't need to worry about missing anything really important if you only read one of the chapters.

Both assemblers come with rather substantial manuals that explain how to use them. This book will not attempt in any way to duplicate that information, for obvious space reasons. We will, though, discuss the most basic file editing commands and how to assemble, save, and run programs using each. But it is assumed that any questions regarding specific functions in either assembler will be answered by their respective manuals.

Merlin 8/16

Merlin 8/16 is actually a combination product. When you buy it, the package has three assemblers in it. They are:

Assembler	**Operating System**	**System Required**
Merlin 8	DOS 3.3	Apple IIe,IIc or IIGS
Merlin 8	ProDOS	Apple IIe,IIc or IIGS
Merlin 16	ProDOS	IIGS (or IIe with 65816 or 65802 installed)

Merlin 8 is intended primarly for for use on Apple IIe and IIc computers, and creates code for the 6502/65C02 microprocessor, whose instructions are a subset of the 65816 instructions.

Merlin 16 requires the presence of a 65816 to work properly, and is intended to assemble programs for the Apple IIGS. When this book was written, however, it was running on any Apple IIe and IIc computers that have had a 65816 (or 65802, a IIe/IIc compatible) microprocessor added to them, such as can be done with products from Applied Engineering and Checkmate Technologies.

In the following instructions, we'll assume that you're familiar enough with ProDOS to be able to run *Merlin 16* from BASIC, the Launcher, or some other program selector, and are able to successfully quit *Merlin 16* and return to Applesoft BASIC. Later on, as the programs become more sophisticated, you'll be able to run them directly from the Launcher or a program selector. But, for now, a CALL from Applesoft BASIC is probably the best way. It's also easier to the Monitor for debugging if you run your programs from Applesoft BASIC.

You should also have an initialized disk, formatted under ProDOS, on which you can save the sample programs as we go along. For our examples, we'll assume that disk has the volume name **/PROGRAMS**, but you can use any name you wish. If you have a disk you're already using to save the programs presented earlier, you can continue to use that.

Writing a Program Using the *Merlin 16*

The first step is to get the *Merlin 16* up and running. Use the Apple Program Launcher that comes on your Apple IIGS System Disk to run MERLIN.16, or use whatever other technique you usually use to run a program.

When run, the following title screen will appear.

```
                         Merlin-16 3.00+
                  Copyright (c) 1987 By Glen Bredon
                          14-NOV-87 8:55

C  :Catalog
L  :Load source
S  :Save source
A  :Append file
D  :Disk command
E  :Editor, command mode
O  :Save object code
@  :Set date
Q  :Quit
         Source: A$0901,L$0000

Prefix: /MERLIN/

%
```

Merlin 16 has 3 levels of operation: the main menu, the full screen editor, and the assembler/linker.

The screen above is the main menu. Looking over the list of commands, you can see options for loading and saving source files, object files, executing disk commands and more.

There is also a display of the current ProDOS prefix. Depending on what disk you have *Merlin 16* on, this prefix will vary.

You can use the main menu D command (for Disk) to change the prefix. Try it now by inserting your own program disk (we'll assume it's called /PROGRAM). Press D. The command prompt near the bottom of the screen should change to

```
Disk command:
```

Type in:

```
PREFIX /PROGRAMS
```

and press Return. The disk should on for a moment, and then the Prefix indicator should change to /PROGRAMS.

You can view the disk catalog by pressing the C key (for Catalog). *Merlin* will prompt

```
%Pathname:
```

Press Return alone to use the Prefix shown on the screen, which is presumably /PROGRAMS (or whatever the name of your data disk is) at this point.

When you're done looking at the catalog, press Return to view the main menu again.

To enter your first program, press F to go to the full screen editor mode of *Merlin 16.*

The screen will clear, and the cursor will change to an inverse *I*, and you'll see a vertical bar, and the number 1 at the top of the screen.

The vertical bar is a width indicator, set for most printers, to show how far to the right you can type before the text will be too wide for the printer. This position can be adjusted, and is explained in the *Merlin 8/16* manual.

The number at the upper right corner of the screen is a line number indicator, and gives you an idea of where you're at in your listing. Try it out now by pressing the down arrow, and then the up arrow to move the cursor up and down on the screen. The line number indicator will change as you move. Use the up arrow to bring the cursor back to line 1.

A good assembler is like a word processor for programming. It should have features inserting and deleting text, moving blocks of text around, formatted printing, and so forth—features that make dealing with source files easier. In the previous chapters, we called the list of LDAs, the source listing, even though they weren't saved separately in their own file. With a real assembler, they are. The lines you type in will eventually be saved as a text file. In fact, you could even use another word processor to edit the files if you liked, although you'll probably find the *Merlin* editor more convenient.

The *Merlin 16* assembler is also different from the mini-assembler in that it lets you add text as comments to your programs, very much like a REM statement in Applesoft.

Entering your program. To start off our program, let's begin by putting a title at the beginning. With the cursor on line 1, hold down the Open Apple key, and then press 8. A row of asterisks should appear on line 1. In most assemblers, any line that begins with an asterisk is considered a comment line, and anything after the first asterisk is ignored by the assembler when creating the actual program. In this case, we'll use asterisks to create a title box at the beginning of the program listing.

If you haven't done so already, press Return to move the cursor to line 2 of the listing. Now hold down the Open Apple key and press 9, but don't press Return yet. This time the line will be bracketed by asterisks, and the middle will be left blank. This is where we'll type the title. While we're on the subject, from now on, we'll just indicate Open Apple commands in the form *Open Apple-8,* and assume you'll remember to hold down the Open Apple key while you press 8. If you press the 8 key first, you'll just get the character 8 on the screen.

Use the right-arrow key to move the cursor over a few spaces, then type

```
1st Merlin Program
```

You'll notice that as you type, the asterisk at the end of the line automatically moves ahead. This action is called the *insert mode* and means that the editor automatically inserts the characters in the line as you type them. To avoid this, first use the Delete key to erase what you've typed and move the cursor back to the third character position. Then press Control-I.

This toggles the insert mode, and you'll see the cursor change to a solid block. *Toggling* means that the mode will flip on and off each time you press Control-I. When the insert mode is off, the cursor just types over what is already on the screen, instead of creating new space as you type. This is called the *overstrike mode* and, for now, this is what you want.

You can always tell what mode the editor is in by the appearance of the cursor: *I* indicates insert mode; a solid block means the overstrike mode. Now again type

```
1st Merlin Program
```

If you make a mistake typing, use the left-arrow key to back up. Delete will always remove spaces, regardless of the Insert/Overstrike status.

When everything looks OK, press Return to move the cursor to the next line. Now type Open Apple–9 again to create another line in the box, and fill it in with *By* and your name. It's a good idea to make up a title box for every program you write, so that when you look at the program later, you'll remember what it does. You'll usually want to include even more information, such as the date, any commands the program may recognize, and any other useful information.

This process is called *documenting a program,* and it is a very important step. While you're writing a program, you may remember what each part does, but even by the next morning you'll be much happier if you included lots of text information explaining what each part of the program does.

When you're done filling in the third line, press Return. You should now be on line 4. Press Open Apple–8 to create another solid line for the bottom of the box. If you've done everything correctly, your program should look something like this:

```
**************************************
* 1st Merlin 16 Program              *
* By <your name>                     *
**************************************
```

While you're editing, there are a number of editor commands that can make your life easier. The four directional arrow keys will move the cursor around. You can also press Control-B to move to the beginning of a given line, and Control-N to move to the end.

You can also use Control-I to toggle the insert mode, although using this with the arrow key and the delete key—and keeping everything lined up—takes a little practice. Even though this listing is rather short, you can also use Open Apple–B and Open Apple–N to move to the very beginning and the end of the entire source listing itself.

When you're ready, press Return or use the down arrow to move to line 6. This will leave a blank line below the title box. The assembler doesn't care about all this, but it makes the program look better.

Before you enter the first line, let's review how you entered a line in the mini-assembler. There, you typed in

```
300: JSR FC58
```

There are three pieces of information here. At the left is the address to put the instruction. In the second position is the opcode for the particular instruction you want, in this case JSR. In the third position is the address the JSR needs to go to.

In a real assembler, these positions are also used, and are called *fields*. You usually separate them by spaces, just as you did in the mini-assembler.

The first field is called the *label field*. In a true assembler, you don't have to worry about actual addresses at all. The *Merlin 16* assembler starts off assuming a default address of $8000 (32768 decimal) for every program. This value can be changed if you like, but more on that later.

Adding labels. Since the assembler is going to keep track of actual addresses for us, the first field can be given a name to represent the address of that instruction, and the assembler will make sure that any references to this name are eventually translated into the proper address when the program is assembled.

There is no analogy in BASIC, since in Applesoft BASIC you can't say "line 100 = PRINT MENU", and then later on use the command GOSUB MENU. In an assembler, on the other hand, the line numbers are only of incidental interest, and all JSRs and references to addresses can use a label. This makes it much easier for the programmer, and in itself is a good reason to use a real assembler instead of the mini-assembler, which has no provision for labels.

Let's call the first line of our program BEGIN. Type BEGIN, and then press the space bar once (don't press Return yet). Even though you only typed one space, the cursor will automatically jump to the second field position on the line. The second field is called the *opcode field* and is where you put a given 65816 instruction, such as JSR. *Merlin* automatically uses the space character to separate fields and to move the cursor to a given column so that the final listing will look orderly.

In the second field, type JSR and press the space bar again. The cursor then moves to the third field, which is called the *operand field.* An operand is the information needed by an opcode. For example, a JSR by itself doesn't tell the assembler where the JSR was destined. Type $FC58 here for the operand, and press the space bar again. In the *Merlin 16* assembler, you have to use the dollar sign ($) in front of all hex numbers. If you don't, *Merlin* will treat it as a decimal number.

The fourth, and last, field is called the *comment field.* This is where you can add text to explain what a specific line does. It's customary (some assemblers, though not *Merlin 16,* insist on it) to begin a comment with a semicolon. Type ; CLEAR SCREEN and press Return.

If all went well, your program should look like this:

```
****************************************
* 1st Merlin 16 Program                *
* By <your name>                       *
****************************************

BEGIN   JSR   $FC58     ; CLEAR SCREEN
```

For the second line, we won't use a label. Actually, a label is always optional unless it is directly referenced somewhere else in the program, for example by a JSR somewhere. In that light, we didn't really need the label at the beginning of the first line of the program, but we'll leave it there since it doesn't hurt anything.

Since we don't need a label for the second line, press the space bar once to move the cursor to the opcode field. Now type LDA, a space, and #$C1. Then press the space bar once more, and type

```
; LETTER "A"
```

and press Return. For the next line, space to the second field and type in

```
STA  $5BC  ; SCREEN LOCATION
```

and press Return. Finally, finish the program with the label DONE, and RTS. You don't need an operand for RTS, and you can omit the comment, too.

Your program should now look like Program 4-1.

Program 4-1. First Program

```
******************************************
* 1st Merlin 16 Program                  *
* By <your name>                         *
******************************************

BEGIN   JSR  $FC58    ; CLEAR SCREEN
        LDA  #$C1     ; LETTER "A"
        STA  $5BC     ; SCREEN LOCATION
DONE    RTS
```

Assembling with *Merlin 16*

To assemble the program, press Open Apple–O (for Open dialog box). This will open a small dialog box on the *Merlin* screen in which you can enter direct *Merlin* system commands.

The actual assembly is started by typing

```
ASM
```

When you press Return, text will suddenly appear on the screen, and things should look like Program 4-2.

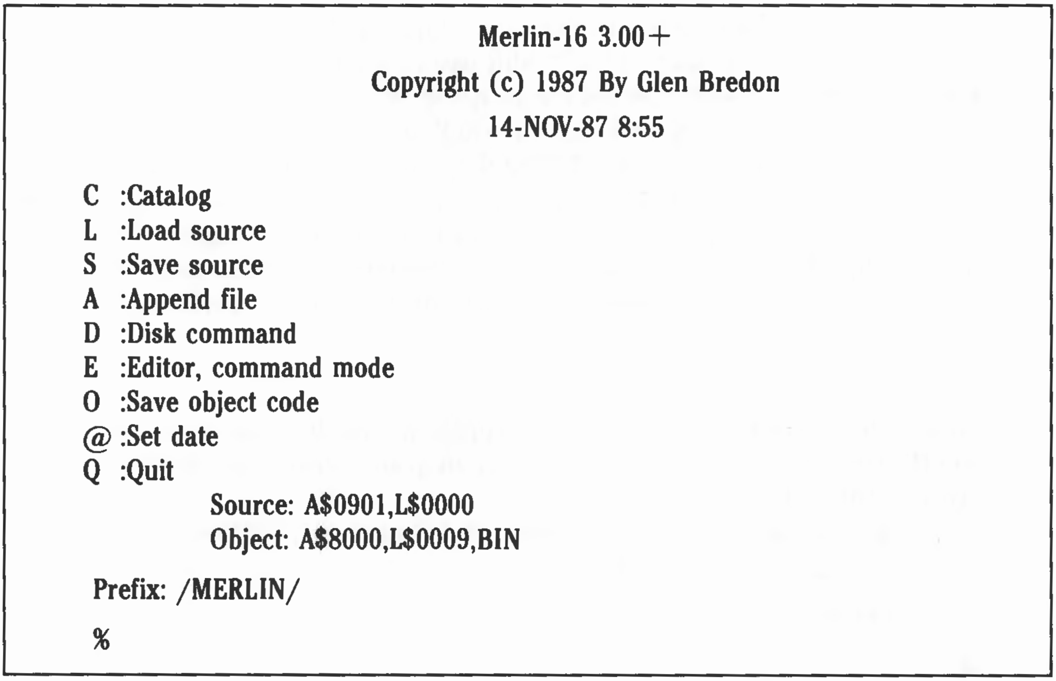
Program 4-2. Assembly of First Program

```
                       1   ******************************************
                       2   * 1st Merlin 16 Program                  *
                       3   * By <your name>                         *
                       4   ******************************************
                       5
008000:  20  58  FC    6   BEGIN   JSR  $FC58    ; CLEAR SCREEN
008003:  A9  C1        7           LDA  #$C1     ; LETTER "A"
008005:  8D  BC  05    8           STA  $5BC     ; SCREEN LOCATION
008008:  60            9   DONE    RTS

--End Merlin-16 assembly, 9 bytes, Errors: 0

Symbol table - alphabetical order:

   ? BEGIN  =$8000 ? DONE  =$8008

Symbol table - numerical order:

   ? BEGIN  =$8000 ? DONE  =$8008
```

There are a number of things to notice. The first is that *Merlin* has created a listing at the far left of the addresses where each instruction will ultimately be put in memory. I mentioned that *Merlin* assumed a starting location of $8000, and you can see each line indicates the memory address followed by the actual machine language for each instruction of your program. If you want the listing to go by a little more slowly, you can press the space bar immediately after typing ASM, and *Merlin* will step through the lines one at a time, keypress by keypress. Pressing Return resumes the normal speed listing.

At the end of the listing is something called the *symbol table.* This prints a list of all the labels used in the program, such as BEGIN and DONE. The questions marks are printed by *Merlin*; they indicate that these labels are not called by name anywhere in the program. You can ignore them if you wish.

To save the program to your disk, you need to go back to the main menu. Type *Q* (for Quit) now in the immediate mode of the editor. The main menu should reappear.



```
                      Merlin-16 3.00+
               Copyright (c) 1987 By Glen Bredon
                      14-NOV-87 8:55

C  :Catalog
L  :Load source
S  :Save source
A  :Append file
D  :Disk command
E  :Editor, command mode
O  :Save object code
@  :Set date
Q  :Quit
          Source: A$0901,L$0000
          Object: A$8000,L$0009,BIN

 Prefix: /MERLIN/

 %
```

You can see that a new indicator has been added to the screen in the lower right corner, below the word *Source*. The heading Object: shows that there is now an object file in memory, and that it has a length of nine bytes. If this indicator does not show up, it's because either an error occurred during the assembly or the file was assembled directly onto the disk, a problem that will be discussed later.

There are now two files that need to be saved, the source file and the object file. To save the source file, press the S key (for save Source file). The prompt will change to

```
%Save:
```

Type in the name MERLIN.1 and press Return. The disk will come on and the source file will be saved to the disk. Then the prompt returns, you can view the disk catalog by pressing the C key (for Catalog).

In the disk catalog you should see the file MERLIN.1.S. The .S suffix is automatically added by *Merlin* when a source file is saved, or loaded, so don't worry about ever having to type this yourself.

To save the object file, press the O key. The prompt

```
%Object:MERLIN.1
```

will appear. *Merlin* is offering the same name as a default. Press the Y key (for Yes) to accept this default. *Merlin* will use this name *without* the .S suffix, so you don't have to worry about overwriting your source file.

If you catalog the disk again, you'll see your source file saved as a text (TXT) file and the object file, MERLIN.1, saved as a binary (BIN) file.

To run the assembled file, you'll have to quit *Merlin* and go to Applesoft BASIC, or a to a program selector other than Apple's Program Launcher, that can run binary files. Applesoft BASIC is the recommended method for now.

Press the Q key to quit *Merlin.* It will ask you to confirm with the prompt

```
%Quit
```

Press Y to finish the quit and go to Applesoft BASIC. When you're in Applesoft you'll probably have to reset the prefix to your /PROGRAMS disk before you can run MERLIN.1.

Assuming the prefix is correct, and that the /PROGRAMS disk is in a drive, you can now type either

```
BRUN MERLIN.1
```

or

```
-MERLIN.1
```

to run the program. You can also type

```
BLOAD MERLIN.1
CALL 32768
```

This last bit may surprise you. Remember, though, that *Merlin 16* used a default address of $8000 (32768) to assemble the program. That is also where the binary file will automatically load MERLIN.1 when you do a BLOAD.

There are two ways of moving the code to $300 (768). The first is to specify the address as part of the BLOAD command

```
BLOAD MERLIN.1,A$300
CALL 768
```

The other way to move the code is to tell the assembler where you want the code to ultimately run. To do that, we'll need to go back to *Merlin 16*. Type BYE in the immediate mode to quit BASIC back to a program launcher, or set the ProDOS prefix back to the *Merlin* program disk and type in

```
-MERLIN.16
```

Assembler Directives: ORG

When *Merlin* is back up and running, load your source file MERLIN.1 from the main menu. Remember that you don't need to include the .S suffix with the name.

When the source file is loaded, enter the editor/assembler with the E command. Then press E to edit the file. The full-screen editor should start up, with the cursor on the first line, in the upper left corner of the screen.

Move the cursor down, using the down arrow, to line 5 (the blank line) and press Return. A new blank line should be inserted. When the editor is in the insert mode, the cursor will be shown as an inverse *I*, and pressing Return will insert a new blank line.

Press the space bar once to go to the opcode field, and type ORG. Then press the space bar once, and type $300 and press Return. The listing is shown in Program 4-3.

Program 4-3. First Program

```
******************************************
* 1st Merlin 16 Program                  *
* By <your name>                         *
******************************************


        ORG  $300
BEGIN   JSR  $FC58     ; CLEAR SCREEN
        LDA  #$C1      ; LETTER "A"
        STA  $5BC      ; SCREEN LOCATION
DONE    RTS
```

ORG is not a 65816 opcode. Instead, it's an instruction specifically for the assembler. ORG stands for **Origin**, and tells the assembler where the machine language program will ultimately run. Instructions like ORG are called assembler *directives*, because they direct the assembler to take a certain action.

After you've added the new line with ORG, press Open Apple–Escape, and then type ASM to assemble the program. If there are no errors, press Q to go back to the main menu.

When you press S to save the modified source file, *Merlin* will prompt you with the name MERLIN.1. *Merlin* remembers the name of the file last loaded. To keep this name, just press Y (for Yes). After the source file is saved, press O to save the object file, and again accept the default name.

When you've saved the new file, quit *Merlin*, go back to BASIC, and type:

```
BLOAD MERLIN.1
CALL 768
```

This time, the file is located at $300. That's because you told *Merlin* where you wanted the file to load with the ORG directive.

More About Labels

Now go back to *Merlin* again, and load MERLIN.1. The listing should look like Program 4-2.

Looking at the listing, you can see addresses like $FC58 and $5BC, and the code value for the letter *A*, $C1. As a program gets larger, and the listing longer, it can start to get rather confusing trying to remember many different number values. To make programming more convenient, most assemblers allow you to give routines a name and remember the address for you.

Start by putting the cursor on line 7, press Return once, and type the following:

```
HOME    EQU  $FC58
SCREEN  EQU  $5BC
```

Now move the cursor to this line:

```
BEGIN  JSR  $FC58     ; CLEAR SCREEN
```

Move the cursor to the *end* of the address $FC58, and press the Delete key until it's completely erased. Type HOME, but don't press Return. Now use the down-arrow key to move down two lines, and do the same thing to replace the address $5BC with SCREEN.

Your program should now look like Program 4-4.

Program 4-4. First Program with EQU

```
****************************************
* 1st Merlin 16 Program                *
* By <your name>                       *
****************************************

        ORG  $300
HOME    EQU  $FC58
SCREEN  EQU  $5BC
BEGIN   JSR  HOME      ; CLEAR SCREEN
        LDA  #$C1      ; LETTER "A"
        STA  SCREEN    ; SCREEN LOCATION
DONE    RTS
```

Use Open Apple–O and the command ASM again to assemble this listing. The assembly output is shown in Program 4-5.

Program 4-5. Assembly of First Program With EQU

```
                  1  ****************************************
                  2  * 1st Merlin 16 Program                *
                  3  * By <your name>                       *
                  4  ****************************************
                  5
                  6          ORG  $300
                  7
           =FC58  8  HOME    EQU  $FC58
           =05BC  9  SCREEN  EQU  $5BC
                 10
000300: 20 58 FC 11  BEGIN   JSR  HOME
000303: A9 C1    12          LDA  #$C1
000305: 8D BC 05 13          STA  SCREEN
000308: 60       14  DONE    RTS
--End Merlin-16 assembly, 9 bytes, Errors: 0
Symbol table - alphabetical order:
   ? BEGIN =$0300 ? DONE =$0308 HOME =$FC58 SCREEN =$05BC

Symbol table - numerical order:
   ? BEGIN =$0300 ? DONE =$0308 SCREEN =$05BC HOME =$FC58
```

You'll notice that this time the assembler translates the labels HOME and SCREEN into their assigned addresses. Labels are always associated with some value in the source listing. If you look at the symbol table at the end of the listing, you'll also notice that there are no question marks next to the labels

HOME and SCREEN, like there are next to BEGIN and DONE. The assembler is telling us that the labels HOME and SCREEN are actually referenced by the program, whereas BEGIN and DONE are not. This is intended as a debugging aid, to point out any labels you defined, but might have forgotten to use.

Whenever the assembler encounters a label, either at the beginning of a line, or following the **EQU** directive, it assigns a value, usually an address, to it. For EQU statements, it uses whatever value is on the line. If the label is at the beginning of the line, it uses its own internal address counter for where it's at in the program.

For instance, since BEGIN is the first statement in the program, the assembler gives BEGIN a value of $300. As it continues to assemble each line, it keeps track of where it is. By the time it gets to DONE, the address counter is up to $308, and that's what it assigns to DONE. Thus, if you want some other part of the program to do a JSR, for example, to BEGIN or DONE, you just use the line

```
JSR  DONE
```

or

```
JSR  BEGIN
```

In this program, such a JSR wouldn't make much sense, just as a GOSUB to the first or last line in a BASIC program wouldn't make sense; but, as your programs get larger, you'll want to go to subroutines within the program. In assembly language, you use the labels, not line numbers, to tell the JSR where you want it to go.

Labels can be used for more than addresses. We could also assign a label to the value for the letter *A* as shown in Program 4-6.

Program 4-6. Using EQU to Define a Character

```
****************************************
* 1st Merlin 16 Program                *
* By <your name>                       *
****************************************

         ORG  $300

HOME     EQU  $FC58
SCREEN   EQU  $5BC
LETTERA  EQU  $C1

BEGIN    JSR  HOME      ; CLEAR SCREEN
         LDA  #LETTERA  ; LETTER "A"
         STA  SCREEN    ; SCREEN LOCATION
DONE     RTS
```

Using EQU for Constants

However, there is an easier way. Enter the full-screen editor, and use the Delete key to remove just the characters $C1 from line 12. Replace it with the characters "A" (quotes included) like this:

```
        LDA  #"A"     ; LETTER "A"
```

Now quit the editor and try another assembly. This time you'll see the assembler has correctly used the value $C1 for the letter *A*. That's because the letter codes have been standardized, and the assembler already knows all the codes for all the letters.

You should also go back to BASIC, after saving the new source and object files, and run the new assembly, just to prove to yourself that the new listing works (and to make sure you haven't made any errors along the way).

There's nothing wrong with assigning a constant (as opposed to an address) with an EQU statement, it just takes up a little more room in your listing and the computer's memory. This technique is used when you want to use a number value throughout a listing, but want to keep your options open on being able to change your mind later.

For instance, suppose you're testing a program that goes through a loop 200 times, and that the number 200 is used many times in the program. During testing, it might be nice to just use the number 5 for a shorter loop, instead. Using the label

```
COUNT  EQU  5
```

makes it easy to change later, without having to search through the listing for all the number 5's on every line.

There's one other common error you can avoid. Sometimes programmers will define a constant this way:

```
COUNT  EQU  #$5
```

and then, later in the listing, this way:

```
        LDA  COUNT
```

They think that the pound sign is included in the label COUNT. It isn't. The assembler evaluates each operand as a numeric expression, and then stores the *result* as a the number value, *not* the text of the line that generated the result. The instruction assembled as though the line read

```
        LDA  $5
```

When the program runs, the accumulator is loaded with the *contents of location $5*, not the actual value 5. Because there is no error generated during the assembly, and because the value loaded into the accumulator can be almost anything (and usually is), this kind of mistake can be very difficult to track down.

Therefore, be sure you remember to always put the pound sign in front of any labels that you want used as an absolute value.

```
COUNT  EQU  $5
       LDA  #COUNT
```

As your programs get larger, so will the listing of all the lables at the end of the assembly. If you would like *Merlin* to omit the label list, you can add the instruction LST OFF to the end of your listing. LST is a *Merlin* directive that tells the assembler not to list the lines following that instruction to the screen or printer. With LST OFF at the end, your listing would look like this:

```
       STA      SCREEN  ; SCREEN LOCATION
DONE   RTS
       LST OFF          ; SUPPRESS SYMBOL TABLE
```

Assembling Directly to Disk

There is also one other assembly option in the *Merlin 16* assembler that should be mentioned. In the previous examples, we assembled each file and then went to the main menu to save both the source and object files. In many assemblers, there is also the option to write the object file to disk as it's being created. This leaves more room in memory for the source file, although it does slow down the assembly because of the disk access.

To try this out, insert this in the listing after the ORG directive, but before the actual program:

```
       DSK  MERLIN.1
```

DSK (for **disk**) is a special *Merlin 16* directive to tell the assembler to save the object file as it's being created. No quotation marks are needed around the name. Because we are creating the object file, you also don't want to put an .S suffix; that is reserved for the source file. The amended listing is shown is Program 4-7.

Assemble this file. During the assembly, the disk should come on as the file is automatically saved to disk. When you quit the editor/assembler to go to the main menu, you'll also notice there is no Object: indicator. This is because the object file is not created in memory, but is written directly to disk.

If you make changes to a source file, you'll still have to save it with the S command. *Only the object file is automatically written to disk; the source file is not.*

DSK can also be used with another *Merlin 16* command, **TYP** (for **file type**) to create any legal ProDOS file type as an alternative to the usual binary (BIN) file type. This won't be needed right away, but it will come in handy later on.

Program 4-7. Using the *Merlin* DSK Directive

```
****************************************
* 1st Merlin 16 Program                *
* By <your name>                       *
****************************************

           ORG  $300

           DSK  MERLIN.1    ; CREATE OBJECT FILE ON DISK

HOME       EQU  $FC58
SCREEN     EQU  $5BC
LETTERA    EQU  $C1

BEGIN      JSR  HOME        ; CLEAR SCREEN
           LDA  #LETTERA    ; LETTER "A"
           STA  SCREEN      ; SCREEN LOCATION
DONE       RTS
```

Starting a New Program

Whenever you want to erase the current source listing (be sure to save it to disk first), just press Open Apple–O to open the dialog box, and type NEW. If you want to load a new file directly from the main menu, you don't have to type NEW first.

Long Addresses in *Merlin 16*

In the *Merlin 16* assembler, there is a special opcode syntax for the long addressing modes of the LDA and STA instructions. To indicate you want to use a long address, use the greater than symbol (>) in front of the label to be assembled in the long address form. The long form of a JSR (JSL) requires no additional syntax. The reason *Merlin* requires a different opcode for a long LDA or STA is to resolve the potentially ambiguous case of LDA LABEL where LABEL equals a value less than $01/0000. For example, the statement LDA $300 could be assembled as either a short form LDA $0300 ($AD 00 03), or as the long form LDA $000300 ($AF 00 03 00).

Program 4-8 is a program segment that illustrates some of the different instructions possible.

Program 4-8. Long Addressing Example

```
                         1  **********************************************
                         2  *      LONG ADDRESSING EXAMPLE               *
                         3  *       MERLIN 16 ASSEMBLER                  *
                         4  **********************************************
                         5
              =050300    6  LABEL1   EQU   $050300    ; $05/0300
              =061A00    7  LABEL2   EQU   $061A00    ; $06/1A00
              =0300      8  LABEL3   EQU   $300       ; $00/0300
                         9
008000: AD 00 03        10           LDA   LABEL1     ; SHORT ADDRESS ONLY
008003: 8D 00 1A        11           STA   LABEL2     ; SHORT ADDRESS ONLY
                        12
008006: AF 00 03 05     13           LDA   >LABEL1    ; LONG ADDRESS
00800A: 8F 00 1A 06     14           STA   >LABEL2    ; LONG ADDRESS
                        15
00800E: AF 00 03 00     16           LDA   >LABEL3    ; LONG ADDRESS
008012: AD 00 03        17           LDA   LABEL3     ; SHORT FORM
                        18
008015: 22 00 1A 06     19           JSL   LABEL2     ; LONG ADDRESS
                        20
008019: AF 00 03 00     21           LDAL  LABEL3     ; LONG ADDRESS
                        22
00801D: 8F 00 1A 06     23           STAL  >LABEL2    ; LONG ADDRESS
--End Merlin-16 assembly, 33 bytes, Errors: 0
```

This listing shows how various label addresses are resolved by different opcodes, and it also shows the syntax of the JSL instruction. In the first case (lines 10, 11), LABEL1 and LABEL2 are truncated to two bytes, even though both evaluate to three bytes, and the short address mode of LDA and STA are used. In the second case (lines 13, 14), LABEL1 and LABEL2 are assembled using the long address form. Lines 16, 17 show the alternate possible outputs of assembling the address $300, depending on which form of LDA is used. Line 19 shows the assembly of the JSL instruction.

There is also another syntax available for telling *Merlin* to use the long form: add *L* to the opcode, as in LDAL LABEL or STAL LABEL. Lines 21 and 23 show this.

Merlin in Review

If you've worked through the examples in this chapter, you should be able to enter, edit, assemble, and save both a source listing and the object file using the *Merlin 16* assembler. To learn more about editing, such as how to cut, copy and paste sections, or how to use search and replace, you should read the manual that came with *Merlin*.

You should have an understanding of how to use labels in a source program to represent a given number value or address, how to use ORG and EQU to control the values that labels are assigned, and where the program will load into memory from disk.

Merlin directives introduced in this chapter:

EQU ORG LDAL STAL DSK TYP LST

Chapter 5

Assembling a Program with *APW*

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Assembling a Program with *APW*

The *APW (Apple Programmer's Workshop)* assembler is the second assembler we'll discuss in this book. The information presented about labels and assembler directives is roughly equivalent to that presented in the last chapter on the *Merlin 16.*

If do not have the *APW*, you may wish to skip this chapter, so as to not add to the burden of remembering what's already been discussed that is specific to the *Merlin 16.* In general, the *Merlin 16* is a much simpler program to use, and this chapter may seem more difficult. This is because the *APW* was not designed with the novice programmer in mind. Is is, though, possible to master.

Before beginning this section, you should spend at least some time reviewing the documentation that came with the *APW* regarding installation and basic file handling procedures.

A word of warning: The *APW* was not designed for the beginner. The discussion in this chapter has been made as clear as possible, but there is no getting around the fact that even a mimimal assembly with the *APW* seems like a lot of work at first. If you do have difficulties, don't be discouraged about programming altogether. The *APW* is covered in this book because it is likely that many people will have that assembler when they read this. However, it is not necessarily the best choice for someone who is not a professional programmer.

Apple Programmer's Workshop

The *Apple Programmer's Workshop (APW)* system is made up of many subunits, which create a program development environment. The *APW* can only be run on an Apple IIGS using the ProDOS 16 operating system.

When the *APW* is run, what is actually in memory is a shell program that has very few commands of its own. It knows how to load and run the other modules as you need them. The general theory of operation is as follows:

Editor	Edit and save FILE (SRC)	source file
Assembler	Assembles and saves FILE.ROOT	object module
Linker	Processes FILE.ROOT into loader file.	
	Execute loader file	run program
	Change file type to BIN, SYS, S16 or other type recognizable by Program Launcher or SYSTEM boot process.	

First, the editor is used to create the original source listing from which the machine language program will ultimately be generated. When the source file is ready, it is saved to disk. The *APW* shell is then instructed to assemble the program. This generates a file called the *object module* that is an intermediate file to the final usable program. The assembler automatically adds the suffix .ROOT to a name you specify as what you want for the final usable file.

Next, the shell is instructed to process the intermediate file, through a process called *linking*. It processes it into a file, called a *loader file*, that is executable from within the *APW* shell. This program has the file type EXE (Executable), and can only be run from within the *APW* system.

To create the final file that can be run from the Program Launcher or BASIC, the shell is given a command to tell it exactly what kind of final file type the program should have. This is so the programmer can create any of the legal ProDOS file types, such as ProDOS 16 system files (S16), ProDOS 8 system files (SYS), desk accessories (CDA), or others. Of course, the assembler can't tell if the program you have written is appropriate to the file type you specify. It's up to you to stay out of trouble.

The assembly and link processes can be done in one step, and there is also a provision in the *APW* assembler for creating a command file that will do the entire process automatically by just executing the command file.

In the following instructions, we'll assume that you're familiar enough with ProDOS to be able to run *APW* from the Launcher, or some other program selector, and are able to successfully quit *APW* and return to Applesoft BASIC. Later on, as the programs become more sophisticated, you'll be able to run them directly from the Launcher or a program selector. For now, a CALL from Applesoft BASIC is probably the best way. It is also easier to get into the Monitor for debugging if you run your programs from Applesoft.

You should also have an initialized disk, formatted under ProDOS, on which you can save the sample programs as we go along. For our examples, we'll assume that disk has the volume name /PROGRAMS, but you can use any name you wish. If you have a disk you're already using to save the programs presented earlier, you can continue to use that.

Writing a Program Using the *APW*

The first step is to get the *APW* up and running. Use the Apple Program Launcher that comes on your Apple IIGS System Disk to run the *APW*, or use whatever other technique you have decided on to run the *APW*.

When run, the following title screen will appear:

```
                    Apple IIGS Programmer's Workshop V2.0
                     Copyright Byte Works, Inc. 1980-1986
                     Copyright Apple Computer, Inc. 1986
                             All Rights Reserved

#
```

The screen you see is the main level of the *APW* shell. The pound sign (#) is the *APW* shell prompt. There is no list of commands on the screen, but you can enter HELP to print a list of available help files. Type HELP now and press Return to see how this works. If you get a ProDOS: File not found error, it means there are no help files on your particular *APW* disk. See the *APW* manual for details on setting up help files.

If you do have help files on your disk, you can also ask for help on a specific item by typing the word HELP followed by a space and one of the subject names as printed in the HELP list. For example, if you wanted information about printing files, you could type in

```
HELP PRINTER
```

If you've prepared your own data disk, now would be a good time to set the prefix to tell the *APW* about it. To set the prefix, just type

```
PREFIX /PROGRAMS
```

and press Return. The disk should come on for a moment, and the prefix should now be set to /PROGRAMS. To look at your disk, and make sure that the prefix is properly set, type

```
CATALOG
```

and press Return. You should get the directory listing for your disk. Don't worry that this might cause the *APW* to forget where its help files are located—it still remembers where its own files are.

To enter your first program, you'll need to go to the editor module of the *APW*. The editor requires any file it opens have a name, so you'll have to give it a name to begin. Type

```
EDIT APW.1.S
```

The .S suffix is not required for *APW* files, and the *APW* doesn't do any automatic management of the filenames, but adding the .S makes it easier to keep your files straight.

After a moment, the screen will change, and you'll be in the editor. At the bottom of the screen is a status line that tells you the line and column position of the cursor, how much memory is left, and the name of the current source file, which should read APW.1.S.

Try it out now by using the directional arrow keys to move the cursor around on the screen. The line and column number indicators will change as you move. Use the up-arrow key to bring the cursor back to line 1, column 1.

A good assembler is like a word processor for programming. It should have features like inserting and deleting text, moving blocks of text around, formatted printing, and so forth.

In the previous chapters, we called the list of instructions such as LDA, the source listing, even though they weren't saved separately in their own file. With a real assembler, they are. The lines you type in will eventually be saved as a text file. In fact, you can even use another word processor to edit the files if you like, although you'll probably find the *APW* editor more convenient.

In contrast to the mini-assembler, this assembler also lets you add text as comments to your programs, very much like a REM statement in Applesoft.

To start off our program, let's begin by putting a title at the beginning. With the cursor on line 1, type an asterisk (*) and hold down until it starts repeating. Fill the line to column 30 and then stop. If you go too far, just press the Delete key to back up and erase extra characters.

In most assemblers, any line that begins with an asterisk is considered a comment line, and anything after the first asterisk is ignored by the assembler when creating the actual program. In this case, we'll use asterisks to create a title box at the beginning of the program listing.

If you haven't done so already, press Return to move the cursor to line 2 of the listing. Start this line with an asterisk also, space over a few spaces, then type

1st APW Program

Finally, use the space bar or right arrow until the cursor is again in column 30, type an asterisk, and then press Return.

Type another line just like the second, only this time fill it in with *By* and your name. It's a good idea to make up a title box for every program you write, so that when you look at the program later, you'll remember what it does. You'll usually want to include even more information, such as the date, any commands the program may recognize, and any other information that may be useful.

This process is called *documenting* a program, and is a very important part. While you're writing a program, you may remember what each part does, but even by the next morning you'll be much happier if you include lots of text information explaining what each part of the program does.

When you're done filling in the third line, press Return. You should now be on line 4. Now type another line of 30 asterisks to finish the bottom of the box. If you've done everything correctly, your program should look something like this:

```
**********************************************
* 1st APW Program                            *
* By <your name>                             *
**********************************************
```

While you're editing, there are a number of editor commands that will make life easier. The four directional arrow keys will move the cursor around. You can also press Open Apple–< (or Open Apple–,) to move to the beginning of a given line, and Open Apple–> (or Open Apple–.) to move to the end.

Open Apple–E controls the *insert mode.* When the editor is in insert mode, it automatically inserts the characters in the line as you type them.

Open Apple–E toggles the insert mode, and you'll see the words at the bottom of the screen change from EDIT to EDIT INSERT. Toggling means that the mode will flip on and off each time you press Open Apple–E. When the insert mode is off, the cursor just types over what is already on the screen, instead of creating new space as you type. This is called the *overstrike mode.* If you make a mistake typing, use the left-arrow key or the Delete key to back up. Delete will always remove spaces, regardless of the Insert/Overstrike status.

Don't worry if it seems a little awkward at first. With a little practice, it will become much easier. Although the listing is rather short, you can also use Open Apple–1 and Open Apple–9 to move to the very beginning and the end of the entire source listing itself. You might want to try out these commands now to get a feel for things before we get to entering the actual program.

When you're ready, press Return, or use the down arrow to move to line 6. This will leave a blank line below the title box. The assembler doesn't care about all this, but it makes the program look better.

Before you enter the first line, let's review how you entered a line in the mini-assembler. You typed in

```
300: JSR FC58
```

There are three pieces of information here. At the left is the address to put the instruction. In the second position is the opcode for the particular instruction you want, in this case JSR. In the third position is the address the JSR needs to go to.

In a real assembler, these positions are also used, and are called *fields.* You usually separate them by spaces, just as you did in the mini-assembler.

The first field is called the *label field.* In a true assembler you almost don't have to worry about actual addresses at all.

Since the assembler is going to keep track of actual addresses for us, the first field can be given a name to represent the address of that instruction, and the assembler will make sure that any references to this name are eventually translated into the proper address when the program is assembled.

There is no analogy in BASIC, since in Applesoft BASIC you can't say line 100 = PRINT MENU, and then later on use the command GOSUB MENU. In an assembler, on the other hand, the line numbers are only of incidental interest, and all JSRs and references to addresses can use a label. This makes it much easier for the programmer, and in itself is a good reason to use a real assembler instead of the mini-assembler, which has no provision for labels.

Let's call the first line of our program BEGIN. Type BEGIN now, and then press the TAB key once (don't press Return yet). The cursor will automatically jump to the second field position on the line. The second field is called the *opcode field,* and is where you put a given 65816 instruction, such as JSR. *APW* uses any number of space characters to separate fields. The TAB key moves the cursor to a given column so that the final listing will look orderly.

In the second field, type JSR and press the TAB key again. The cursor then moves to the third field, which is called the *operand field.* An operand is the information needed by an opcode. For example, a JSR by itself wouldn't tell the assembler where the JSR was destined. Type $FC58 here for the operand, and press the TAB key again. In the *APW* assembler, you have to use the dollar sign ($) in front of all hex numbers. If you don't, *APW* will treat it at a decimal number.

The fourth, and last, field is called the comment field. This is where you can add text to explain what a specific line does. It is customary (some other assemblers insist on it) to begin a comment with a semicolon. Type "; CLEAR SCREEN" and press Return.

If all went well, your program should look like this:

```
*****************************************
* 1st APW Program                       *
* By <your name>                        *
*****************************************

BEGIN   JSR   $FC58     ; CLEAR SCREEN
```

For the second line, we won't use a label. Actually, a label is always optional unless it is directly referenced somewhere else in the program, for example by a JSR somewhere. In that light, we didn't really need the label at the beginning of the first line of the program, but we'll leave it there since it doesn't hurt anything.

Since we don't need a label for the second line, press the TAB key once to move the cursor to the opcode field. Now type LDA, TAB, and #$C1. Then press the TAB key once more, type

```
; LETTER "A"
```

and press Return. For the next line, TAB to the second field and type in:

```
        STA   $5BC      ; SCREEN LOCATION
```

and press Return. Finally, finish the program with the label DONE, and an RTS. You don't need an operand for RTS, and you can omit the comment too. Program 5-1 shows how your program should now look.

Program 5-1. First Program

```
*****************************************
* 1st APW Program                       *
* By <your name>                        *
*****************************************

BEGIN   JSR   $FC58     ; CLEAR SCREEN
        LDA   #$C1      ; LETTER "A"
        STA   $5BC      ; SCREEN LOCATION
DONE    RTS
```

Assembler Directives

Before assembling, there's one more requirement. The *APW* assembler assumes, and rather insistently too, that everything you assemble is just a smaller part of some larger program. These pieces are called *code segments*, and every code segment must have a **START** and an **END** assembler command in it.

It also assumes that our program will be operating with the Accumulator in the long, or two-byte wide, mode of the 65816 microprocessor. Since that has not been covered yet, we'll need to add a line to tell it not to use the long Accumulator mode quite yet.

To add these new lines to the listing, first go to the end of the listing, TAB to the second field, and type END. Then use the up arrow to move to line 6, and insert these lines:

```
      LONGA OFF
MAIN  START
```

The new listing is shown in Program 5-2.

Program 5-2. First *APW* Program

```
****************************************
* 1st APW Program                      *
* By <your name>                       *
****************************************

        LONGA OFF

MAIN    START

BEGIN   JSR   $FC58      ; CLEAR SCREEN
        LDA   #$C1       ; LETTER "A"
        STA   $5BC       ; SCREEN LOCATION
DONE    RTS

        END
```

START, END, and LONGA are not true 65816 opcodes. Instead, they're instructions specifically for the assembler and are called assembler *directives*, because they direct the assembler to take a certain action. Most assemblers have quite a number of directives to make assembling programs easier.

START and END are special *APW* directives that mark out the beginning and end of a program segment. **LONGA OFF** is a directive that tells the assembler not to use the long mode for the LDA and STA instructions.

Assembling a Program

To assemble this program, you need to leave the full-screen editor. This is done by typing Control-Q. The screen will change to the editor file menu. Press S to save the source file to disk. Then press E to exit back to the *APW* shell.

The actual assembly is started by typing

```
ASSEMBLE +L +S APW.1.S
```

When you press Return, the disk will come on for a while, the text shown in Program 5-3 will appear on the screen.

Program 5-3. Assembly of First *APW* Program

```
0001 0000            *******************************************
0002 0000            * 1st APW Program                         *
0003 0000            * By <your name>                          *
0004 0000            *******************************************
0005 0000
0006 0000                   LONGA OFF
0007 0000
0008 0000            MAIN   START
0009 0000
0010 0000  20 58 FC  BEGIN  JSR   $FC58     ; CLEAR SCREEN
0011 0003  A9 C1            LDA   #$C1      ; LETTER "A"
0012 0005  8D BC 05         STA   $5BC      ; SCREEN LOCATION
0013 0008  60        DONE   RTS
0014 0009
0015 0009                   END

Symbols

000000  BEGIN    000008  DONE

15 source lines
0 macros expanded
0 lines generated
```

There are a number of things to notice here. First, *APW* has created a listing at the far left of each line number in your program, and the *relative* addresses where each instruction will ultimately be put in memory. The *APW* is different than the *Merlin* in that it doesn't use any absolute memory addresses until the very end of the program construction process, and sometimes it doesn't use them then.

You can see each line indicates a memory address, starting at 0000 followed by the actual machine language codes for each instruction of your program.

At the end of the listing is the *symbol table*. This prints a list of all the labels used in the program, such as BEGIN and DONE.

In the **ASSEMBLE** command, the +L and +S tell the assembler to print out the assembled listing to the screen and to add the symbol table at the end. If you don't wish to see these, just omit these parts of the command line.

To save the program to your disk, you need to tell the assembler what filename to use. To do this, type

```
ASSEMBLE APW.1.S KEEP=APW.1
```

KEEP is an *APW* directive for saving the output file.

After the assembly is complete, type CATALOG. On the disk you should see your source file, APW.1.S, and also the file APW.1.ROOT. This is an intermediate file created by the *APW* assembler, and is called an *object file* by Apple Computer in the *APW* environment. Contrary to the common usage of the term object file, this file is not directly executable program code. Instead it consists of the program plus information to be used when that segment is ultimately combined with other segments in the big program.

To convert the object file into something that can be used somewhere requires a few more steps.

The Linker

Another part of the *APW* shell is something called the Linker. This is the system that pulls all those pieces together when constructing a large program. Fortunately, there is a command that will both assemble the file and link our file into an almost-final file. To assemble and link your program, type

```
ASML APW.1.S KEEP=APW.1
```

ASML is the *APW* shell command to do both the assembly and the link of the source file.

After this assembly, CATALOG the disk again. Now, in addition to your source file and the intermediate APW.1.ROOT file, you should see the desired APW.1 file. You'll notice that its file type is EXE. This means that it is a file type executable within the *APW* shell. Unfortunately, our programs aren't quite yet sophisticated enough to survive outside of the normal Applesoft BASIC/ ProDOS 8 environment, so we'll need one more step to get what we need.

The file type you need is a binary type (BIN). To change the output file EXE into a binary file, you need to use the *APW* shell command **MAKEBIN**. To use this now, type

```
MAKEBIN APW.1 ORG=$300
```

ORG is another assembler directive used to tell the assembler where you want the program to run. In just a moment, we'll see how to include this in the assembly listing itself.

If you catalog the disk again, you'll see the file type of APW.1 has now changed to BIN.

To run the assembled file, you'll have to quit *APW* and go to Applesoft BASIC or to a program selector other than Apple's Program Launcher—one that can run Binary files. Applesoft BASIC is the recommended method for now.

Type QUIT to quit the *APW*.

When you're in Applesoft BASIC, you'll probably have to reset the prefix to your /PROGRAMS disk before you can run your program APW.1.

Assuming the prefix is correct, and that the /PROGRAMS disk is in a drive, you can now type either

```
BRUN APW.1
```

or

```
-APW.1
```

to run the program. You can also type

```
BLOAD APW.1
CALL 768
```

You'll recall that in using the MAKBIN command, you specified the starting address $300 (768 decimal) for the file. Using the ORG= statement in the MAKBIN command is one way to tell the assembler where you want the code to ultimately run. The other is to put the ORG directive in the program source listing itself. To do that, we'll need to go back to the *APW*. Type BYE in the immediate mode to quit BASIC back to a program launcher, and from there go back to the *APW*.

By the way, this long cycle time between the *APW* and Applesoft BASIC is the other disadvantage of using the *APW* at this stage in your learning. Eventually, you'll be able to write self-contained programs that can be run directly from the Program Launcher, or even from within the *APW* shell, but for now, changing back and forth is necessary.

More Assembler Directives: ORG, KEEP, and EQU

When the *APW* is back up and running, load your source file APW.1 by typing

```
EDIT APW.1.S
```

Before entering any new text, type Open Apple–E to put the editor in the insert mode. When it is, the words EDIT INSERT will be displayed in the status line at the bottom of the screen. Move the cursor down, using the down arrow, to line 5 (the blank line) and press Return. A new blank line should be inserted. When the editor is in the insert mode, pressing Return will insert a new blank line.

Press the TAB key once to go to the opcode field, and type ORG. Then press the TAB key, and type $300 and press Return twice.

Next press the TAB key, type KEEP, tab to the next field, and type APW.1 and then press Return. The listing should now look like Program 5-4.

Program 5-4. First *APW* Program with KEEP Directive

```
*******************************************
* 1st APW Program                         *
* By <your name>                          *
*******************************************

         ORG     $300

         KEEP    APW.1

         LONGA   OFF

MAIN     START

BEGIN    JSR     $FC58       ; CLEAR SCREEN
         LDA     #$C1        ; LETTER "A"
         STA     $5BC        ; SCREEN LOCATION
DONE     RTS

         END
```

Like ORG, **KEEP** is another assembler directive. It tells the assembler what name to use in creating the output files.

After you've added the new lines with ORG and KEEP, press Control-Q to go to the editor file menu, and save the new listing with the S command. Then assemble and link the source file with the command

```
ASML APW.1.S
```

You'll notice that this time you don't need to use the KEEP command. When the assembly is done, convert the EXE file APW.1 to a binary file by typing

```
MAKEBIN APW.1
```

Since the ORG directive was included in the source file, you don't need to use it here.

Try running this file from Applesoft BASIC to prove that it is equivalent to the first. You may also want to use the Monitor (CALL −151 from Applesoft BASIC) to look at the object file in memory.

More About Labels

Now go back to the *APW* again and load APW.1. The listing should look like Program 5-4.

Looking at the listing, you can see addresses like $FC58 and $5BC, and the code value for the letter *A*, which is $C1. As a program gets larger, and the listing longer, it can get confusing trying to remember a lot of different number values. To make programming more convenient, most assemblers allow you to give routines a name and they remember the address for you.

Start by putting the cursor on line 13, press Return once, and type the following:

```
HOME     EQU  $FC58
SCREEN   EQU  $5BC
```

Now move the cursor to the *end* of the address $FC58, and press the Delete key until it's completely erased. Now type HOME, but don't press Return; instead, use the down arrow to move down two lines, and do the same thing to replace the address $5BC with SCREEN. The Program is shown in Program 5-5.

Program 5-5. First *APW* Program with EQU

```
*******************************************
* 1st APW Program                         *
* By <your name>                          *
*******************************************

         KEEP   APW.1

         ORG    $300

         LONGA  OFF

MAIN     START

HOME     EQU    $FC58
SCREEN   EQU    $5BC

BEGIN    JSR    HOME     ; CLEAR SCREEN
         LDA    #"A"     ; LETTER "A"
         STA    SCREEN   ; SCREEN LOCATION
DONE     RTS

         END
```

Quit the editor with Control-Q, save the source file, and then assemble by typing

```
ASML +L +S APW.1.S
```

Since we've added the +L command, the listing will appear on the screen, and should look like Program 5-6.

The main items of interest here are the listing itself and the Local Symbols listing, although you may find the other information interesting.

You'll notice that this time the assembler translates the labels HOME and SCREEN into their assigned addresses. Labels are always associated with some value in the source listing.

Program 5-6. Assembly of First *APW* Program with EQU

```
0001 0000                *****************************************
0002 0000                * 1st APW Program                       *
0003 0000                * By <your name>                        *
0004 0000                *****************************************
0005 0000
0006 0000                        ORG     $300
0007 0000
0008 0000                        KEEP    APW.1
0009 0000
0010 0000                        LONGA   OFF
0011 0000
0012 0000                MAIN    START
0013 0000
0014 0000                HOME    EQU     $FC58
0015 0000                SCREEN  EQU     $5BC
0016 0000                LETTERA EQU     $C1
0017 0000
0018 0000  20 58 FC      BEGIN   JSR     HOME        ; CLEAR SCREEN
0019 0003  A9 41                 LDA     #"A"        ; LETTER "A"
0020 0005  8D BC 05              STA     SCREEN      ; SCREEN LOCATION
0021 0008  60            DONE    RTS
0022 0009
0023 0009                END

Local Symbols

000000 BEGIN     000008 DONE     00FC58 HOME 0000C1 LETTERA
0005BC SCREEN

23 source lines
0 macros expanded
0 lines generated
Link Editor V1.0 B3.2

Segment:

00000300 00000009 Code: MAIN

Global symbol table:

00000300 G 01 00 MAIN

Segment Information:

  Number  Type    Length       Org

     1    $00     $00000009    $00000300

There is 1 segment, for a length of $00000009 bytes.
```

Whenever the assembler encounters a label, either at the beginning of a line or following the EQU directive, it assigns a value (usually an address) to it. For EQU statements, it uses whatever value is on the line. If the label is at the beginning of the line, it uses its own internal address counter for where it is in the program.

For example, since BEGIN is the first statement in the program, the assembler gives BEGIN a relative value of $0. As it continues to assemble each line, it keeps track of where it is. By the time it gets to DONE, its address counter is at $8, and that's what it assigns to DONE. Thus, if some other part of the program wanted to do a JSR, for example, BEGIN or DONE, you could just use the line

```
        JSR  DONE
```

or

```
        JSR  BEGIN
```

In this program, such a JSR wouldn't make much sense—just as a GOSUB to the first or last line in a BASIC program wouldn't make sense. But, as your programs get larger, you'll want to go to subroutines within the program. In assembly language, you use the labels, not line numbers, to tell the JSR where you want it to go. The label MAIN is not included in the local symbol table, because it is not considered to be within your program by *APW*. It's listed in the Global Symbol table, and it has been given an address value of $300 there.

Labels as Constants

Labels can be used for more than addresses. We could also assign a label to the value for the letter *A* (Program 5-7).

There's nothing wrong with assigning a constant (as opposed to an address) with an EQU statement, it just takes up a little more room in your listing and the computer's memory. This technique is used when you want to use a number value throughout a listing, but want to keep your options open so you can change your mind later. For example, suppose you're testing a program that goes through a loop 200 times, and that the number 200 is used in many different places in the listing. During testing, it might be nice to just use the number 5, for a shorter loop, instead. Using the label

```
COUNT  EQU  5
```

makes it easy to change later, without having to search through the listing for all the number 5's on every line.

There's also another common error to avoid. Sometimes people define a constant like this:

```
COUNT   EQU  #$5
```

and then later try to do this:

```
        LDA   COUNT
```

They think that the pound sign is included in the label COUNT. It isn't. The assembler evaluates each operand as a numeric expression, and then it stores the *result* as a the number value, *not* the text of the line that generated the result. The instruction is assembled as though the line read

```
        LDA   $5
```

When the program runs, the accumulator is loaded with the *contents of location $5,* not the actual value 5. Because there is no error generated during the assembly, and because the value loaded into the accumulator can be almost anything (and usually is), this kind of mistake can be very difficult to track down.

Therefore, be sure to remember to always put the pound sign in front of any labels that you want used as an absolute value.

```
COUNT   EQU  $5
        LDA  #COUNT
```

Program 5-7. Using EQU to Define a Character

```
*******************************************
* 1st APW Program                         *
* By <your name>                          *
*******************************************

          ORG      $300

          KEEP     APW.1

          LONGA    OFF

MAIN      START

HOME      EQU      $FC58
SCREEN    EQU      $5BC
LETTERA   EQU      $C1

BEGIN     JSR      HOME        ; CLEAR SCREEN
          LDA      #LETTERA    ; LETTER "A"
          STA      SCREEN      ; SCREEN LOCATION
DONE      RTS

          END
```

Long Addresses in *APW*

In the *APW* assembler, the assembler automatically decides which form, long or short, of LDA and STA to use, depending on operand. If the address evaluates to $FFFF or less, the short form is used. If the address evaluates to three or more bytes ($01/0000 or greater), the long address form is used. If you know your address will evaluate to only two bytes, and you still want to force the long addressing mode, you can precede the label with a greater-than sign (>).

Program 5-8 is an assembly program segment that illustrates some of the different instructions possible.

Program 5-8. *APW* Long Addressing Example

```
0001 0000                 ****************************************
0002 0000                 *   LONG ADDRESSING EXAMPLE            *
0003 0000                 *          APW ASSEMBLER               *
0004 0000                 ****************************************
0005 0000
0006 0000                 MAIN    START
0007 0000
0008 0000                 LABEL1  EQU     $050300     ; $05/0300
0009 0000                 LABEL2  EQU     $061A00     ; $06/1A00
0010 0000                 LABEL3  EQU     $300        ; $00/0300
0011 0000
0012 0000  AF 00 03 05            LDA     LABEL1
0013 0004  8F 00 1A 06            STA     LABEL2
0014 0008
0015 0008  AF 00 03 00            LDA     >LABEL3
0016 000C  8F 00 03 00            STA     >LABEL3
0017 0010
0018 0010  AD 00 03               LDA     LABEL3
0019 0013  8D 00 03               STA     LABEL3
0020 0016
0021 0016  22 00 1A 06            JSL     LABEL2
0022 001A
0023 001A                         END
```

In the first case (lines 12, 13), LABEL1 and LABEL2 both evaluate to three bytes, so the long address mode of LDA and STA are used. In the second case (lines 15, 16), LABEL3 only evaluates to two bytes. $0300. The greater-than symbol is used to force the assembler to use the long address form. Without the greater-than sign, the assembler would use the short address form, as shown on lines 18, 19. Line 21 shows the assembly of the JSL instruction.

APW in Review

If you've worked through the examples in this chapter, you should be able to enter, edit, assemble, and save both a source listing and the object file using the *APW* assembler. To learn more about editing, such as how to cut, copy and paste sections, or how to use search and replace, you should read the manual that came with *APW*.

You should also now understand how to use labels in a source program to represent a given number value or address, how to use ORG and EQU to control the values that labels are assigned, and where the program will load into memory from disk.

Chapter 6

Loops and Counters

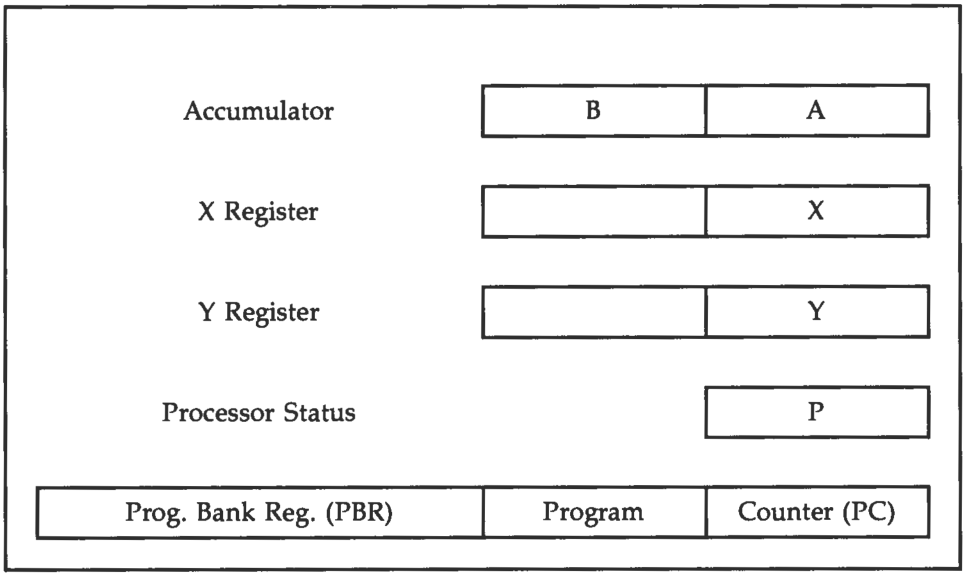
Chapter 6

Loops and Counters

In BASIC, the FOR-NEXT loop is an important part of many programs; this is also true in assembly language programming. The only difference is how the loop-counter combination is actually carried out.

In BASIC, the testing of counters is done either by IF-THEN statements or automatically in the NEXT statement of a FOR-NEXT loop. In assembly language, the testing is done by examining *flags* in the *Processor Status Register* (Figure 6-1). These flags indicate the results of the last mathematical operation of the 65816; general zero/nonzero conditions of numbers loaded into the X, Y and Accumulator registers; and other handy things within your program.

Figure 6-1. 65816 Microprocessor Model



The Processor Status Register, abbreviated *P* in the 65816 model, is the fourth register of the 65816, one not previously mentioned. Before going on with loops and counters, it's necessary to briefly discuss the Status Register and binary numbers.

Different from the other three registers (the Accumulator and the X and Y registers) the Status Register only holds a single byte. You'll recall that each byte in the Apple can have a value from 0 to 255 ($00 to $FF).

As it happens, there are many ways of looking at and interpreting numbers. One common way of looking at numbers is to consider only size. When we notice that 255 is larger than 128, we gain a very simple bit of information—we learn whether a number is either less than, equal to, or greater than another number.

A second way of looking at numbers is to use the digits that make up the number as a carrier of information. For example, street addresses generally increment by 100 for each city block, regardless how many houses are actually on the street. The address 9105 is usually one block further than 9005. The leading two digits tell you how many blocks away from the first street the address is.

Binary Numbers

In the *binary* number system, you're limited to counting by groups of 2. However, this system allows you to see more information in a number. This in turn can make it that much more useful for an assembly language program.

We have already seen how a single byte can be represented either as 0 to 255 or $00 to $FF. In the binary system, the same byte can have the range of 00000000 to 11111111. For instance, 133 (base ten) was represented as $85 (hexadecimal). In binary it has the appearance of 10000101. Each of the eight positions in a binary number are called *bits* (a word created from the term BInary digiTS). There are eight bits in a byte. In this case, each 1 or 0 can represent the presence or absence of a given condition. Thus, eight distinct pieces of information are conveyed, as well as all the various combinations possible.

Before you run shrieking from the room, remember that this is all done to make things easier (really), not harder. Besides, learning base sixteen (hex) wasn't that bad a few chapters back, was it? So, let's take a moment to see what these bits and bytes are all about.

The Apple is an electronic device and, actually, in many ways, a simple one at that. In most parts of its circuitry, the flow of electricity is either off or on. That's it. No in-between. Having two possible conditions is perfect for base two.

The idea of a number base has to do with how many symbols, or units, you use for counting. We normally use 10. There are a total of 10 possible symbols to write in a single position before we have to start doubling up and using two positions to represent a number. You'll recall that in hex, by using 0 through 9 and A through F we had 16 possibilities; thus we were in base 16. With the on/off nature of the Apple, we're limited to 2 possibilities: 0 or 1.

How high can we count with just two symbols in one position? Not very. We start at 0, then go to 1, and that's it—we're out of symbols. Then we have to add another position. The next number, therefore, is 10. As before, remember that, in this case, 10 represents what we usually call two. 100 would represent the quantity 4 in base ten.

By using eight positions, we can go up to 11111111, which just happens to be 255. This is the same maximum value as our bytes. And, if the truth be known, it's not just coincidence—the value 255 is a result of the computer being based on the binary system of numbering. We use the numbers 0 through 255 because we are using eight bits to make up each byte. Whether each bit is 0 or 1 depends on whether the part of the electrical circuit that is responsible for that bit is off or on.

Counting in base 2:

Binary	**Hex**	**Decimal**
00000000	$00	000
00000001	$01	001
00000010	$02	002
00000011	$03	003
00000100	$04	004
00000101	$05	005
00000110	$06	006
00000111	$07	007
00001000	$08	008
00001001	$09	009
00001010	$0A	010
00001011	$0B	011
00001100	$0C	012
00001101	$0D	013
00001110	$0E	014
00001111	$0F	015
00010000	$10	016
00010001	$11	017
00010010	$12	018
00010011	$13	019
. . .		
. . .		
. . .		
11111000	$F8	248
11111001	$F9	249

Binary	Hex	Decimal
11111010	$FA	250
11111011	$FB	251
11111100	$FC	252
11111101	$FD	253
11111110	$FE	254
11111111	$FF	255

Although binary numbers may seem overwhelming in the sheer visual size of each number, it's fairly unlikely you'll ever have to convert a binary number to decimal, or even to hexadecimal. It's discussed here mainly so that you'll have seen the underlying principles of how number values in the computer are created, and why the terms *binary* and *bits* show up once in a while.

You might notice, however, that there is a distinct correlation between the binary number patterns and the hex number patterns, whereas there is no apparent visual relationship between binary and decimal. For example, in the hex column, the number changes to $10 at the same point that the binary number changes from 00001111 to 00010000. In fact, the very observant will notice that the two digits in the hex number are made up from the upper and lower four bits (called a *nibble*) of the binary number. If you can count from $0 to $F (0 to 15 decimal) in the binary system, you can convert any binary number you see to its hexadecimal equivalent.

For example:

```
10011101 (binary) =
1001              = 9  = $90
    1101          = 13 = $0D
------------------------------
10011101               = $9D
```

The Status Register

As was mentioned above, the bits that make up a number can be used as *flags* or indicators for eight independent conditions. By individually setting or clearing the eight bits in a byte, the computer can store the status of eight different things in just one byte. That's the idea behind the Status Register.

Here is a representation of a single byte, made up of eight bits. In particular, the byte shown in Figure 6-2 is the Status Register of the 65816. The important difference between this register and the others is that it's not used to store number values. Instead, it indicates various conditions.

Figure 6-2. The Status Register

7	6	5	4	3	2	1	0
N	V	M	B X	D	I	Z	E C
Sign	Overflow	Accumulator Size Select	Break or X/Y Register Size Select	Decimal	Interrupt	Zero	Carry or Emulation

The bits of the Status Register are numbered from right to left, 0 to 7. Each bit in this register indicates the results of different operations, and is called a *flag.* It's by using this register that we can create counters and loops in our programs. Bit 1 is the *zero flag.* In terms of commands discussed so far, the zero flag is affected by an LDA, LDX, or LDY.

If the value loaded into the Accumulator, X, or Y register were $00, the flag would be set to 1. If it were a nonzero number, the flag would be 0. Seemingly backward perhaps, but remember each flag is set to show the presence or absence of a given condition; in this case the presence of 0. The setting or clearing of each Status Register flag is done automatically by the 65816 after each program step, indicating the results of any particular operation.

Incrementing and Decrementing

To create a counter and then a loop, we'll use the Status Register to tell when a given register or memory location reaches zero. We will also need a way of changing the value of a counter in a regular fashion. In the 65816, this is done by *incrementing* or *decrementing* (adding or subtracting 1 each time) a memory location, or the X or Y register. This is done with one of the following commands:

	Accumulator	**X Register**	**Y Register**	**Memory Location**
Increment: (Add 1)	INC	INX	INY	INC
Decrement: (Subtract 1)	DEC	DEX	DEY	DEC

This table shows the commands used to increment or decrement a particular register or memory location.

The usual syntax for using these commands is an assembly listing as illustrated by the following sample lines:

```
INX            ; Add 1 to the X register
INY            ; Add 1 to the Y register
INC   $0600    ; Add 1 to a memory location
DEX            ; Subtr. 1 from the X register
DEY            ; Subtr. 1 from the Y register
DEC   $AA53    ; Subtr. 1 from a memory location
```

For the X and Y register operations, the command stands alone, with no need of an operand. In the case of **INC** and **DEC,** the memory locations to be operated on are given.

In the *Merlin* assembler, INC and DEC are used for both the Accumulator and a memory location. For example,

```
INC            ; Add 1 to accumulator
INC   MEM      ; Add 1 to location mem
```

In the first line, INC alone tells the assembler to increment just the Accumulator. By adding the label MEM, it knows it needs to increment a memory location.

Some assemblers use the opcodes **INA** and **DEA** for incrementing and decrementing the Accumulator, others, like the *APW,* require you to put the letter *A* in the operand field, like this:

```
INC   A        ; ADD 1 TO ACCUMULATOR
DEC   A        ; SUBTRACT 1 FROM ACCUMULATOR
```

The increment/decrement commands affect the zero flag, depending on whether the result of the operation is 0 or not.

One thing to mention here is the *wraparound* nature of all the operations. To understand this, examine the following chart.

Original Value	Result of Increment	Result of Decrement	Z-Flag Set	Z-Flag Contents
$05	$06	$04	no;no	0;0
$0F	$10	$0E	no;no	0;0
$01	$02	$00	no;yes	0;1
$FF	$00	$FE	yes;no	1;0
$00	$01	$FF	no;no	0;0

The effects of incrementing and decrementing different one-byte values are shown, along with the effects on the zero flag after the operation. The first case is simple: 5 + 1 = 6; 5 − 1 = 4. In both cases, the result is a nonzero number, so the zero flag is not set. For $0F, the same holds true. Remember that, in hex, the number after $0F is $10. In the case of $01, incrementing produces $02. When we decrement $01, the result is $00; the zero flag is set.

Here's where it gets interesting. When the starting value is $FF, adding 1 would normally give $100. However, since a single byte only has a range of $00 to $FF, the new 1 is ignored, and the value becomes $00. This sets the zero flag. In the case of decrementing $FF, $FF − 1 = $FE, so the zero flag is not set.

If we start with $00, although incrementing produces the expected $01, decrementing wraps around in the reverse of the previous case, giving $FF. Both results are nonzero, so Z (short for the Z-flag), is clear—that is, it's not set—for both operations.

Looping with BNE

The only thing missing now to enable you to create a loop is a way of testing the Z flag and then being able to get back to the top of the loop for another pass. In BASIC, a simple loop might look like this:

```
10 HOME
20 X = 255
30 PRINT X
40 X = X - 1
50 IF X < > 0 THEN GOTO 30
60 END
```

In this program, the counter X is set to 255. The value is printed and then decremented, and the process repeated until the counter reaches zero. We can make the loop execute any number of times by properly setting the initial value of X.

In assembly language, the test and the GOTO are done with a *branch instruction*. In this case, the one we'll use is **BNE**, which stands for **Branch Not Equal** (to zero). This is a *conditional instruction*, and will be executed only when a register is loaded with a nonzero number. This can happen either directly with something like LDA #$01, or as the result of an arithmetic operation, such as INX. Program 6-1 is the assembly language equivalent of the BASIC listing.

This listing shows both the source lines, and the object code output on the left, as it would be printed during an assembly.

The program can be tested by going to Applesoft BASIC, BLOADing it (it should load automatically at $300), and then doing a CALL 768.

Note: If you're using the *APW* assembler, be sure to add the START, END, and KEEP directives. Review Chapter 5 if you are unsure as to how to create a binary file using *APW*.

The program starts with the usual screen clear, and then loads the X register with a starting value of $FF. The loop starts by storing the contents of the X register at $5BC; this will make the loop's action visible as a character on the screen for each pass through the loop. Lines 10, 15, and 16 introduce a new monitor routine, **WAIT** = $FCA8, which is a delay function based on the contents of the Accumulator. This is required because, without it, the loop would execute so quickly you couldn't see it in action. Experiment with different values in the Accumulator on line 16 to see what effect they have; and try eliminating the JSR WAIT altogether for maximum speed.

On line 17, DEX subtracts one from the current value of the X register. The BNE will then continue the loop back up to LOOP until the X register reaches $00, at which point the test will fail, and program execution will fall through to the RTS at the end of the program.

Program 6-1. Loop Demo Routine 1

```
                           1 ******************************************
                           2 *       LOOP DEMO ROUTINE #1             *
                           3 *       MERLIN 8/16 ASSEMBLER            *
                           4 ******************************************
                           5
                           6           ORG  $300
                           7
            =FC58          8 HOME      EQU  $FC58
            =05BC          9 SCREEN    EQU  $05BC
            =FCA8         10 WAIT      EQU  $FCA8      ; MONITOR WAIT ROUTINE
                          11
000300: 20  58  FC        12 BEGIN     JSR  HOME       ; CLEAR VIDEO SCREEN
000303: A2  FF            13           LDX  #$FF       ; X = 255
000305: 8E  BC  05        14 LOOP      STX  SCREEN     ; PUT CHAR ON SCREEN
000308: A9  FF            15           LDA  #$FF       ; ACC = 255
00030A: 20  A8  FC        16           JSR  WAIT       ; MAXIMUM WAIT TIME
00030D: CA                17           DEX             ; X = X - 1
00030E: D0  F5  =0305     18           BNE  LOOP       ; BRANCH IF X <> 0
000310: 60                19 DONE      RTS             ; THAT'S ALL FOLKS!

--End Merlin-16 assembly, 17 bytes, Errors: 0
```

Looping with BEQ

The complement of the BNE instruction is **BEQ**, **Branch EQual** (to zero). It operates in just the opposite fashion as BNE, that is, branching only when the register or memory location reaches a value of zero.

For example, consider this BASIC listing:

```
10 HOME
20 X=255
```

```
30 PRINT X
40 X=X-1
50 IF X=0 THEN 70
60 GOTO 30
70 END
```

In this case, the loop continues as long as X is not equal to zero. If it is, the branch instruction is carried out and the program ends. The equivalent in assembly language is shown in Program 6-2.

Program 6-2. Loop Demo Routine 2

```
                         1 ****************************************
                         2 *         LOOP PROGRAM #2              *
                         3 *      MERLIN 8/16 ASSEMBLER           *
                         4 ****************************************
                         5
                         6         ORG  $300
                         7
          =FC58          8 HOME    EQU  $FC58
          =05BC          9 SCREEN  EQU  $05BC
          =FCA8         10 WAIT    EQU  $FCA8
                        11
000300: 20  58  FC      12 BEGIN   JSR  HOME       ; CLEAR SCREEN
000303: A2  FF          13         LDX  #$FF       ; START COUNTER AT 255
000305: 8E  BC 05       14 LOOP    STX  SCREEN     ; PUT CHAR ON SCREEN
000308: A9  80          15         LDA  #$80       ; TIME DELAY VALUE
00030A: 20  A8  FC      16         JSR  WAIT
00030D: CA              17         DEX             ; X = X - 1
00030E: F0  03  =0313   18         BEQ  DONE       ; DONE IF X = 0
000310: 4C  05  03      19         JMP  LOOP       ; NEXT CYCLE
000313: 60              20 DONE    RTS             ; ALL DONE!

--End Merlin-16 assembly, 20 bytes, Errors: 0
```

Notice that this program also uses a new command, **JMP** (Jump). JMP is like a GOTO in BASIC. It doesn't expect an eventual RTS. The JMP on line 19 will cause program execution to jump to the routine starting at LOOP each time. Only when the X-register reaches zero does the BEQ take effect and cause the program to skip to the RTS at end. Here is the way this would appear when put into memory, and then listed with the L command from the Monitor:

```
 *300L
1=m  1=x  1=LCbank (0/1)
0/0300:    20  58  FC     JSR   FC58
```

```
00/0303:  A2 FF      LDX  #FF
00/0305:  8E BC 05   STX  05BC
00/0308:  A9 80      LDA  #80
00/030A:  20 A8 FC   JSR  FCA8
00/030D:  CA         DEX
00/030E:  F0 03      BEQ  0313 {+03}
00/0310:  4C 05 03   JMP  0305
00/0313:  60         RTS
```

The assembler automatically translates the positions of LOOP and END into the appropriate addresses to be used by the BEQ and JMP when it assembles the code.

Remember that to the left are the addresses and the values for each opcode and its accompanying operand. The more understandable translation to the right is Apple's interpretation of this data.

Notice that the JMP's and JSR's are immediately followed by the address (reversed) that they're to jump to, such as in the first JSR at $300.

However, branch instructions are handled a differently. As opposed to a JSR or JMP that go to an *absolute* memory location, a branch goes to a *relative* memory address. That is to say, it goes to an address relative to where the branch instruction itself is located. At $30E, the $F0 is the opcode for BEQ. The $03 that follows is an offset that tells the 65816 to branch *down* through the code three bytes from the address of the *next* instruction that follows the branch itself (at $310). Adding $03 to $310 gives us $313, the address of the desired RTS.

Branching in the reverse direction (up through the listing) is also possible and is shown by operands greater than $80. There is not much need of going into great detail about the actual calculations used, since your assembler will determine the proper values for you when assembling code, and Apple's disassembler will give the destination address when reading other code.

As the X register is incremented in this program, we'll stuff the value into the screen location so we can see something on the screen as the counter advances.

There are also two other branch instructions, **BRA (BRanch Always)**, and **BRL (BRanch Long)**, that you can use instead of a jump instruction. BRA can only be used when you don't have to branch more than 127 bytes forward or backward. BRL will branch to any address in the 64K address space. The main advantage of BRA is for creating programs that are *position independent*.

When a program is position independent, it doesn't matter where it is loaded into memory. It will run equally well anywhere. For example, if you loaded Program 6-2 at location $8000, and tried to run it, what would happen when it got to the JMP LOOP on line 19? Remember, the assembler assembled this line as JMP $305. If the program were loaded at $8000, there wouldn't be anything related to this program at $305 when the JMP was executed. This would probably result in a program crash, with one of those unpleasant BRK messages.

An alternative is to use the BRA instruction as shown in Program 6-3.

Program 6-3. Loop Demo Program 2A

```
                         1 *****************************************
                         2 *          LOOP PROGRAM #2A            *
                         3 *       MERLIN 8/16 ASSEMBLER          *
                         4 *****************************************
                         5
                         6         ORG  $300
                         7
              =FC58      8 HOME    EQU  $FC58
              =05BC      9 SCREEN  EQU  $05BC
              =FCA8     10 WAIT    EQU  $FCA8
                        11
000300: 20  58  FC      12 BEGIN   JSR  HOME       ; CLEAR SCREEN
000303: A2  FF          13         LDX  #$FF       ; START COUNTER AT 255
000305: 8E  BC  05      14 LOOP    STX  SCREEN     ; PUT CHAR ON SCREEN
000308: A9  80          15         LDA  #$80       ; TIME DELAY VALUE
00030A: 20  A8  FC      16         JSR  WAIT
00030D: CA              17         DEX             ; X = X - 1
00030E: F0  02  =0312   18         BEQ  DONE       ; DONE IF X = 0
000310: 80  F3  =0305   19         BRA  LOOP       ; NEXT CYCLE
000312: 60              20 DONE    RTS             ; ALL DONE!

--End Merlin-16 assembly, 19 bytes, Errors: 0
```

This is also a good time to stress the importance of working through each of these examples on your own, step by step, to make sure that you understand exactly what happens at each instruction, and how it relates to the rest of the program.

Incrementing Two or More Bytes

The discussion of the increment and decrement commands has so far been limited to the assumption that a single byte is involved. Suppose, however, that you wanted to store the value for an address, which requires at least two bytes, not counting the bank byte. By using the BEQ instruction you can create a procedure, or *code segment*, that will increment or decrement a pair of bytes.

Code segment refers to a procedure, or to part of a procedure, that can be embedded in your own programs to accomplish a given task. Although Program 6-4 has a title and an equate statement at the beginning, this program would never be used by itself, but rather would be used as a part of a larger program.

Program 6-4. Two-Byte Increment Example

```

                              *    TWO-BYTE INCREMENT EXAMPLE       *
                              *          MERLIN ASSEMBLER           *


          =0006               PTR     EQU  $06        ; $06,07

008000: E6 06                 INCR    INC  PTR        ; ADD 1 TO LOW BYTE
008002: D0 02       =8006             BNE  NEXT       ; SKIP IF NOT = $00
008004: E6 07                         INC  PTR+1      ; ADD 1 TO HIGH BYTE

008006: EA                    NEXT    NOP             ; YOUR PROGRAM
CONTINUES HERE...


-- End Merlin-16 assembly, 7 bytes, Errors: 0
```

In Program 6-4, a two-byte pair labeled **PTR (PoinTeR)** is defined. We'll assume that the two bytes contain the value for an address, with the low byte for the address in location $06, PTR. The high byte is stored in location $07. We could have used labels like PTRL and PTRH, for Pointer Low and Pointer High for locations $06 and $07. But a better, more commonly used system is to use the labels PTR and PTR+1. Most assemblers can handle mathematical expressions in the operand field, so PTR+1 will be properly calculated as $06+1 = $07.

The program works by first incrementing the low byte, PTR. If the result of the increment is not zero, no wraparound has occurred, and the flow of control goes to NEXT, where the body of your own program is found. If PTR is equal to $00, the BNE fails and PTR+1, the high byte is incremented.

The instruction at NEXT introduces a new, simple 65816 instruction, **NOP**. NOP stands for **No Operation**, and does just that—nothing. NOP is used in this example program so the assembly will be complete even though we don't know what might be placed at the NEXT statement.

NOP actually generates a byte of code, $EA. This can be useful when you want to deactivate a part of a program you're debugging, without having to do a new assembly. By putting NOPs in memory where you want to erase part of your program, the program will still execute and will ignore the NOPs when it gets to that part of the program. If you over-write part of your program with zeros instead, a BRK would occur when the first 0 was encountered.

If, at some point, you wish to just create a label in a program you're writing, this can also be done, although the actual technique varies depending on what assembler you are using. In the *Merlin* assembler, you can just type a label and leave the opcode and operand fields blank. A comment is allowed. For example:

```
LABEL                   ; BEGINNING OF A SECTION
        LDA     PTR
        ETC...
```

In the *APW* assembler, a specific *APW* directive, **ANOP (Assembler NOP**, not to be confused with the other NOP) must be used:

```
LABEL   ANOP            ; BEGINNING OF A SECTION
        LDA     PTR
        ETC...
```

You might ask why you would want to do this. One of the most common reasons is as simple as convenience in editing. Suppose you are working on a part of your program, and it looks like this:

```
LABEL   STA     SCRN    ; STORE CHARACTER ON SCREEN.
```

Suddenly realize you forgot to start the segment with LDA #$C1, or some other important instruction. Normally, you would have to erase the text LABEL from the beginning of the current line, and then insert a new line above it with the new LABEL in it, like this:

```
LABEL   LDA     #$C1
        STA     SCRN
```

By making the beginning of the routine a label with no opcode, you can edit the lines below it at any time, adding or deleting instructions or data as you wish without having to retype the first line of the routine:

```
LABEL                   ; BEGINNING OF SECTION
        LDA     #$C1
        STA     SCRN
```

In the *APW*, the lines look like this:

```
LABEL   ANOP            ; BEGINNING OF A SECTION
        LDA     #$C1
        STA     SCRN
```

A label without an operand is also used at the beginning of a data storage section for similar reasons, namely easy adding and deleting of new entries. Data storage in an assembly source listing is discussed in Chapter 9.

Going back to the idea of incrementing a two-byte pointer, it has been mentioned before that the 65816 has a two-byte mode where all register (A, X, and Y) operations can be made to take place two bytes at a time. In such a mode, any of the increment or decrement commands will correctly operate on *both* bytes in one instruction. However, this does not eliminate the need for the multiple byte techniques discussed here, because in such programs you'll most likely be using *four* bytes (a long address) to store both the bank byte and address bytes of the address. Thus you'll still need a similar multibyte increment or decrement on occasion. When operating in the two-byte mode, the following program segment would increment four bytes properly:

```
PTR     EQU     $06         ; $06,07,08,09

INCR    INC     PTR         ; INCREMENT $06 AND $07
        BNE     NEXT        ; IF NOT = $0000
        INC     PTR+2       ; $08,09
NEXT    NOP                 ; YOUR PROGRAM HERE...
```

The 65816 knows whether to increment one or two bytes with the INC command, depending on the condition of a special flag bit, as is described in Chapter 7.

The pair of bytes that make up a two-byte address or half of a four-byte address are called *data words.* A word, in computer terminology, is the width in bytes or bits of data chunks as handled by the microprocessor. The 65816 has a bit of a split personality in this regard: It can use either 8-bit or 16-bit words. When dealing with a long address, the byte pairs are sometimes referred to as the *low-order word* and the *high-order word,* analogous to the low- and high-order bytes of a two-byte address. For the address $0006/1A00, $0006 is the high-order word, $1A00 is the low-order word.

There are other computers, like the Apple Macintosh, that can deal with 32 bits (4 bytes) at a time. Generally speaking, the greater the data width, the more powerful the machine—although this is a simplification that ignores clock speed (how fast each instruction is executed), the total number of instructions available to the microprocessor, overall system design, and other factors that contribute to the final net performance of a computer.

Decrementing Two or More Bytes

Decrementing a two-byte pointer is slightly different, only because we are looking for a transition from $00 to $FF (or $0000 to $FFFF). This is done using a compare instruction as part of the segment (see Program 6-5).

Program 6-5. Two-Byte Decrement Example

```
                           ************************************************
                           *    TWO-BYTE DECREMENT EXAMPLE                *
                           *           MERLIN ASSEMBLER                   *
                           ************************************************

             =0006         PTR      EQU  $06         ; $06,07

008000: C6 06              INCR     DEC  PTR         ; SUBTRACT FROM LOW BYTE
008002: A5 06                       LDA  PTR         ; LOAD FOR CMP
008004: C9 FF                       CMP  #$FF        ; WRAPAROUND?
008006: D0 02  =800A                BNE  NEXT        ; NOPE.
008008: C6 07                       DEC  PTR+1       ;SUBTR. 1 FROM HIGH BYTE

00800A: EA                 NEXT     NOP              ; YOUR PROGRAM CONTINUES HERE...

--End Merlin-16 assembly, 11 bytes, Errors: 0
```

We can't use this code segment:

```
DEC     PTR         ; SUBTRACT 1 FROM PTR
BNE     NEXT
DEC     PTR+1       ; SUBTRACT 1 FROM PTR+1
```

because PTR will reach 0 one cycle *before* we want to decrement PTR+1. Remember, the count-down will look like something like this:

Total Address:	PTR	PTR+1
$502	$02	$05
$501	$01	$05
$500	$00	$05
$4FF	$FF	$04

When PTR reaches $00, PTR+1 doesn't change until the *next* cycle of our code segment. Therefore, the CMP #$FF is required to see when the DEC PTR has wrapped around to $FF, signifying it's time to decrement PTR+1.

In the two-byte mode, the program segment would be similar:

```
PTR     EQU  $06        ; $06,07,08,09
DECR    DEC  PTR        ; DECREMENT $06 AND $07
        LDA  PTR
        CMP  $FFFF
        BNE  NEXT       ; IF NOT = $FFFF
        DEC  PTR+2      ; DECREMENT $08,09
NEXT    NOP             ; YOUR PROGRAM HERE...
```

Long Address Jump Instruction: JML

Just as the JSR instruction had a long addressing counterpart in JSL, so the jump instruction has its counterpart, **JML (JuMp Long)**. Like the short form jump instruction, JML is a one-way trip (use JSL for a returning subroutine). The only difference between JMP and JML is that JML jumps to an absolute three-byte address in a given bank. JMP is limited to the current bank that the program is executing in.

In a program, JML would assemble like this (the address $06/1A00 is arbitrary):

```
              =0 61A00   LABEL    EQU  $061A00    ; $06/1A00

008000: 5C 00 1A 06                JML  LABEL


--End Merlin-16 assembly, 4 bytes, Errors: 0
```

Using the Monitor COUT Routine

The loop shown earlier lets you print text and numbers in a very limited way—wouldn't it be nice to have a general text printing routine available? Such a routine already exists within the Monitor routines; it's labeled **COUT** (pronounced C-OUT, for Character Output), and is located at $FDED. COUT is used by loading the accumulator with the value for the character you wish to print, and then calling the routine.

The neat part about using COUT is that you don't have to write your own routines to handle screen control (what the line length is, when to scroll, and so forth). Better still, COUT can also be used to send characters to a disk file or printer, but more on that later.

We're not done yet, though. We would like to have the counter value in the accumulator so we can print it via COUT, but unfortunately many built-in routines like COUT change the contents of the accumulator and other registers when they're used. Thus, although the counter might be at 5 when we called COUT, the accumulator might hold 37 when control returned to our program.

To solve this, we'll have to change the program. This time we'll use a memory location as the counter, and then load the Accumulator on each pass through to print out a visible sign of the counter's activity. Good locations to use for experimenting are locations $06 through $09. These are not used by Applesoft BASIC, DOS, or the Monitor. It's important to avoid conflicts with Apple's normal activities while running your own programs.

We'll also go back to using BNE, since this requires fewer lines of source code, and is a better programming approach. In addition, a few blank lines have been added to the listing to break up the logical groups of instructions for easier reading (Program 6-6).

Program 6-6. Loop Demo Program 2B

```
                         ****************************************
                         *        LOOP PROGRAM #2B              *
                         *     MERLIN 8/16 ASSEMBLER            *
                         ****************************************

                                 ORG  $300

          =0006          CTR     EQU  $06
          =FC58          HOME    EQU  $FC58
          =FDED          COUT    EQU  $FDED

000300: 20 58 FC         BEGIN   JSR  HOME        ; CLEAR SCREEN
000303: A9 FF                    LDA  #$FF        ; START COUNTER TO 255
000305: 85 06                    STA  CTR         ; STORE IN 'CTR'

000307: A5 06            LOOP    LDA  CTR         ; GET CURRENT VALUE
000309: 20 ED FD                 JSR  COUT        ; PRINT CHARACTER
00030C: C6 06                    DEC  CTR         ; CTR = CTR - 1
00030E: D0 F7  =0307             BNE  LOOP        ; DONE IF CTR = 0

000310: 60               DONE    RTS              ; ALL DONE!

--End Merlin-16 assembly, 17 bytes, Errors: 0
```

A CALL to this routine via our usual 300G from the Monitor, or a CALL 768 from BASIC, should clear the screen and then print all the available characters on your Apple—in all three display modes (normal, flashing, and inverse). We no longer need the WAIT routine because the characters will be printed left to right, as opposed to all in the same spot on the screen. The beep you hear is from when the Control-G (Bell) is printed to the screen via COUT. The invisible control characters account for the blank region between the two main segments of output characters.

The alphabet is backward because we started at the highest value and worked our way down. The BNE test works because the loop will continue until CTR reaches 0.

You'll remember, though, that when a byte is *incremented* by 1 from $FF, the result also wraps around back to $00. This will produce an action also testable by a BNE. Using this wraparound effect of the increment command, we can rewrite the program to be a little more conventional, counting in normal alphabetical order (Program 6-7).

Program 6-7. Loop Demo Program 3

```
                        ****************************************
                        *         LOOP PROGRAM #3              *
                        *     MERLIN 8/16 ASSEMBLER            *
                        ****************************************

                                 ORG  $300

            =0006       CTR      EQU  $06
            =FC58       HOME     EQU  $FC58
            =FDED       COUT     EQU  $FDED

000300: 20 58 FC        START    JSR  HOME       ; CLEAR SCREEN
000303: A9 00                    LDA  #$00       ; START COUNTER AT '0'
000305: 85 06                    STA  CTR        ; STORE VALUE

000307: A5 06           LOOP     LDA  CTR        ; GET CURRENT VALUE
000309: 20 ED FD                 JSR  COUT       ; PRINT CHARACTER
00030C: E6 06                    INC  CTR        ; CTR = CTR + 1
00030E: D0 F7  =0307             BNE  LOOP       ; GO AGAIN IF NOT

000310: 60              DONE     RTS             ; ALL DONE!

--End Merlin-16 assembly, 17 bytes, Errors: 0
```

A CALL to this routine should now print out the characters in a more familiar manner.

The ASCII System

The examples used so far have each put characters on the screen by using a number code to represent a given character. This coding system is based on the ASCII character set. ASCII (American Standard Code for Information Interchange) is a coding scheme for transmitting text. It's also used in the Apple for encoding text in memory, screen display, disk files, printer output, and many other areas. The chart in Appendix E gives all the characters and their ASCII values.

You've probably already used the ASCII system if you've ever used the ASC(or CHR$(commands in Applesoft BASIC. A program line that says

```
10 D$ = CHR$(4)
```

assigns the string variable D$ to the ASCII character number 4, a Control-D. Likewise, the line

```
50 PRINT CHR$(9);"80N"
```

tells the program to print the character associated with the ASCII code 9, in this case a Control-I. Most Applesoft BASIC programs use the ASC(and CHR$(commands for creating control characters for printers, DOS, and so forth; but you can print any character, depending on the code you want. For instance, this line would print the letter *A*:

```
100 PRINT CHR$(65)
```

It turns out that it is possible to encode all the alphabetic characters (upper- and lowercase), numerics, special symbols, and control codes using only 128 number values. You can count to 128 using only the first seven bits of an eight-bit byte. This means that ASCII is considered a *7-bit code* since all the information required to determine which character has been sent (or is stored in memory) is contained in bits 0 through 6 of the byte. This makes the condition of bit 7 (the eighth bit) to be somewhat irrelevant. Thus $8A (10001100) is reasonably equivalent to $0A (00001100) as far as its ASCII interpretation is concerned.

However, the matter of the high bit (bit 7) being set or clear can create considerable confusion when it's not the same as what the computer or output device (such as a printer) expects. This is because many hardware devices use the high bit to signal an alternate character set (such as inverse and flashing on the Apple screen) and block graphics characters on the some printers.

Generally, the Applesoft BASIC assembly language routines and screen memory operate internally with the high bit set (set = on = 1) on all characters. That is to say, characters retrieved from the keyboard via $C000, and characters stored in the screen area of memory ($400 to $7F8), usually have the high bit set (values greater than $80). This is also the way Applesoft BASIC stores data within program lines. (To keep you on your toes though, strings within a program, such as A$ = "CAT", and ProDOS text files on disk, have the high bit clear.) When using COUT (the Monitor output routine), the high bit should be set (load the Accumulator with values greater than $80) before calling COUT or storing to the screen.

The ASCII system doesn't start with *A* as the first character (code number = 1). Instead, they assigned the first 32 values to what are called *control characters.* These were originally designed to be special codes to tell the mechanical teletype machines when to feed a new sheet of paper, when the transmission was complete, and other commands.

These codes are still used today, and your Apple IIGS keyboard has a key marked *Control* on it. When you hold down this key, it modifies the actual key pressed, much the same way a shift key changes a lowercase *a* into an uppercase *A*. For control characters, it creates the character Control-A. In printed listings such as those found in magazines and books, control characters are sometimes indicated with a caret (ˆ) symbol, like this:

ˆA = Control-A
ˆD = Control-D

It turns out then, that Control-A, is ASCII character 1, Control-B = 2, and so on. In addition, the ASCII character set can be arranged in groups to make things easier to keep track of:

ASCII character codes (decimal):	ASCII character codes (hex):	Characters in Group:
0 to 31	$00 to $1F	Control characters
32 to 63	$20 to $3F	Special characters (%,$,0–9,>,<, . . .)
64 to 95	$40 to $5F	Uppercase letters (A,B,C, . . .)
96 to 127	$60 to $7F	Lowercase letters (a,b,c, . . .)

You can see that the groups seem more logical in their hex number groups rather than in their decimal groups. This is another example where being comfortable with hex number makes your life a little easier. You still don't have to be able to convert a hex number to an ASCII character, but seeing the pattern helps keep everything straight in your head.

By the way, you might also notice that each group is made up of $20 characters (32 decimal). This means that by adding or subtracting $20 (32 decimal) from the ASCII value for an uppercase letter, you can print the equivalent control or lowercase letter.

The Applesoft BASIC lines

```
20 PRINT CHR$(65 + 32)
30 PRINT CHR$(65 − 32)
```

print a lowercase *a*, and Control-A, respectively.

Commands Learned So Far

Here are the new commands you've learned, plus the ones covered in previous chapters.
In this chapter:

```
BEQ  BNE  BRA  BRL
JML  JMP  NOP
```

And in previous chapters:

BRK JSL JSR LDA LDX LDY
RTL RTS STA STX STY STZ
TAX TAY TXA TXY TYA TYX
XBA

Secret #3

If you ran either of the LOOP programs, you may have noticed that your cursor changed to a new character after the programs were run.

The Apple IIGS has a special "hidden" command to make the cursor anything you want.

For example, from Applesoft BASIC, type Control-Shift-6, then type an underline character (near the Delete key), followed by Return.

The cursor should change to a blinking underline character.

What's actually going on is that whenever the computer sees a Control-ˆ (ASCII code 30, decimal), it takes whatever the next character is and uses that for the cursor. You can do this from within a program with a line like this:

```
10 PRINT CHR$(30);“+” : REM MAKE CURSOR A “+”
```

Try this with different keyboard characters and see what cursors you can find for your own programs. To restore the cursor to normal, you can press Control-RESET, or set the cursor equal to the Delete key.

Chapter 7

Comparisons in Assembly Language

Chapter 7

Comparisons in Assembly Language

In the last chapter, you learned how to use instructions like BEQ and BNE to create simple loops. We used the X and Y registers as counters, and incremented or decremented by 1 for each cycle of the loop.

Now let's expand our repertoire of instructions by adding some new ones, and in the process add some flexibility to what we can do with loops and tests in general.

In previous programs, we relied on the counters reaching zero and testing the Z-flag to take appropriate action. Suppose however, that you wish to test for a value other than zero. This is done using two new kinds of instructions, compare and branch-on-carry.

The **compare** instruction, with the mnemonic **CMP**, tells the computer to compare the contents of the Accumulator against some other value. The other value can be specified in a variety of ways. A simple test against a specific value would look like this:

```
CMP #$A0
```

This would be read "Compare Accumulator with an immediate $A0." This would tell the 65816 to compare the Accumulator with the specific value $A0. On the other hand, you may want to compare the Accumulator with the *contents* of a given memory location. This would be indicated by

```
CMP $A0
```

In this case, the 65816 would go to location $A0, see what was there, and compare that to the Accumulator. It's important to understand that the contents of $A0 may be anything from $00 to $FF, and it is against the contents that the Accumulator will be compared. In each case, the comparison is done by subtracting the Accumulator from the specified value (although the result is invisible to the programmer).

The other new instructions are **Branch-on-carry**. Branch-on-carry instructions, coincidentally enough, use the *Carry flag*. This is used to determine the result of the comparison. Right next to the Z-flag (zero flag) in the Status Register is the bit called the Carry (Figure 7-1).

Figure 7-1. The Carry Bit of the Status Register

7	6	5	4	3	2	1	0
						Z	E C
						Zero	Carry or Emulation

This is used during addition and subtraction by the 65816. Because the compare operation involves subtraction, the Carry flag can also be used to test the result of a comparision. This is done with two branch instructions, **BCC** and **BCS**. BCC stands for **Branch on Carry Clear**. If the Accumulator is *less than* the value compared against, BCC will branch appropriately. BCS stands for **Branch on Carry Set**, and is taken whenever the Accumulator is *equal to or greater than* the value used.

This means you can not only test for specific values, but also test for ranges.

Program 7-1 is a variation on the LOOP program presented in Chapter 6, that only prints the letters A through Z.

This program is not designed for efficiency, but rather to demonstrate the principles of using BCC and BCS. The counter, CTR, is started at 0, as before. However, the LOOP part of the program has now been given some intelligence. It first compares the value of CTR with the ASCII value for the letter *A*, $C1. If CTR is less than $C1, program execution skips the use of COUT, and branches to L2, which increments CTR. Eventually, CTR reaches $C1, and printing begins. When CTR reaches the ASCII value of Z plus 1, $DB, BCS takes effect and the program ends. Remember that because BCS tests for *greater than or equal*—test for *one more* than the last value you want to print.

The X and Y registers can be compared in a similar manner by the codes CPX and CPY.

BEQ and BNE are also still usable after a compare operation. Here's a summary:

Command	**Action**
CMP	Compares Accumulator to something
CPX	Compares X register

CPY	Compares Y register
BCC	Branch if register < value
BEQ	Branch if register = value
BNE	Branch if register < > value
BCS	Branch if register >= value
BRA	Branch always

Program 7-1. Loop Demo 4 Using CMP

```
                               ****************************************
                               *          LOOP PROGRAM #4             *
                               *     MERLIN 8/16 ASSEMBLER            *
                               ****************************************

                                          ORG  $300

                  =0006        CTR        EQU  $06
                  =FC58        HOME       EQU  $FC58
                  =FDED        COUT       EQU  $FDED

000300:  20 58 FC              START      JSR  HOME      ; CLEAR SCREEN
000303:  A9 00                            LDA  #$00      ; START COUNTER AT '0'
000305:  85 06                            STA  CTR       ; STORE VALUE

000307:  A5 06                 LOOP       LDA  CTR       ; GET CURRENT VALUE
000309:  C9 C1                            CMP  #$C1      ; "A" CHAR, HI BIT SET
00030B:  90 07  =0314                     BCC  L2

00030D:  C9 DB                            CMP  #$DB      ; ASCII "Z" + 1
00030F:  B0 07  =0318                     BCS  DONE      ; ALL DONE!

000311:  20 ED FD                         JSR  COUT      ; PRINT CHARACTER

000314:  E6 06                 L2         INC  CTR       ; CTR = CTR + 1
000316:  80 EF  =0307                     BRA  LOOP      ; ALWAYS BRANCH

000318:  60                    DONE       RTS            ; ALL DONE!


--End Merlin-16 assembly, 25 bytes, Errors: 0
```

Reading Data from the Keyboard

A good part of many formal machine language courses deal with just system I/O, that is, getting data In and Out via different devices. Writing such things as printer drivers, disk access routines, and hardware interface software are the areas that hardcore programmers spend their youth mastering. Using the built-in routines on the Apple simplifies this greatly because you don't have to do most of thef I/O details. You've already seen this is true by having used COUT ($FDED) for screen output, without having to know anything about how the actual operation is carried out. The keyboard is even easier.

In the memory map we've been using for the Applesoft BASIC, the address range from $C000 to $FFFF is devoted to hardware in that these memory ranges cannot be altered by running programs (we're ignoring the additional GS RAM for the time being). The range from $D000 to $FFFF is used by the ROM routines that we've been calling. The range from $C000 to $CFFF is assigned to I/O devices. Typically the second digit from the left gives the slot number of the device. For instance, if you have a printer in slot #1, a look at $C100 will reveal the machine language code in ROM on the card that makes it work. At $C600 you'll probably find the code that makes the disk drive in slot 6 boot.

$C000 to $C0FF is reserved not for slot 0, but for doing special things with the hardware portions of the Apple itself.

An attempt to disassemble from $C000 will not produce a recognizable listing, but it will probably cause your Apple to act a bit odd. This range is made up of a number of memory locations actually wired to physical parts of your Apple. If from the Monitor you type

```
* C030 <RETURN>
```

you'll see some random value displayed and the speaker should click. (If it doesn't click the first time, try again.) Each time you access $C030, the speaker will click as it moves in response to your action.

The keyboard is also tied into a specific location. By looking at the contents of $C000, you can tell if a key has been pressed. In BASIC, it's done with a PEEK (−16384). In machine language, you would usually load a register with the contents of $C000, such as:

```
    LDA $C000
```

Because it is difficult to read the keyboard at exactly the instant someone has pressed the key, the keyboard is designed to hold the value of the last key pressed until either another key is pressed or you clear something called the *strobe*, by accessing an alternate memory location, $C010. The strobe is wired to clear a character off the keyboard once a program has read the keypress.

It's always a good idea to clear the keyboard when you're done with it, otherwise you'll have the value for the key pressed for *your* input still hanging around for whatever reads the keyboard next, such as the next keyboard read in your own program, or an INPUT statement in BASIC. The strobe is cleared by any read or write operation. It's the mere access to it in any manner that accomplishes the clear. However, because of the way the microprocessor and hardware work, a read actually accesses the location *twice.*

Thus, although both a LDA $C010 or STA $C010 would clear the strobe, the LDA has the double disadvantage of ruining the contents of the accumulator, and *clearing two characters off the keyboard if the keyboard buffer is turned on*. This is very important to keep in mind. Although the LDA command will work (and some programs use this), it makes your program incompatible with keyboard buffering. If the user were to type HELLO THERE, your program would only see HLOTEE.

The last point to be aware of is that the keyboard is set up to tell you when a key is pressed by the value that is read at $C000. Now you might think that the logical way would be to keep 0 in $C000. Perhaps, but that's not the way it's done. Instead, we must add $80 the ASCII value of the key pressed. If a value less than $80 is at $C000, it means a key has not been pressed.

To illustrate all this, let's look at some sample programs to read data from the keyboard. Look at Program 7-2.

Program 7-2. Keyboard Demo 1

```
                          ****************************************
                          *     KEYBOARD PROGRAM #1A           *
                          *     MERLIN 8/16 ASSEMBLER          *
                          ****************************************

                                  ORG  $300

            =C000         KYBD    EQU  $C000
            =FDED         COUT    EQU  $FDED
            =FC58         HOME    EQU  $FC58


000300: 20  58  FC        START   JSR  HOME      ; CLEAR SCREEN

000303: AD  00  C0        LOOP    LDA  KYBD      ; READ KEYBOARD
000306: C9  80                    CMP  #$80      ; KEY PRESSED
000308: 90  F9  =0303             BCC  LOOP      ; TRY AGAIN IF NOT...

00030A: C9  9B            CHECK   CMP  #$9B      ; 'ESCAPE' KEY
00030C: F0  05  =0313             BEQ  DONE

00030E: 20  ED  FD        PRINT   JSR  COUT      ; PRINT ASCII CHARACTER
000311: 80  F0  =0303             BRA  LOOP      ; DO IT AGAIN

000313: 60                DONE    RTS


--End Merlin-16 assembly, 20 bytes, Errors: 0
```

Line 15 loads the Accumulator from location $C000. This is then compared to $80, the minimum value for a key down. If the value read was less than $80, we go back for another look. Once a value greater than $80 is found, we can then check to see exactly what key was pressed.

Like any well-written program, this one avoids being in an infinite loop by allowing you to press the Escape key to stop it. The test specifically for the Escape key is on line 19.

All keys other than Escape are passed on to be printed on line 22, after which the program branches back to do it all over again.

You've probably noticed that the program runs on printing the same character until you press another key. That's because the strobe is never cleared.

A better program is Program 7-3.

Program 7-3. Keyboard Demo 1B: A Better Way

```
                         1 ******************************************
                         2 *      KEYBOARD PROGRAM #1B          *
                         3 *      MERLIN 8/16 ASSEMBLER         *
                         4 ******************************************
                         5
                         6            ORG  $300
                         7
            =C000        8 KYBD       EQU  $C000
            =C010        9 STROBE     EQU  $C010
            =FDED       10 COUT       EQU  $FDED
            =FC58       11 HOME       EQU  $FC58
                        12
                        13
000300: 20  58  FC      14 START      JSR  HOME       ; CLEAR SCREEN
                        15
000303: AD  00  C0      16 LOOP       LDA  KYBD       ; READ KEYBOARD
000306: C9  80          17            CMP  #$80       ; KEY PRESSED
000308: 90  F9  =0303   18            BCC  LOOP       ; TRY AGAIN IF NOT...
                        19
00030A: 8D  10  C0      20 CLEAR      STA  STROBE     ; CLEAR CHARACTER
                        21
00030D: C9  9B          22 CHECK      CMP  #$9B       ; 'ESCAPE' KEY
00030F: F0  05  =0316   23            BEQ  DONE
                        24
000311: 20  ED  FD      25 PRINT      JSR  COUT       ; PRINT ASCII CHARACTER
000314: 80  ED  =0303   26            BRA  LOOP       ; DO IT AGAIN
                        27
000316: 60              28 DONE       RTS
                        29

--End Merlin-16 assembly, 23 bytes, Errors: 0
```

This should work better. Here the keyboard is cleared whenever a character is read and printed. Why not clear it right after the read on line 15? If we did it there, the only way we would see the character is if the user pressed the key in the time between when the strobe was automatically cleared and when the keyboard was checked again. This would create such a small time window that keypresses would very likely be missed. It is a much better technique to only clear the strobe after an actual keypress has been detected.

In trying out this program, you should type in enough text to wrap around onto the next line, and you should also try the arrow keys and Return. You may think all this performs as expected (with the exception of the missing cursor), but this should not be taken for granted. Without the screen management of COUT, you'd have to do quite a bit more programming to keep things straight. Once more, this is the advantage of using the routines already present in the computer, rather than have to worry about the details yourself.

The Emulation Bit

As mentioned earlier, there is a way to control the size of the Accumulator, X, and Y registers. This is done using the Carry, along with two other bits, in the Status Register.

On the first Apple II computers, before the Apple IIGS was a gleam in anybody's eye, the Accumulator, X, and Y registers were limited to only a single byte. That's why Applesoft BASIC is designed to only use one byte of these registers, and why when you call a machine language routine from Applesoft BASIC, the default register size is only a single byte.

In addition, the Status Register used bit 4 for a Break instruction flag (telling the system that a BRK instruction had been encountered), and bit 5 was not used at all.

When the 65816 was designed, they wanted to create a system that was compatible with the older machines, yet that was an improvement on the original design of the 6502 microprocessor used in the first Apples.

Figure 7-2. The Status Register

7	6	5	4	3	2	1	0
N	V	M	B X	D	I	Z	E C
Sign	Overflow	Accumulator Size Select	Break or X/Y Register Size Select	Decimal	Interrupt	Zero	Carry or Emulation

The answer was to give the Carry bit a dual function (see Figure 7-2). By adding a new command, **XCE (eXchange Carry with Emulation bit)**, the designers created a method for using two other bits in the Status Register for a new function. This is done by telling the 65816 to change the meaning of the Break flag to indicate the size of the X and Y registers (one or two bytes), and to use the previously unused bit 5 to indicate the size of the Accumulator. In the new state, bits 4 and 5 are labeled the *m* (Memory) and *x* (indeX) bits.

In the same way that XBA exchanged the current contents of the A part of the Accumulator with the B part, the XCE instruction swaps the current value of the Carry bit (0 or 1) with an invisible *emulation* bit. The emulation bit is an extra bit, in addition to the eight bits that make up the Status Register, but it can only be changed using the Carry flag and the XCE instruction.

When the Emulation bit is 1, the A, X, and Y registers are limited to a single byte in size, and their size cannot be immediately changed. The *m* and *x* bits have no real value at this point, because in the emulation mode they technically don't exist.

When the Emulation bit is 0 (native mode), the size of the Accumulator can be changed by changing the *m* register, and the size of the X and Y registers can be controlled using the *x* register. Note that a lowercase *x* is used to differentiate the *x* bit from the actual X register. The *x* bit controls the size of both the X and Y registers together; they cannot be independently set to different sizes.

Register Sizes:

	Accumulator
m = 0	2 bytes (16 bits)
m = 1	1 byte (8 bits)

	X and Y
x = 0	2 bytes (16 bits)
x = 1	1 byte (8 bits)

There is no underlying meaning to the 0 or the 1, as such. Rather they're just arbitrary flag values for the two modes. In general, 0 in the *m* or *x* flags indicates the full 16-bit mode.

You've seen the status of the Emulation bit shown, when the BRK instruction was used in debugging a program in Chapter 3:

```
00/0308: 00 00              BRK 00
 A=00EF X=0000 Y=0000 S=01DD D=0000 P=B0
 B=00 K=00 M=0C Q=80 L=1 m=1 x=1 e=1
*
```

Along with the registers, the Processor Status Register, P = $B0, is shown. You can also see the display of the Emulation bit; *e* is set to 1, meaning that a BRK instruction will set bit 4 if encountered and that the size of the A, X, and Y registers are limited to one byte and cannot be changed. Because the *e* bit is a separate and invisible addition to the Status Register, its condition cannot be determined by looking at the value of P in the register display itself.

The register display also shows the condition of the *m* and *x* bits. This display is set up whenever a BRK instruction is encountered, and is used to help you see what the entire system status is at a given point in a running program.

Setting and clearing the Carry. To change the Emulation bit in a program, you must first *condition* (set to a 0 or 1) the Carry bit. There are two commands specifically for conditioning the Carry bit, **SEC (SEt Carry)** and **CLC (CLear Carry)**. SEC sets the Carry bit to 1; CLC sets it to 0.

If you want set clear the Emulation bit to 1 (sometimes called the Native mode) so you can change register sizes, you must first put a zero in the Carry (CLC), and then exchange this with the Emulation bit (XCE):

```
CLC   ; c = 0
XCE   ; e = 0 = native mode
```

To set the Emulation bit back to 1 (called the Emulation mode), you must set the Carry to 1 (SEC), and then do the exhange:

```
SEC   ; c = 1
XCE   ; e = 1 = emulation mode
```

To change the *m* and *x* bits in the Status Register, there are two commands, **SEP (SEt Processor status bits)** and **REP (REset Processor status bits)**. Notice that the designers were a bit inconsistent here using set/clear for one pair, and set/reset for the other.

In any event, REP and SEP are used to make any bit in the Status Register either 0 or 1. They look like this in a program:

```
SEP   #$10     ; %00010000 binary
REP   #$30     ; %00110000 binary
```

The comments show the operand number in binary form. In the SEP instruction, you set the bits in the operand to match whatever bits in the Status Register you want set to 1. In the REP instruction, the desired bits are also indicated by 1's in the operand; however, the corresponding bits in the Status Register will be cleared to 0 by the instruction.

In the first line, SEP #10 sets bit 4, the *m* bit, to 1, thus setting the Accumulator to a 1-byte size (8 bits). In the second line, REP #30 clears both the *m* and *x* bits (bits 4 and 5), making both the Accumulator and index registers 2 bytes wide (16 bits).

The most common use of the REP and SEP instructions is to clear or set the *m* and *x* bits to control the A, X, and Y register sizes. They're rarely used to change any of the other Status Register bits, although nothing prohibits it.

To demonstrate the effects of these instructions, enter Program 7-4.

Program 7-4. *e*-, *m*-, and *x*-Bit Demo

```
                  1 ******************************************
                  2 *         e-, m- and x-bit demo          *
                  3 *         MERLIN 16 ASSEMBLER            *
                  4 ******************************************
                  5
                  6         ORG  $300
                  7
       =FC58      8 HOME    EQU  $FC58
                  9
       =05BC     10 SCRN1   EQU  $5BC        ; SCREEN LOCATION #1
       =063C     11 SCRN2   EQU  $63C        ; SCREEN LOCATION #2
                 12
000300: 20 58 FC 13 BEGIN   JSR  HOME        ; CLEAR SCREEN
                 14
000303: A9 C1    15         LDA  #"A"        ; 1 BYTE LETTER "A"
000305: 8D BC 05 16         STA  SCRN1       ; PUT ONE BYTE ON SCREEN
                 17
000308: 18       18         CLC              ; C = 0
000309: FB       19         XCE              ; E = 0 = NATIVE (16-BIT MODE)
                 20
00030A: C2 20    21         REP  #$20        ; %00100000 = M = 0
                 22
00030C: A9 C1 00 23         LDA  #"A"        ; 2-BYTE LETTER "A"
00030F: 8D 3C 06 24         STA  SCRN2       ; PUT TWO BYTES ON SCREEN
                 25
000312: 38       26         SEC              ; C = 1
000313: FB       27         XCE              ; E = 1 = EMULATION (8-BIT MODE)
                 28                          ; AUTOMATIC SEP #$30
                 29
000314: 60       30 DONE    RTS
                 31

--End Merlin-16 assembly, 21 bytes, Errors: 0
```

After assembling, BLOAD and run the object file with a CALL 768.

The program starts off very much like the sample program in Chapter 3 with the mini-assembler. The ASCII value for the letter *A* is loaded into the Accumulator and then is stored at memory location $5BC, which makes it visible as a screen character.

Now, the exciting part. Line 18 sets the carry to zero, in preparation for the XCE that immediately follows. The XCE sets the Emulation bit to zero, which puts the 65816 into the native mode that enables the option of changing register sizes. Line 21 uses the REP #$20 instruction to clear bit 5, the *m* bit, to zero. This puts the Accumulator in the 2-byte (16-bit) mode.

When the 65816 encounters the LDA instruction on line 23, it now *loads two bytes* into the Accumulator. This has two immediate, and important effects. First, even though you think you're loading the value $C1 into the Accumulator, you need to be aware that the full 16-bit value, $00C1, is used. Second, because this value does take two bytes, the instruction is assembled as a total of three bytes, as opposed to only two when the 8-bit mode is used.

The one- or two-byte status of a register also applies to any store operations associated with it. In this program, the STA SCRN2 instruction on line 24 puts *two bytes* on the screen, for the complete value $00C1. Notice that the $C1 (the low-order byte) is stored first at $63C, followed byte $00 (the high-order byte) at $63D. This is visual proof of the reversed-order use of byte pairs by the 65816.

The final stage of our program is to return the computer to the 8-bit emulation mode. This is a requirement for any routine that you call from Applesoft BASIC that changes the register sizes or emulation bit. If you don't restore things properly, Applesoft BASIC itself will crash when you exit your routine.

Line 26 sets the Carry bit (C = 1), so that the following XCE instruction will set the emulation bit to 1. We don't have to worry about resetting the register sizes, because setting the emulation bit to 1 automatically removes the *m*- and the *x*-bit functions, and makes all registers 1 byte wide.

To see how this program lists from the Monitor, go to the Monitor now, and list the program starting at $300.

```
1=m  1=x  1=LCbank (0/1)

00/0300: 20 58 FC   JSR  FC58
00/0303: A9 C1      LDA  #C1
00/0305: 8D BC 05   STA  05BC
00/0308: 18         CLC
00/0309: FB         XCE
00/030A: C2 20      REP  #20
00/030C: A9 C1      LDA  #C1
00/030E: 00 8D      BRK  8D
00/0310: 3C 06 38   BIT  3806,X
00/0313: FB         XCE
00/0314: 60         RTS
```

You may be surprised to see that the disassembly doesn't look quite right after the REP #20 instruction at $30A. This is because the disassembler doesn't recognize the REP instruction as such, and it continues to disassemble the instructions in the 8-bit mode. This shows what would happen if the Emulation or the *m* or *x* bits were set incorrectly and you were to enter your program at $30A—the program would not interpret the bytes there as you had expected.

To properly disassemble the bytes from $30A, type in

```
0=m
```

and press Return. Now type 309L to list

```
0=m  1=x  1=LCbank (0/1)

00/030A: C2 20       REP  #20
00/030C: A9 C1 00    LDA  #00C1
00/030F: 8D 3C 06    STA  063C
00/0312: 38          SEC
00/0313: FB          XCE
00/0314: 60          RTS
```

Notice that the *m* and *x* indicators at the top of the listing shows that *m* is now set to 0. As you examine different parts of memory, you must specifically set these settings, when they're not conditioned by hitting a BRK in a program. The Monitor does not make any assumptions about the condition of the various registers. This is so you can examine any part of memory at will and set the registers as you think they will be when that part of your program is executing. You can examine the current register settings at any time in the Monitor by typing Control-E (Examine registers) and pressing Return.

Looking at the listing starting at $30C, you can now see the LDA with the two-byte operand. The STA instruction still takes only one byte. The 65816 only needs to know the starting address of the byte pair, so the instruction lists the same in either mode. What changes is how many bytes are written to memory starting at $63C.

The converse situation in listing also applies. Now that the *m* flag is set to 0 (16-bit Accumulator mode), try listing starting at $300 again.

```
0=m  1=x  1=LCbank (0/1)

00/0300:  20 58 FC   JSR  FC58
00/0303:  A9 C1 8D   LDA  #8DC1
00/0306:  BC 05 18   LDY  1805,X
00/0309:  FB         XCE
00/030A:  C2 20      REP  #20
00/030C:  A9 C1 00   LDA  #00C1
00/030F:  8D 3C 06   STA  063C
000/0312: 38         SEC
00/0313:  FB         XCE
00/0314:  60         RTS
```

Notice that now the instructions at $303 and $306 list improperly. These were assembled as 8-bit instructions. You are now disassembling in the 16-bit mode.

Try rewriting the program using the long (16-bit; x = 0) X and Y mode, instead of the long accumulator mode, and see how the listing changes. Be sure to run your new program to make sure that it works, and that it returns to the 8-bit mode for Applesoft BASIC properly. You may wish to experiment with different combinations of *e*, *m*, and *x* modes to get the feel for what your options are in any given program.

Notes for the *APW* Assembler

If you have the *APW* assembler, you'll need to use the directives **LONGA ON/OFF** and **LONGI ON/OFF** to tell the assembler you're changing the *m* and *x* modes, respectively. The *Merlin* assembler automatically changes its

Program 7-5. *e*-, *m*-, and *x*-Bit Demo for the *APW* Assembler

```
****************************************
*       e-, m- and x-bit demo          *
*         APW ASSEMBLER                *
****************************************
        KEEP    EMX.DEMO
        ORG     $300
        LONGA   OFF        ; STARTING CONDITION
        MSB     ON         ; HI BIT = ON
MAIN    START
HOME    EQU     $FC58
SCRN1   EQU     $5BC       ; SCREEN LOCATION #1
SCRN2   EQU     $63C       ; SCREEN LOCATION #2
BEGIN   JSR     HOME       ; CLEAR SCREEN
        LDA     #"A"       ; 1 BYTE LETTER "A"
        STA     SCRN1      ; PUT ONE BYTE ON SCREEN
        CLC                ; C = 0
        XCE                ; E = 0 = NATIVE (16 BIT MODE)
        REP     #$20       ; %00100000 = M = 0
        LONGA   ON
        LDA     #"A"       ; 2 BYTE LETTER "A"
        STA     SCRN2      ; PUT TWO BYTES ON SCREEN
        SEC                ; C = 1
        XCE                ; E = 1 = EMULATION (8 BIT MODE)
*                            AUTOMATIC SEP #$30
DONE    RTS
        END
```

mode when it sees the REP and SEP instructions in the listing. The *APW*, however, requires that the programmer include these assembler directives in the listing. Program 7-5 is the example program in the *APW* format.

LONGA OFF is required at the beginning because Applesoft BASIC CALLs our routine with all registers set to 8 bits. Then, after the REP #$20 instruction, the appropriate LONGA ON directive is again required to tell the assembler we have switched modes.

MSB (Most Significant Bit) ON is also required at the beginning to tell the assembler to use the hi-bit ASCII (value larger than $80) form when assembling the LDA #"A" instructions.

More on Switching Modes

For those who may have previously done some programming on the 6502 or 65C02, it's important to mention that changing the Emulation bit doesn't have a dramatic effect on how the 65816 operates. Virtually all of the same instructions are available in both modes. Because the terms emulation and native *modes* are used, there is a tendency to think that one mode must exclude many of the instructions of the other. This is not the case. There are a few instructions, like REP and SEP that are meaningless in a given mode, but they are just ignored if encountered. REP and SEP are meaningless in the 8-bit mode because the A, X and Y registers are already limited to 8 bits, and REP and SEP cannot change the *m* or *x* bits at the same time as the Emulation bit.

The main hazard to the programmer in switching modes is the change in the length of certain instructions such as the LDA and STX instructions. As you have seen from the sample disassemblies of our demonstration program, the same segment of object code can be interpreted by the 65816 in very different ways, depending on the status of the *e*, *m*, and *x* bits. If your program sets these flags to one condition, and then jumps to another part of the program that was written assuming a different set of conditions, very strange things are likely to happen, and it can be very difficult to track down the problem. When debugging programs that use mixed register sizes and modes, this should be one of the first things you check when debugging a program.

Commands Learned So Far

Here are the new commands you've learned, plus the ones covered in previous chapters:

In this chapter:

BCC BCS CLC CMP CPX

CPY REP SEC SEP XCE

And in previous chapters:

BEQ BNE BRA BRK BRL JML
JMP JSL JSR LDA LDX LDY
NOP RTL RTS STA STX STY
STZ TAX TAY TXA TXY TYA
TYX XBA

Chapter 8

Simple Math

Chapter 8

Simple Math

This chapter will introduce the basic math operations of addition and subtraction in assembly language. To some extent, you've already seen how this is done. In Chapter 6, you saw how the increment and decrement commands could be used to add and subtract. Unfortunately it performs these functions only by *one* each time (VALUE + 1 or VALUE − 1).

If you're really ambitious, you could, with the commands you know already, add or subtract any number by using a loop of repetitive operations, but this would be a bit slow. Fortunately, a better method exists.

You'll recall that a byte is an individual memory location that can hold a value from $00 to $FF (0–255 decimal). This number comes about as a direct result of the way the computer is constructed, and the way in which you count in base two. In base two, each position of the byte is called a bit, and the positions are numbered from right to left, from 0 to 7.

The pattern for counting is similar to normal decimal or hex notation. The value is increased by adding 1 each time to the digit on the far right, carrying as it becomes necessary. In base 10, you have to carry every tenth count; in hex, every sixteenth. In base two, the carry is done every other time.

The first few numbers look like this:

Hex	Decimal	Binary
$00	0	0 0 0 0 0 0 0 0
$01	1	0 0 0 0 0 0 0 1
$02	2	0 0 0 0 0 0 1 0
$03	3	0 0 0 0 0 0 1 1
$04	4	0 0 0 0 0 1 0 0

Notice that in going from 1 to 2, we would add 1 to the 1 already in the first position (bit 0). This generates the carry to increment the second position (bit 1). Here is the end of the series:

$FD	253	1 1 1 1 1 1 0 1
$FE	254	1 1 1 1 1 1 1 0
$FF	255	1 1 1 1 1 1 1 1

Observe what happens when the upper limit of the counter is finally reached. At $FF (255) all positions are full. When the next increment is done, we should carry 1 to the next position to the left; unfortunately that position doesn't exist.

When you use an increment instruction, the byte value wraps around to $00, and the extra bit just created is ignored. Suppose we were incrementing a two-byte address pointer. When the low-order byte reached $FF, we would want the next increment to add 1 to the high-order byte. For example:

Address Value	High-Order Byte	Low-Order Byte
$01FF	$01	$FF
+ 1	$00	$01
$0200	$02	$00

If you were using the INC instruction to add one each time, however, you would lose the newly created bit from the increment at $FF. The way this is usually handled in a loop is to use the BNE or BEQ test, like this:

```
PTR     EQU  $06         ; $06,07
LOOP    INC  PTR         ; PTR = PTR + 1
        BNE  NEXT        ; LESS THAN $00 SO CONTINUE
        INC  PTR+1
NEXT    ???              ; REGULAR PROGRAM HERE...
```

This program segment will increment the two byte pointer PTR, PTR+1 by one each time. It works by testing for the specific condition in which PTR (the low-order byte) has just been incremented from $FF to $00. In all other cases, the BNE just branches out of the increment segment. When PTR is $00, 1 is added to PTR+1 (the high-order byte) to properly increment the address value.

In the 16-bit mode of the 65816, this problem is temporarily avoided by allowing this increment command to operate on *both* bytes of a two-byte pointer. With the Emulation and Memory bits clear (e = 0, m = 0), the following instruction works for a two-byte pointer:

```
INC   PTR        ; INCREMENTS PTR,PTR+1
```

This instruction automatically takes care of any bits that need to be carried from the low-order to the high-order byte.

However, the solution is only temporary. Remember that the Apple IIGS allows up to three bytes to be used to define an address (for example, $01/300 = Bank 1, location $300). What to do when the two-byte pointer reaches $FFFF and we need to increment a bank byte?

Add with Carry

The answer is to use some general-purpose instructions that will add and subtract any value—not just 1—and condition the carry bit if appropriate.

The addition instruction we'll use is **ADC (ADd with Carry)**. When an addition is done with this command, and the result would generate a bit in a new position wider than the byte width indicated by *m*, the carry is set. ADC can only be used to add to the value already in the Accumulator, so the *x*-bit (for X and Y register sizes) is not a direct concern. The source of the value to be added to the contents of the Accumulator is limited only by the addressing modes available to the ADC instruction itself, which, as it happens, are rather extensive.

Because ADC always adds the value of the carry bit to the calculated sum, it's important to clear the carry bit before doing the actual addition. For example, consider this program segment:

```
LDA  #$05
ADC  #$07
STA  RESULT
```

As it stands, there are two possible results. If the carry happened to be clear when this was executed, the value in RESULT would be $0C (12 decimal). If, however, the the carry had been set (perhaps as the result of some previous operation), then RESULT would have be $0D (13 decimal).

This problem is avoided using the **CLC (CLear Carry)** instruction introduced in Chapter 7.

```
CLC             ; CLEAR CARRY IN PREPARATION FOR ADDITION.
LDA  #$05       ; LOAD ACCUMULATOR WITH VALUE "5"
ADC  #$07       ; ADD "7" TO IT.
                ; RESULT NOW = 12 ($0C)
```

This segment adds 5 and 7 using immediate values. Logically, the CLC could have been done after the LDA #$05, but before the ADC #$07 itself. Although it need only precede the ADC command, it has no effect on the LDA, so it's put at the beginning of the routine for aesthetic purposes. It also helps identify the overall unit as a math routine. Most program segments that use CLC and ADC are usually written as shown.

The contents of two memory locations can also be added using the following instructions:

```
CLC
LDA  MEM        ; 1ST MEMORY LOCATION.
ADC  MEM2       ; 2ND MEMORY LOCATION.
STA  RSLT       ; STORE RESULT SOMEWHERE.
```

When the result of an ADC instruction is greater than $FF (or $FFFF in the two-byte mode: m = 0), the Carry bit will be set to 1, and this will automatically be added to the result of the next addition or subtraction. For example, suppose you wanted to add $120 to the base address $1F0. You would start with the low-order bytes:

Starting Lo Byte:	$F0	Carry = 0
ADC #$20	$20	
Result:	$10	Carry = 1

And then add the high-order bytes:

Current Hi Byte:	$01	Carry = 1
ADC #$01	$01	
Result:	$03	Carry = 0

This gives the correct two-byte result of $0210, and is equivalent to:

```
  $1F0
+ $120
  $310
```

Notice that the Carry is also automatically cleared if the result of the addition did not result in a new carry bit being generated.
The steps above are equivalent to this source code segment:

```
CLC
LDA   #<$1F0     ; LOW-ORDER BYTE OF $1F0 = $F0
ADC   #<$120     ; ADD LOW-ORDER BYTE OF $120 = $20
STA   RSLT       ; STORE LOW-ORDER RESULT = $10
LDA   #>$1F0     ; HIGH-ORDER BYTE OF $1F0 = $01
ADC   #>$120     ; ADD HIGH-ORDER BYTE OF $120 = $01
STA   RSLT+1     ; STORE HIGH-ORDER BYTE OF RESULT = $03
```

In a two-byte mode, the operation is similar. Let's assume a base address of $01/$FF00, to which we will add $00/0200:

Starting Low Word:	$FF00	Carry = 0
ADC #$0200	$0200	
Result:	$0100	Carry = 1

Next addition:

Current High Word:	$0001	Carry = 1
ADC #$0000	$0000	
Result:	$0002	Carry = 0

This gives the correct four-byte result of \$02/0100, and is equivalent to:

$$\begin{array}{r} \$0001/\text{FF00} \\ +\ \$0000/0200 \\ \hline \$0002/0100 \end{array}$$

In this example, you'll notice that all four hexadecimal digits of the bank address are shown. In the Monitor listing, however, only one byte is shown for the bank byte, because that is all that is maintained by the 65816 itself. If you look at the long address operand generated by the mini-assembler in Chapter 3, or the assembler output from *Merlin* or *APW*, you'll see it also is only three bytes.

Because it's not convenient to switch between 8- and 16-bit modes for the ADC and other operations, most long addresses on the Apple IIGS are *loaded and stored* as four bytes. This is more practical than trying to handle the minimal three bytes that are required. Thus, although the high byte of the high word is always zero, it's still carried around in calculations for efficiency's sake.

Program 8-1 and 8-2 are sample programs using the ADC instruction. Note the use of the CLC before each ADC.

Program 8-1. Math Demo 1

```
                 ****************************************
                 *     MATH DEMO PROGRAM #1             *
                 *        MERLIN ASSEMBLER              *
                 ****************************************

                          ORG  $300

           =0006 N1       EQU  $06
           =0008 N2       EQU  $08
           =000A RSLT     EQU  $0A

000300: 18       BEGIN    CLC            ; GET READY FOR ADDITION
000301: A5 06             LDA  N1        ; GET 1ST NUMBER
000303: 65 08             ADC  N2        ; ADD 2ND NUMBER
000305: 85 0A             STA  RSLT      ; STORE RESULT
000307: 60       DONE     RTS            ; ALL DONE!

--End Merlin-16 assembly, 8 bytes, Errors: 0
```

Program 8-2. Math Demo 2

```
                  *******************************************
                  *     MATH DEMO PROGRAM #2                *
                  *       MERLIN ASSEMBLER                  *
                  *******************************************

                          ORG  $300

           =0006  N1      EQU  $06

           =000A  RSLT    EQU  $0A

000300: 18        BEGIN   CLC              ; GET READY FOR ADDITION
000301: A5 06             LDA  N1          ; GET 1ST NUMBER
000303: 69 80             ADC  #$80        ; ADD #$80 TO ACC.
000305: 85 0A             STA  RSLT        ; STORE RESULT
000307: 60        DONE    RTS              ; ALL DONE

--End Merlin-16 assembly, 8 bytes, Errors: 0
```

Program 8-3. Math Demo 3A

```
                  *******************************************
                  *    MATH DEMO PROGRAM #3A                *
                  *       MERLIN ASSEMBLER                  *
                  *******************************************

                          ORG  $300

           =0006  N1      EQU  $06
           =0008  N2      EQU  $08
           =000A  RSLT    EQU  $0A

000300: 18        BEGIN   CLC              ; GET READY FOR ADDITION
000301: A5 06             LDA  N1          ; GET 1ST NUMBER, LO BYTE
000303: 65 08             ADC  N2          ; ADD 2ND NUMBER, LO BYTE
000305: 85 0A             STA  RSLT        ; STORE RESULT, LO BYTE

000307: A5 07             LDA  N1+1        ; GET 1ST NUMBER, HI BYTE
000309: 65 09             ADC  N2+1        ; ADD 2ND NUMBER, HI BYTE
00030B: 85 0B             STA  RSLT+1      ; STORE RESULT, HI BYTE

00030D: 60        DONE    RTS              ; ALL DONE


--End Merlin-16 assembly, 14 bytes, Errors: 0
```

In the first program, the value in N1 is added to the contents of N2 and stored in RSLT. In the second program, N1 is added to the immediate value #$80, and is also stored in RSLT. Note the CLC before the ADC to insure an accurate result. This routine could be used either as a subroutine in part of a larger assembly language program, or called from BASIC after passing the values to locations 6 and 8.

The main disadvantage to all these programs is that we're limited to one-byte values for both the original values and the result of the addition. Thus, if the result exceeds $FF, the carry is ignored.

The solution is to use the Carry bit to create a two-byte addition routine (see Program 8-3).

Notice that N1, N2 and RSLT are all two-byte numbers, with the second byte of each pair being used for the high-order byte. This allows us to use values and results from $00 to $FFFF (0–65535).

Once the two low-order bytes of N1 and N2 are added, and the partial result is stored, the high-order bytes are added. If an overflow was generated in the first addition, the Carry will be set and an extra unit will be added in the second addition. Note that the Carry remains unaffected during the LDA N1+1 operation.

You may want to BLOAD the object code for Program 8-3, and then call it from this BASIC program, Program 8-4.

Program 8-4. Math Demo 3A BASIC CALL

```
 0 REM MACHINE ADDITION ROUTINE
10 HOME
20 INPUT "N1,N2?";N1,N2
30 N1 = ABS (N1):N2 = ABS (N2)
40 POKE 6,N1 - INT (N1 / 256) * 256: POKE 7, INT (N1 / 256)
50 POKE 8,N2 - INT (N2 / 256) * 256: POKE 9, INT (N2 / 256)
60 CALL 768
70 PRINT : PRINT "RESULT IS: "; PEEK (10) + 256 * PEEK (11)
80 PRINT : GOTO 20
```

The ABS( ) statements on line 30 of Program 8-4 eliminate values less than zero. Although there are conventions for handling negative numbers, this routine is not that sophisticated.

Many times the number being added to a base address is known to always be $FF or less, so only one byte for N2 is needed. A two/one addition routine is shown in Program 8-5.

Notice that if the carry is set, the value in N1+1 gets incremented by one, even though the ADC says an immediate $00. The $00 acts as a dummy value to allow the carry to do its job.

Program 8-5. Math Demo 3B

```
                         1 *****************************************
                         2 *     MATH DEMO PROGRAM #3B             *
                         3 *         MERLIN ASSEMBLER              *
                         4 *****************************************
                         5
                         6          ORG  $300
                         7
               =0006     8 N1       EQU  $06
               =0008     9 N2       EQU  $08
               =000A    10 RSLT     EQU  $0A
                        11
000300: 18              12 BEGIN    CLC              ; GET READY FOR ADDITION
000301: A5 06           13          LDA  N1          ; GET 1ST NUMBER, LOW BYTE
000303: 65 08           14          ADC  N2          ; ADD 2ND NUMBER, LOW BYTE
000305: 85 0A           15          STA  RSLT        ; STORE RESULT, LOW BYTE
                        16
000307: A5 07           17          LDA  N1+1        ; GET 1ST NUMBER, HIGH BYTE
000309: 69 00           18          ADC  #$00        ; ADD CARRY ONLY (NO 2ND HIGH BYTE)
00030B: 85 0B           19          STA  RSLT+1      ; STORE RESULT, HIGH BYTE
                        20
00030D: 60              21 DONE     RTS              ; ALL DONE

--End Merlin-16 assembly, 14 bytes, Errors: 0
```

Subtraction in Assembly Language

Subtraction is done very much like addition, except that a *borrow* is required. Rather than using a separate borrow flag for this operation, the computer uses the opposite of the Carry as a borrow. That is, a set Carry flag will be treated by the subtract command as a *clear borrow* (or no borrow taken); a clear Carry as a *set borrow* (borrow unit taken).

The command for subtraction is **SBC** **(SuBtract with Carry)**. The borrow is cleared with the command **SEC,** for **SEt Carry**. (Remember, things look backward here). Program 8-6 is the subtraction equivalent of a our two-byte addition program presented earlier.

The program can be called with a slight variation on the Applesoft BASIC program we used for the addition programs (Program 8-7).

This assembly language routine will work fine for subtracting one positive number from another, but how can we handle negative numbers? Negative numbers can be thought of as a way of handling certain common arithmetic possibilities, such as when subtracting a larger number from a smaller one, (for example, 3 − 5 = −2), and when adding a positive number to a negative number (such as 5 + −8 = −3) to obtain a given result.

To be successful, then, what we must come up with is a system that will be consistent with the arithmetic of signed numbers as you now know it.

Program 8-6. Subtraction Example 1

```
                     ********************************************
                     *       SUBTRACTION EXAMPLE #1             *
                     *          MERLIN ASSEMBLER                *
                     ********************************************

                                 ORG   $300

            =0006    N1          EQU   $06          ; $06,07
            =0008    N2          EQU   $08          ; $08,09
            =000A    RSLT        EQU   $0A          ; $0A,0B

000300: 38           BEGIN       SEC                ; SET CARRY = ‘CLEAR BORROW’
000301: A5 06                    LDA   N1           ; GET LOW BYTE OF 1ST VALUE
000303: E5 08                    SBC   N2           ; SUBTRACT LOW BYTE OF 2ND VALUE
000305: 85 0A                    STA   RSLT         ; PUT IN LOW BYTE OF ‘RSLT’

000307: A5 07                    LDA   N1+1         ; GET HIGH BYTE OF 1ST VALUE
000309: E5 09                    SBC   N2+1         ; SUBTRACT N2 WITH BORROW IF NEEDED
00030B: 85 0B                    STA   RSLT+1       ; PUT IN HIGH BYTE OF ‘RSLT’

00030D: 60           DONE        RTS                ; DONE!


--End Merlin-16 assembly, 14 bytes, Errors: 0
```

Program 8-7. Subtraction Example BASIC CALL

```
 0 REM MACHINE SUBTRACTION ROUTINE
10 HOME
20 INPUT "N1,N2?";N1,N2
30 N1 = ABS(N1): N2 = ABS(N2):REM NO NEG. NUMBERS YET
35 IF N2 > N1 PRINT "WE CAN'T DO THAT YET!":END
40 POKE 6,N1 - INT (N1 / 256) * 256: POKE 7, INT (N1 / 256)
50 POKE 8,N2 - INT (N2 / 256) * 256: POKE 9, INT (N2 / 256)
60 CALL 768
70 PRINT : PRINT "RESULT IS: "; PEEK (10) + 256 * PEEK (11)
80 PRINT : GOTO 20
```

The Sign Bit

A good first approach to the problem is to just arbitrarily decide to use one of the 8 bits in a byte as a flag to indicate whether the number is positive or negative. If the bit is clear, the number will be positive. If the bit is set, the number will be regarded as negative. We'll use bit 7 (the eighth bit) for this. Thus +5 would be represented

00000101

While −5 would be shown as

10000101

Note that by sacrificing bit 7 to show the sign, we're now limited to values from −128 to +127. When using two bytes to represent a number, such as an address, this means we'll be limited to a range of −32768 to +32767. Sound familiar? If you've ever noticed the limits for integer variables in Applesoft BASIC, you'll recognize this as the same range.

Although this new scheme is very pleasing in terms of simplicity, it does have one minor drawback—it doesn't work. If we attempt to add a positive and a negative number using this result, we get disturbing results:

$$\begin{array}{rl} +5 & 00000101 \\ \underline{+\ -8} & \underline{10001000} \\ -3 & 10001101 \ = -13 \end{array}$$

Although we should get −3 as the result, using our signed bit system we get −13. There must be a better way. Well, with the help of what looks a lot like numeric magic, we can get something that works, although some of the conceptual simplicity gets lost in the process.

What we'll invoke for this magic is the idea of number *complements.* You've probably heard of complementary angles (when dealing with two angles that add up to 180 degrees). In binary math, the simplest complement is called a *ones complement*. The ones complement of a number is obtained by reversing each 1 and 0 throughout the original binary number. Let's try this as a negative number.

For example, the ones complement to 5 is

00000101 = +5

11111010 = −5

For 8, it is

00001000 = +8

11110111 = −8

This process is essentially one of *definition,* that is to say that we declare to the world that 1110111 will now represent −8 without specifically trying to justify it. Undoubtedly there are lovely mathematical proofs of such things, presenting marvelous ways of spending an afternoon; but, for our purpose, a general notion of the system will be sufficient. Fortunately, computers are very good at following arbitrary numbering schemes.

Now let's see if we're any closer to a working system.

$$\begin{array}{rl} +5 & 00000101 \\ \underline{+\ -8} & \underline{11110111} \\ -3 & 11111100 \ = -3 \end{array}$$

(00000011 = +3)

That worked. Let's try another:

$$\begin{array}{rl} -5 & 11111010 \\ \underline{+\ +8} & \underline{00001000} \\ 3 & 00000010 \ = 2 \text{ (plus Carry)} \end{array}$$

Well, we seem to be closer. At least our answers will be right half the time. Don't despair, there is a final solution, and that is to use what is called the *twos complement* system. The only difference between this and the ones complement system is that, after deriving the negative number by reversing each bit of its corresponding positive number, *we add one.*

Let's see how it looks.

For −5: **For −8:**

5 = 00000101 8 = 00001000

ones complement...

11111010 11110111

now add one . . .

−5 = 11111011 −8 = 11111000

Now, let's try the two earlier operations.

$$\begin{array}{rl} +5 & 00000101 \\ +\ \underline{-8} & \underline{11111000} \\ \text{-}3 & 11111101 \ = -3 \end{array} \qquad \begin{array}{rl} -5 & 11111011 \\ +\ \underline{+8} & \underline{00001000} \\ +3 & 00000011 \ \text{ (plus Carry)} \end{array}$$

Does 1111101 equal −3?

starting number: 00000011 = 3
ones complement: 11111100
add 1: $\underline{\qquad +1}$
twos complement: 11111101 = −3

It works in both cases. It turns out that twos complement works in all cases. Most of the time, you probably won't have much need for negative numbers, but hopefully you've at least gained a little insight to why integer variables are limited to the size that they are, and if you ever do have to deal with negative numbers, you'll be prepared.

The best thing about this lesson, however, is that we can now use the term *sign bit.* In the Status Register, a flag is provided for the easy testing of bit 7, and this flag is usually called the sign flag. Whenever a byte is loaded into a register, or any arithmetic operation is done, the sign flag will be conditioned according to what the final state of bit 7 (the sign bit) is. For example, LDA #$80 will set the sign flag to 1 (set), whereas a LDA #$40 will clear the flag. This is tested using the commands **BPL (Branch on PLus)** and **BMI (Branch on MInus)**.

The Sign Bit as a Flag

Regardless of whether you're using signed numbers or not, these instructions can be very useful for testing bit 7 of a byte. Many times, bit 7 is used in various parts of the Apple to indicate the status of something. For example, the keyboard location, $C000, sets the sign bit (we've also been calling it the high bit) whenever a key is pressed. Up until now, we've always tested by comparing the value returned from $C000 to the value #$80, such as in this partial listing:

```
LOOP  LDA  KYBD     ; READ KEYBOARD
      CMP  #$80     ; KEY PRESSED?
      BCC  LOOP     ; TRY AGAIN IF NOT . . .
```

This program will stay in a loop until a key is pressed. The keypress is detected by the value returned in $C000 being equal or greater to $80. A more elegant method is to use the BPL command as shown in Program 8-8.

Program 8-8. Keytest

```
                      *******************************************
                      *        KEYTEST PROGRAM #2              *
                      *         MERLIN ASSEMBLER               *
                      *******************************************

                                ORG  $300

          =C000       KYBD      EQU  $C000
          =C010       STROBE    EQU  $C010

000300: AD 00  C0     CHECK     LDA  KYBD       ; GET VALUE FROM KYBD
000303: 10 FB  =0300            BPL  CHECK      ; NO KEYPRESS, TRY AGAIN

000305: 8D 10  C0     CLR       STA  STROBE     ; CLEAR KEYBOARD

000308: 60            DONE      RTS

--End Merlin-16 assembly, 9 bytes, Errors: 0
```

In this case, as long as the high bit stays clear (no keypress), the BPL will be taken and the loop continued. As soon as a key is pressed, bit 7 will be set to one, and the BPL will fail. The strobe is then cleared and the return done.

The Open Apple ($C061) and Option ($C062) keys (equivalent to push-buttons on joysticks) work in a similar way. If bit 7 of the corresponding memory locations are set, the button is being pushed. Program 8-9 shows an example.

Program 8-9. Button Test

```
                          *********************************************
                          *              BUTTON TEST                  *
                          *           MERLIN ASSEMBLER                *
                          *********************************************

                                      ORG   $300

            =C061         PB0         EQU   $C061       ; PUSH-BUTTON 0 OR OPEN APPLE KEY

000300: AD 61  C0         CHECK       LDA   PB0         ; GET STATUS BYTE
000303: 10  FB  =0300                 BPL   CHECK       ; AGAIN IF NO BUTTON PUSH

000305: 60                DONE        RTS


--End Merlin-16 assembly, 6 bytes, Errors: 0
```

A variation on Program 8-9 is to check for the high bit set with the BMI instruction:

```
CHECK  LDA  PB0       ; GET STATUS BYTE
       BMI  DONE      ; BRANCH IF PUSHED
       BRA  CHECK     ; BPL WOULD WORK TOO...
DONE   RTS
```

Short Loops with BMI and BPL

BPL and BMI are also used to terminate a loop of less than 128 cycles that must end when the Y register passes 0. For example:

```
ENTRY  LDY  #$50      ; STARTING VALUE FOR THE LOOP
LOOP   DEY            ; Y = Y - 1
       BPL  LOOP      ; AS LONG AS Y IS POSITIVE (for example, < $80)
DONE   RTS
```

or:

```
ENTRY  LDY  #$A0      ; STARTING VALUE FOR THE LOOP
LOOP   INY            ; Y = Y + 1
       BMI  LOOP      ; AS LONG AS Y IS NEGATIVE (for example, > $7F)
DONE   RTS
```

In the first example, the Y register will wrap from $00 to $FF when it passes zero, causing the BPL to fail, thus terminating the loop. In the second example, the wrap is from $FF to $0, and BMI is used. The main drawback to this approach is that your loop counter must always be either positive or negative until the critical point. In other words, you couldn't start at $FF and count down to zero because $FF is already negative, so the BPL wouldn't work to keep the loop going.

Chapter 9

Logical and Shift Operators

Chapter 9

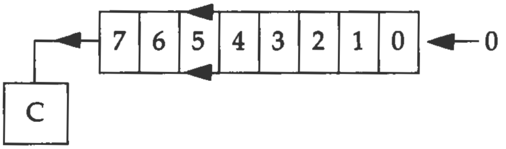
Logical and Shift Operators

In this chapter you'll see how to use two important types of commands: *shift* operators and *logical* operators. Shift operators are somewhat easier to understand, so we'll start with them.

Shift Operators: ASL

In the last chapter, you saw how to do simple addition and subtraction. This was done with the ADC and SBC instructions. Although the 65816 doesn't specifically have a multiply and divide instruction, there are instructions that come close and can be used to build an actual multiply or divide routine.

The shift commands give you the option of shifting each bit in the Accumulator or a given memory location one position to the left or right. The first two shift commands we'll look at are **ASL (Arithmetic Shift Left)** and **LSR (Logical Shift Right)**.



ASL
(Arithmetic Shift Left)

In the case of ASL, each bit is moved to the left one position, with bit 7 going into the Carry, and bit 0 being forced to a zero. In addition to the Carry, the Sign and Zero Flags are also affected, depending on the resulting condition of bit 6 and whether the entire result is zero or not. Here are some examples showing the result of doing an ASL on given values, and the resulting status of the Carry, Sign, and Zero flags. The binary representation of each number has been spaced in the middle for easier reading.

ASL

Value		Result		(C)	(N)	(Z)
Hex	Binary	Hex	Binary	Carry	Sign	Zero
$00	0000 0000	$00	0000 0000	0	0	1
$01	0000 0001	$02	0000 0010	0	0	0
$80	1000 0000	$00	0000 0000	1	0	1
$81	1000 0001	$02	0000 0010	1	0	0
$FF	1111 1111	$FE	1111 1110	1	1	0

In the first case, there is no net change to the Accumulator (or shifted memory location), although the Carry and Sign flags are cleared and the Zero flag is set (BCC, BPL and BEQ would work). The zero at each bit position was replaced by a zero to its right.

However, in the case of $01, the value doubles to become $02 as the 1 in bit 0 moves to the bit 1 position. In this case, all three flags are cleared.

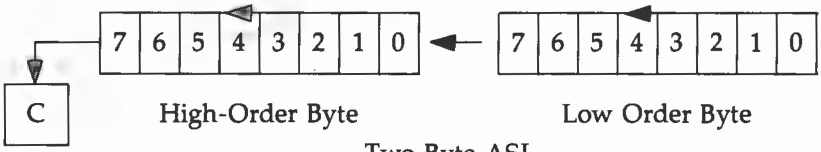
When the starting value is $80 or greater, the Carry will be set. In the case of $80 itself, the value returns to 0 after the shift, since the only 1 in the pattern, bit 7, is pushed out into the Carry.

Notice that in the case of $FF, the Sign flag gets set as bit 6 moves into position 7. Remember that bit 7 is also called the Sign bit.

ASL has the effect of doubling the byte being operated on. This can be used as an easy way to multiply by any power of 2. By using multiple ASLs, you can multiply by 2, 4, 8, 16, and so on, depending on how many ASLs you use.

```
LDA  #$05        ; STARTING VALUE = 5
ASL              ; ACC = 10 = 5 * 2
ASL              ; ACC = 20 = 5 * 4
ASL              ; ACC = 40 = 5 * 8
```

The examples assume that the *m* flag is in the 8-bit mode. If *e* and *m* = 0 (16-bit memory mode), then *two* bytes will be shifted at a time:

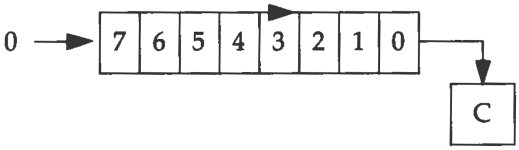


Two Byte ASL

In the 16-bit mode, a zero is put in bit 0 of the low-order byte, bit 7 of the low-order byte is put in bit 0 of the high-order byte, and bit 7 of the high-order byte is put in the Carry. This still has the effect of doubling the two-byte value.

Logical Shift Right: LSR

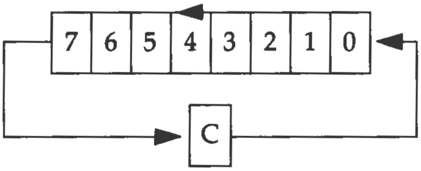
The complement of the ASL command is **LSR (Logical Shift Right)**. It behaves identically, except that the bits all shift to the right.



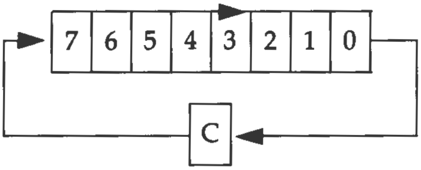
LSR
(Logical Shift Right

This can be used to *divide* by multiples of 2. It's also a nice way to test whether a number is even or odd: Even numbers always have bit 0 clear; odd numbers will always have it set. By doing an LSR followed by a BCC or BCS, you can test for this. LSR also conditions the Sign and Zero flags.

In both LSR and ASL, one end or the other always gets forced to a zero. Sometimes this is not desirable. The rotate commands—**ROL** and **ROR (ROtate Left** and **ROtate Right)**—are the solution to this.



ROL
(Rotate One Bit Left)



ROR
(Rotate One Bit Right)

With these commands, the Carry not only receives the pushed bit, but its previous contents are used to load the now-available end position.

ROL and ROR are used rather infrequently, but they do turn up occasionally in math functions such as multiply and divide routines.

Addressing modes for the shift operations include the absolute modes and indexed modes using the X register (with the exception of (MEM,X). The Y register cannot be used as an index in any of the shift operations.

Logical Operators

If you have ever used a statements like these:

```
IF X>5 AND Y=1 THEN 100
IF X=5 OR A$="WORD" THEN PRINT "HELLO"
```

you have already used an Applesoft BASIC version of what are called logical, or Boolean, operators. In Applesoft BASIC, logical operators are used for testing a group of conditions. In assembly language, the intuitive ideas of AND and OR are extended to produce a specific mathematical function that has uses beyond group conditional instructions.

Let's start with one of the most commonly used commands, **AND**. You're already familiar with the basic idea of this one from your daily speech. If this *and* that are a certain way, *then* I'll do something. This same way of thinking can be applied to your computer.

Let's consider a case where there are two things to be compared, A and B, and each can be a true or false. This will correspond to the statement "If A and B, then do something."

It's possible to draw a simple chart that illustrates all the possibilities.

AND

		B	
		False	True
A	False	No	No
	True	No	Yes

The chart shows four possibilities. If A is false, and B is false, then A AND B obviously aren't true, so we get a No answer. Likewise, if only one of either A or B is true, but not the other, then the result is still No. Only when *both* are true is the result Yes.

These results can also be written out as

False AND False = No
False AND True = No
True AND False = No
True AND True = Yes

For our purposes it would be more useful to rewrite the chart and sentences using 1 for True and Yes, and 0 for False and No.

AND

		B	
		0	1
A	0	0	0
	1	0	1

0 AND 0 = 0
0 AND 1 = 0
1 AND 0 = 0
1 AND 1 = 1

This table can be used to define a new mathematical *function,* AND. A mathematical function is just a set of rules for determining what numbers should result (the output) whenever a defined operation (function) is done on a given starting group of numbers (the input).

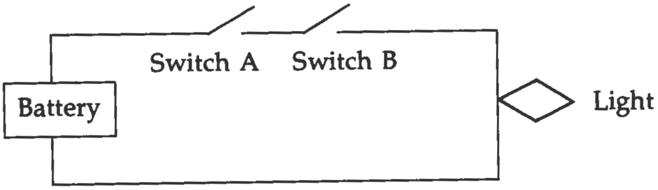
Many years ago, you learned four fundamental mathematical functions—multiply, divide, add, and subtract—and to do so you memorized a set of rules (or instant-recall answers) for each of the functions.

The Function AND

AND is a mathematical function also. In fact, the idea that mathematical functions could simulate logic was quite the rage in Lewis Carroll's (of *Alice in Wonderland* fame) time, and a fellow named George Boole did quite a bit of work in the area. It's Boole's name that's been given to this topic of ANDs and ORs—which is called Boolean math.

It's actually quite an interesting subject. In the same way that multiplication and division have real-world examples with miles-per-hour and how many yards of cloth are needed for a dress, Boolean functions can be applied to areas outside BASIC programs and the logic of true and false. For example, consider this setup of a battery, a light, and two switches.

We'll put the two switches in line with one another between the battery and the light:



In this setup, the light will only come on when *both* switch A *AND* B are on. You can quickly see that the physical analogy of switches and lights is identical to the mathematical function of AND. It also should give you a clue as to why AND is a very easy function to implement on a computer.

Once you've created a rule for dealing with 1's and 0's, you can apply those rules to the bits in a binary number.

Does 5 AND 3 have meaning? It turns out that it does, although the answer will not be 8. As we look at these numbers on a binary level, how to get the result of 5 AND 3 will be more obvious:

A = 5	0 1 0 1
B = 3	0 0 1 1
A AND B	0 0 0 1 = 1

If you use the chart created earlier and apply it to each set of matching bits in A and B, you will obtain the result shown. Starting on the left, two 0's in bit-position 3 (the fourth bit from the right) give zero as a result. For the next two bits, only a single 1 is present, in each case still giving zero as a result. Only in the last position do you get the necessary 1's in *both* number's 0-bits to yield one as the result.

Thus 5 AND 3 does have meaning, and the answer is 1.

AND is used for a variety of purposes. These include:

- To force 0's in certain bit positions.
- As a *mask* to let only 1's in certain positions "through."

Using ANDed in a Program

When an AND operation is done, the contents of the Accumulator are ANDed with another specified value. The result of this operation is then put back in the Accumulator. The other value may either be given by way of the immediate mode, or held in a memory location. Here are some of the possible addressing modes for AND:

```
LDA #$80
AND #$7F
AND $06
AND $300,X
AND ($06),Y
```

To better understand how AND is used, let's consider this scenario:

Suppose you have a program that gets a key from the keyboard, and then checks to see if it's a certain command. Let's suppose for a moment that your looking for the letter *A* in an input command. Your program would probably look something like this:

```
GETKEY  LDA  KYBD      ; CHECK KEYBOARD
        BPL  GETKEY    ; NO KEY YET
        STA  STROBE    ; KEY GOT - CLEAR KYBD

CHECK   CMP  #"A"      ; $C1 = "A"
        BEQ  ROUTINE   ; THAT'S FOR US!
        BNE  GETKEY    ; TRY AGAIN...
```

This seems to be a good start, but what about when the user types the A key with the CAPS LOCK key up (lowercase *a*)? You could check for both keys:

```
CHECK   CMP  #"A"      ; $C1 = "A"
        BEQ  ROUTINE   ; THAT'S FOR US!
        CMP  #"a"      ; $E1 = "a"
        BEQ  ROUTINE   ; THAT'S FOR US TOO!
        BNE  GETKEY    ; TRY AGAIN...
```

This would do the job for this particular key, but what if your program has 50 commands? Do you want to do a double-check for each key? Probably not. It would be nice if there was a way to turn all lowercase input characters to uppercase in one step, *before* all the testing was done. The answer is to use the AND command. To see how this works, look at the binary values for the letters *A* and *a:*

```
A  = $C1 = 1100 0001
a  = $E1 = 1110 0001
              ^
           bit 5
```

Notice that the only difference is that a lowercase a has bit 5 set to one. If we could clear just this bit, the value would correspond to an uppercase *A*.

The way to do this is with the AND command, and to create what is called a *mask*. A mask, in engineering and art terms, is something that only lets certain parts of an image through. If we treat the bit pattern for the letter a as an image, what we want is a mask that will not let the one in bit 5 through. That can be accomplished like this:

```
      LDA  VALUE     ; $E1 = "a"
      AND  #$DF      ; $DF = %1101 1111
                     ; Result = "A"
```

Here's the process illustrated:

```
   a  =   $E1 = 1110 0001
AND   #$DF = 1101 1111
-------------------------
A     =   $C1 = 1100 0001
```

Notice that at each position, the binary version of $DF has a one (except bit 5). This means that ones and zeros in the input value, $E1, come through unchanged. However, the zero at bit 5 in the mask value, $DF, *forces* a zero in the output value at the same position.

AND is almost always used to *force zeros* in a given position, and to let the other data in the pattern through unchanged. The *Merlin* assembler lets you use binary numbers as an operand by putting a percent symbol (%) in front of the number, like this:

```
LDA  VALUE       ; $E1 = "a"
AND  #%11011111  ; $DF
                 ; Result = "A"
```

This makes it easier to see exactly what mask you're using.

In general, AND is used to force zeros in a value. This is done using a mask with all bits set to 1 except for those which you wish to force to 0:

```
LDA  MEM         ; GET VALUE TO WORK ON
AND  #MASK       ; FORCE BITS TO 0
STA  MEM         ; PUT IT BACK IN MEMORY
```

Clear Bits and Words

There is also an instruction specifically for clearing bits in a byte or word in memory, called **TRB (Test and Reset Bits)**. This probably should have been named TCB for Test and Clear Bits, but those engineers like to keep you guessing. The T for test is a bit redundant too. It just means that it uses the bits in the Accumulator just like the AND instruction does.

TRB acts just like AND, except that it will only clear one or two bytes *in memory*. The result is *not* left in the Accumulator, although the mask is required to be in the Accumulator for its use.

Here's a program segment that converts a lowercase *a* to *A* in a memory location:

```
LDA  #%11011111  ; $DF = MASK
TRB  MEM         ; CONVERT MEMORY LOC. VALUE
```

BIT

The command somewhat related to AND is BIT. This is provided to allow a program to determine the condition of specific bits in a byte or word. It also has some secondary uses. When BIT is executed, quite a number of things happen. First, bits 6 and 7 of the memory location referenced are transferred directly to the Sign and Overflow bits. Since we've not discussed the Overflow flag, let me say briefly that it is bit 6 in the Status Register, and has two associated branch instructions **BVC (Branch on oVerflow Clear)** and **BVS (Branch on oVerflow Set)**. After a BIT instruction, BVC, BVS, BPL, and BMI may be used to test the status of bits 6 and 7 in the referenced memory location. For example:

```
BIT  MEM        ; TEST A MEMORY LOCATION
BPL  ROUTINE1   ; BRANCH IF BIT 7 = 0
BMI  ROUTINE2   ; BRANCH IF BIT 7 = 1
BVC  ROUTINE3   ; BRANCH IF BIT 6 = 0
BVS  ROUTINE4   ; BRANCH IF BIT 6 = 1
```

The most frequent use of the BIT instruction is to either test a memory location, like the keyboard byte, $C000 without affecting the contents of the Accumulator, or to access a softswitch, like the keyboard strobe, again without affecting the contents of the Accumulator. This program illustrates both:

```
      LDA  #"X"     ; CHARACTER "X"
KYBD  BIT  $C000    ; WAIT FOR KEYPRESS
      BPL  KYBD     ; NONE YET.
      BIT  $C010    ; CLEAR KEYBOARD STROBE
      JSR  COUT     ; PRINT "X" NO MATTER WHAT KEY PRESSED.
```

The other use of BIT is to test to see if one or more bits in the memory location match bits set in the Accumulator. If one or more do, the Zero flag will be cleared (Z=0). If no match is made, the Zero flag will be set (Z=1). This is done by ANDing the Accumulator and the memory location, and conditioning the zero flag depending on the result. The confusing part is that the test (BNE for a match) may seem backward. Alas, it's unavoidable—it's just one of those notes to scribble in your book so as to remember the quirk each time you use it.

Here's an example to test for bits 0 or 2 set:

```
LDA  #$05       ; 0000 0101
BIT  MEM
BNE  MATCH      ; ONE OR BOTH BITS MATCH
BEQ  NOMATCH    ; NEITHER BIT IN MEM IS "ON"
```

BIT is usually used to test for a single bit being on. If you want to test for *all* of a group of bits being on, the AND instruction can be combined with a compare.

To test for *both* bits 6 and 7 being on:

```
LDA  MEM
AND  #$C0       ; 1100 0000 = BITS 6 & 7
CMP  #$C0       ; COMPARE TO SAME VALUE
BEQ  MATCH      ; ONLY IF "BOTH" BITS ON
BNE  NOMATCH    ; IF BOTH NOT ON
```

This last example is somewhat subtle, in that the result in the Accumulator after the AND will only equal the value with which it was ANDed if each bit set to one in the test value (the AND operand) has an equivalent bit on in the Accumulator (loaded from the memory location).

Take note that TRB and TSB (discussed below) both condition the Zero flag in the same way as the BIT instruction, and so could be used for a test, but they also re-write the tested bits in memory.

ORA and EOR

These two commands bring up an interesting error of sorts in the English language, and that is the difference between and **inclusive OR** and the **exclusive OR**. When you say "I'll go to the store if it stops raining OR a bus comes by," it has two possible interpretations. The first is that if *either* event happens, then the result will happen. This also includes the possibility that both may happen. This is called an *inclusive OR* type statement.

The other possibility is that the conditions to be met must be one or the other but not both. This might be called the most pure form of an *or* statement. It's either night OR day, but never both together. This would be called an *exclusive OR* statement.

In assembly language, the inclusive or function is called **ORA** for **OR Accumulator**. The other is called **EOR** for **Exclusive OR**. Here are the charts for both functions:

ORA

		Acc.	
		0	1
Memory	0	0	1
	1	1	1

EOR

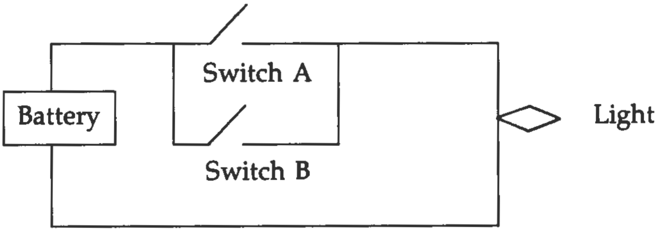
		Acc.	
		0	1
Memory	0	0	1
	1	1	0

First, consider the chart for ORA. If either or both corresponding bits in the Accumulator and the test value match, then the result will be a 1. Only when neither bit is 1 does a 0 value for that bit result. The main use for ORA is to force a 1 at a given bit position. In this manner it is the complement to the AND operator (which forces 0's).

Here are some examples of the effect of the ORA command:

	Example #1:		**Example #2:**	
Accumulator:	$80	1000 0000	$83	1000 0011
ORA Value:	#$03	0000 0011	#$0A	0000 1010
Result:	$83	1000 0011	$8B	1000 1011

Use of ORA also conditions the Sign and Zero flags, depending on the result, which is automatically put into the Accumulator.



In this setup, the switches are in parallel, giving the electricity a choice of paths to the light. The light will only come on when either switch A *OR* B are on (inclusive).

To specifically set bits in a memory location to ones, there is a special purpose instruction **TSB (Test and Set Bits)**. This is used by loading the Accumulator with a mask where the bits are set at each position that you want forced to one in the memory location. For example, if you wanted to set the high bit of a memory location, the following would do it:

```
LDA  #$80      ; %1000 0000 = HIGH BIT SET
TSB  MEM       ; SET HIGH BIT IN MEMORY
```

Like TRB, the result is left *only* in memory, and the Accumulator is not changed.

Exclusive OR: EOR

The EOR command is somewhat different in that the bits in the result are set to 1 only if one or the other corresponding bits in the Accumulator and test value are set to 1, but not both.

EOR has a number of uses. The most common is in encoding data. An interesting effect of the table given is that for any given test value, the Accumulator will flip back and forth between the original value and the result each time the EOR is done. For example:

	Example #1:		Example #2:	
First pass:				
Accumulator:	$80	1000 0000	$83	1000 0011
ORA Value:	#$03	0000 0011	$0A	0000 1010
Result:	$83	1000 0011	$89	1000 1001
Second pass:				
Accumulator:	$83	1000 0011	$89	1000 1001
ORA Value:	#$03	0000 0011	$0A	0000 1010
Result:	$80	1000 0000	$83	1000 0010

Program 9-1. Hi-Res Screen Inverter

```
                     **********************************************
                     *          HI-RES SCREEN INVERTER            *
                     *             MERLIN ASSEMBLER               *
                     **********************************************

                             ORG  $300

          =0006      PTR     EQU  $06        ; $06,07
          =2000      SCREEN  EQU  $2000      ; HIRES PAGE 1

000300: A9 20        ENTRY   LDA  #>SCREEN   ; HIGH ORDER BYTE OF $2000
000302: 85 07                STA  PTR+1      ; SET HIGH BYTE OF PTR
000304: A9 00                LDA  #<SCREEN   ; LOW ORDER BYTE OF $2000
000306: 85 06                STA  PTR        ; SET LOW BYTE OF PTR

                     * SETS PTR (6,7) TO $2000

000308: A0 00        START   LDY  #$00       ; INIT Y-REGISTER

00030A: B1 06        LOOP    LDA  (PTR),Y    ; GET EXISTING BYTE
00030C: 49 FF                EOR  #$FF       ; FLIP BITS
00030E: 91 06                STA  (PTR),Y    ; PUT BACK IN MEMORY
000310: C8                   INY             ; Y = Y + 1
000311: D0 F7  =030A         BNE  LOOP       ; BRANCH WHILE Y = $1 TO $FF

000313: E6 07        NXT     INC  PTR+1      ; PTR GOES FROM $2000 TO $2100, ETC.
000315: A5 07                LDA  PTR+1
000317: C9 40                CMP  #$40       ; STOP WHEN PTR = $4000
000319: 90 ED  =0308         BCC  START      ; NOT THERE YET

00031B: 60           EXIT    RTS

--End Merlin-16 assembly, 28 bytes, Errors: 0
```

This phenomenon is used extensively in Apple IIGS graphics to allow images to overlay each other, without destroying the image below.

EOR can also be used to reverse specific bits. Simply place 1's in the positions you wish reversed. EOR #$FF reverses all the bits in a byte.

Program 9-1 uses EOR to reverse, and then restore the entire Hi-Res screen. It's just a variation on Screen Clear #1A in Chapter 10. Use Program 9-2 to draw the screen (or BLOAD your favorite picture), and then change the image.

Program 9-2. Hi-Res Screen Inverter Loader

```
10 PRINT CHR$ (4);"BLOAD HIRES.INVERT,A$300"
20 HGR
25 HCOLOR= 3
30 HPLOT 0,0
40 FOR I = 1 TO 50
45 HCOLOR= RND (1) * 7: HPLOT X,Y
50 X = RND (1) * 279
55 Y = RND (1) * 159
60 HPLOT TO X,Y
70 NEXT I
100 HOME : VTAB 22: PRINT "PRESS A KEY, ESCAPE TO END"
105 GET A$
110 IF A$ = CHR$ (27) THEN TEXT : END
120 CALL 768: GOTO 100
```

Program 9-3 is a final example of how to use a shift operator. This routine prints a number in the binary form to the screen. It works by successively shifting each bit in the byte into the Carry. At that point, depending on whether it was a one or a zero, the routine prints a one or a zero plus a space. You can delete the part that prints spaces if you want a more compact display.

Program 9-4 will load the object file, and input the numbers to be printed.

Program 9-3. Binary Number Printer

```
                            **********************************************
                            *       BINARY NUMBER PRINTER                *
                            *            MERLIN ASSEMBLER                *
                            **********************************************

                                    ORG   $300

               =0006        NUM     EQU   $06
               =0007        TEMP    EQU   $07       ; TEMPORARY WORK AREA

               =FDED        COUT    EQU   $FDED


000300: A5 06               PRBIT   LDA   NUM       ; GET VALUE TO PRINT
000302: A2 08                       LDX   #$08      ; START COUNTER FOR # OF BITS

000304: 0A                  TEST    ASL             ; GET A BIT FROM THE BYTE
000305: 85 07                       STA   TEMP      ; SAVE THE ROTATED BYTE FOR A WHILE
000307: 90 0C  =0315                BCC   PZ        ; GOTO PRINT '0' IF BIT IS CLEAR

000309: A9 B1               P0      LDA   #"1"
00030B: 20 ED FD                    JSR   COUT      ; PRINT A '1'
00030E: A9 A0                       LDA   #$A0      ; 'SPC'
000310: 20 ED FD                    JSR   COUT      ; PRINT THE 'SPACE'
000313: B0 0A  =031F                BCS   NXT       ; GO FOR THE NEXT BIT IN THE BYTE

000315: A9 B0               PZ      LDA   #"0"
000317: 20 ED FD                    JSR   COUT      ; PRINT THE '0'
00031A: A9 A0                       LDA   #$A0      ; 'SPC'
00031C: 20 ED FD                    JSR   COUT

00031F: A5 07               NXT     LDA   TEMP      ; GET THE ROTATING BYTE BACK
000321: CA                          DEX             ; X = X - 1
000322: D0 E0  =0304                BNE   TEST      ; SHIFT IT AGAIN IF WE'RE NOT DONE

000324: 60                  EXIT    RTS


--End Merlin-16 assembly, 37 bytes, Errors: 0
```

Program 9-4. Binary Number Printer Loader

```
10 PRINT CHR$ (4);"BLOAD BINARY.PRINT,A$300"
20 INPUT "NUMBER TO CONVERT?";N
25 IF N = 0 THEN END
30 POKE 6,N: REM STORE NUM FOR ROUTINE
35 PRINT N;" = ";
40 CALL 768: REM CONVERT AND PRINT
50 PRINT : PRINT : GOTO 20
```

Trouble Shooting

Computer repair specialists use the binary nature of numbers to help track down the cause of a hardware-related computer errors. For example, suppose you had a parallel printer that always printed an *at sign* (@) where spaces should be. The decimal ASCII values for a space is 96 and 64 for the @. This information doesn't appear to tell you very much.

Now look at the numbers in binary:

```
Space:  0110 0000
@:      0100 0000
```

In examining the bit pattern, you can see that the patterns are identical, *except for bit 5*. This indicates that the signal for bit 5 is not coming through, and that checking the printer cable wire or connector that is associated with bit 5 would be a good idea.

Most disk- and memory-related data errors are caused by a similar problem, that is, a given bit flips from a one to a zero or vice versa. In modem communications, where data is transmitted over a phone line, this type of error is very likely. It's easy to miss a signal and drop a one to a zero, or for unexpected static to turn a zero into a one. To correct errors like this in transmission, a system of *checksums* has evolved. A checksum is just a number value used to verify the accuracy of transmitted, or even stored, data.

For example, we could design a system where after every 10 bytes were transmitted, we would then send the sum of those ten bytes. If the receiving computer added up the values for the bytes received, and got a different sum, it would know an error had occurred, and the data could be retransmitted. There are a lot of different error-checking systems, but most follow this general principle.

You can also build a checksum into your own programs, so that the running program can check to make sure that no damage has occurred to the program or the data it uses. The *Merlin* assembler has a special pseudo-op, **CHK** (**CHecKsum**) that stores a checksum byte in the program at the point where the instruction is used. The checksum in *Merlin* is generated by doing successive EORs on each byte of the program, and carrying the result of each EOR along for the next one, until the entire program has been scanned. A simple version would look something like this:

```
LDA  BYTE1      ; GET 1ST BYTE
EOR  BYTE2      ; EOR WITH 2ND BYTE, KEEP RESULT
EOR  BYTE3      ; EOR WITH 3RD BYTE, KEEP RESULT
EOR  BYTE4      ; ETC.
```

The final result makes up the checksum byte. Program 9-5 is an example that checks itself to make sure everything's the way it should be. Program 9-6 is an Applesoft BASIC that checks the checksum program.

On the first pass, you should get the message "Program Checks OK.". Line 30 of the BASIC program then POKEs a foreign byte into the program, in the middle of the error message, just so you can see something's changed. On the second run of the program, the program detects that it has been changed, and prints out the error message.

If you're writing programs that others will have to type in, such as in a club newsletter or magazine article, you may want to include the *Merlin* checksum at the end of each your listings so that the person typing the program in can make sure there have been no errors. On longer listings in the remainder of this book, a CHK byte will be included at the end so you too can make sure there are no errors in your listing. (COMPUTE! Publication's *MLX* and *Automatic Proofreader* programs use a similar checksum technique to the one described here except that *MLX* and the *Automatic Proofreader* check each line as it is entered.)

Your Apple IIGS also has a checksum, which is in the last byte of the Applesoft BASIC ROM area at $F7FF. This byte is checked by the internal diagnostic routines that run when you press Control-Option-Open-Apple-Reset. Some copy-protected programs do a checksum on the entire Applesoft BASIC/Monitor ROMs when they run to make sure they're not on a non-standard machine. This really isn't a good idea though, the programs then stop running when Apple updates a ROM, or brings out a new machine.

Program 9-5. Checksum Demo

```
                       ********************************************
                       *       PROGRAM CHECKSUM DEMO              *
                       *          MERLIN ASSEMBLER                *
                       ********************************************

                                   ORG   $300

            =0006      PTR         EQU   $06
            =0008      TEMP        EQU   $08          ; TEMPORARY WORK AREA

            =FDED      COUT        EQU   $FDED

000300: A9  00         CHECK        LDA   #<CHECK     ; LOW BYTE OF BEG OF PROG.
000302: 85  06                      STA   PTR
000304: A9  03                      LDA   #>CHECK     ; HIGH BYTE OF BEG OF PROG.
000306: 85  07                      STA   PTR+1

000308: 64  08                      STZ   TEMP        ; STORE STARTING VALUE

```

```
00030A: A5 08               LOOP    LDA  TEMP
00030C: 52 06                       EOR  (PTR)      ; EOR WITH MEMORY, RESULT IN ACC.
00030E: 85 08                       STA  TEMP       ; STORE RESULT

000310: E6 06               NEXT    INC  PTR        ; PTR = PTR+1
000312: D0 02    =0316              BNE  NEXT2      ; NO WRAP-AROUND
000314: E6 07                       INC  PTR+1

000316: A5 07               NEXT2   LDA  PTR+1
000318: C9 03                       CMP  #>CHKSUM   ; AT END OF PROGRAM YET?
00031A: 90 EE    =030A              BCC  LOOP       ; NOT YET...
00031C: A5 06                       LDA  PTR
00031E: C9 6C                       CMP  #<CHKSUM
000320: 90 E8    =030A              BCC  LOOP       ; STOPS AT BYTE JUST BEFORE 'CHKSUM'

000322: A5 08               TEST    LDA  TEMP       ; GET CHECKSUM
000324: CD 6C 03                    CMP  CHKSUM     ; COMPARE TO STORED VALUE
000327: D0 0E    =0337              BNE  ERROR      ; UHOH, SOMETHING'S CHANGED!

000329: EA                  PROGRAM NOP             ; YOUR PROGRAM HERE...

00032A: A0 00               PRINT   LDY  #$00
00032C: B9 45 03            LOOP1   LDA  MSSG1,Y
00032F: F0 13    =0344              BEQ  DONE       ; END OF MESSAGE
000331: 20 ED FD                    JSR  COUT
000334: C8                          INY             ; NEXT CHARACTER
000335: 80 F5    =032C              BRA  LOOP1

000337: A0 00               ERROR   LDY  #$00
000339: B9 59 03            LOOP2   LDA  MSSG2,Y
00033C: F0 06    =0344              BEQ  DONE
00033E: 20 ED FD                    JSR  COUT
000341: C8                          INY             ; NEXT CHARACTER
000342: 80 F5    =0339              BRA  LOOP2

000344: 60                  DONE    RTS

00345:  D0 F2 EF E7           MSSG1    ASC  "Program Checks Ok.",8D,00
000349: F2 E1 ED A0 C3 E8 E5 E3
000351: EB F3 A0 CF EB AE 8D 00

000359: C5 F2 F2 EF           MSSG2    ASC  "Error in Program!",8D,00
00035D: F2 A0 E9 EE A0 D0 F2 EF
000365: E7 F2 E1 ED A1 8D 00

00036C: 32                    CHKSUM   CHK  ; STORE CHECKSUM


--End Merlin-16 assembly, 109 bytes, Errors: 0
```

Program 9-6. Checksum Demo Loader

```
10 PRINT CHR$ (4);"BLOAD CHECKSUM.TEST,A$300"
20 CALL 768: REM RUN THE TEST
30 POKE 861, ASC ("x") + 128: REM CREATE ERROR
40 CALL 768: REM RUN TEST AGAIN
```

Chapter 10

Addressing Modes and Improved Printing

Chapter 10

Addressing Modes and Improved Printing

An *addressing mode* is a term that simply refers to the different ways a given 65816 instruction can locate the data or memory location it needs. Addressing modes is a rather fundamental concept to programming that has been used throughout this book, we just haven't called it by name.

Flexibility in the ways in which you can address memory is the key to even greater power in your own programs. Consider this chart of just a some of the addressing modes available on the Apple IIGS:

Addressing Mode	**Example**	**Hex Bytes**
Immediate	LDA #$A0	A9 A0
Absolute	LDA $7FA	AD FA 07
Absolute Long	LDA $0107FA	AF FA 07 01
Direct (Zero) Page	LDA $80	A5 80
Implicit/Implied	TAY	A8
Relative	BCC $3360	90 0F
Indexed	LDA $200,X	BD 00 02
Indexed Long	LDA $010200,X	BF 00 02 01
Indirect	LDA ($80)	B2 80
Indirect Long	LDA [$80]	A7 80
Indirect Indexed	LDA ($80),Y	B1 80
Indirect Indexed Long	LDA [$80],Y	B7 80
Indexed Indirect	LDA ($80,X)	A1 80
also:	JSR ($300,X)	FC 00 03

In looking at the examples, you should find all but the last six very familiar. We have used each of them in previous programs presented in this book.

This list does not present all of the available addressing modes on the 65816, but they are the ones we will use most frequently. Let's take a look at each more closely.

Immediate mode. The *immediate* mode was used to load a register with a specific value. In most assemblers this is indicated by the use of the # sign preceding the value to be loaded. This contrasts the *absolute* mode in which the value is retrieved from a given memory location. In this mode, the exact address you're interested in is given. This line will load the Accumulator with the value $A0:

```
LDA #$A0
```

Loads the value $A0 into the Accumulator.

Absolute addressing mode. In contrast to the immediate mode, the absolute mode retrieves a value from a given memory location. In this mode the exact address you're interested in is given.

```
LDA $7FA
```

Copies the value found in location $7FA into the Accumulator.

Direct page mode. *Direct page* addressing is really just a variation on the absolute mode. The main difference is that because the addresses referenced are always in the range of $00 to $FF, direct page addressing only takes two bytes for the complete instruction (see the third column), whereas in the more general case of absolute addressing, three or even four bytes per instruction are required.

A *page* of memory is $100 (256 decimal) bytes. Starting at $0, the first page of memory is called the zero page. Addresses $100 to $1FF are called page one, and so on. Direct page addressing is sometimes called zero page addressing because the default location for the direct page is, in fact, page zero. The direct page area can be moved anywhere in the first 64K of memory, and this is described in the next chapter.

```
LDA $80
```

Copies the value found in location $80 into the Accumulator.

Implicit addressing. *Implicit* (or *implied*) is certainly the most compact instruction in that only one byte of object code is generated by the assembler. The **TAY** command (**Transfer Accumulator to the Y register**) needs no additional address bytes because the source and destination of the data are implied by the very instruction itself.

```
TAY
```

Copies the value found in the Accumulator into the Y register.

Relative addressing. *Relative* addressing is done relative to where the instruction itself is found. Although the Example column (as listed by the Monitor L command) shows it as a branch to a specific address, you'll notice that the actual hex code is merely a plus or minus displacement from the branch point. This was discussed in a previous chapter.

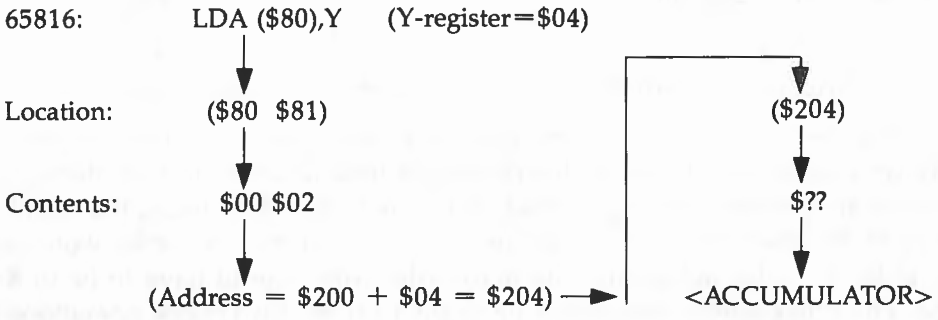
Indexed addressing. At this point you should be able to create your own simple programs. The problem with the four modes discussed so far is that the programs created are rather inflexible in dealing with data from the outside world (such as in input routines), and in doing things like accessing tables and large blocks of data.

Indexed addressing is necessary to write input routines. In the pure form, the contents of the X or Y register are added to the address given in the instruction to determine the final address. In the example given (LDA $200, X), if the X register holds 0, the Accumulator will be loaded with the contents of location $200. If the X register instead holds a 4, location $204 will be accessed. Indexing is ideal for accessing tables of data, or any range of memory.

This addressing mode works fine as long as you know exactly where in memory the data table is. What happens when the table could be in a movable location, such as when dealing with an interface card that could be in any slot? Another problem area would be in dealing with a large variety of possible base addresses, such as the starting address of each line on the text or graphics screens. To print a character or to plot a point, the computer uses the base address of each line and then adds an appropriate horizontal offset to get to the desired position. Using indexed addressing, there would have to be a specific instruction for each possible screen line since the address is built into the instruction itself.

Indirect addressing. The solution to this is to use the *indirect indexed* mode. This really is an elegant method. First the 65816 goes to the given direct page location (the base address *must* be a direct page address). Indirect addressing is indicated in the assembly source listing by the use of parentheses. In the example, LDA ($80), the 65816 goes to locations $80 *and* $81 to get the low- and high-order bytes of the address stored there. Then it adds the value of the Y-register to that address (see Figure 10-1).

Figure 10-1. Indirect Indexed Addressing



These two-byte direct page address pairs are often called *pointers,* and you will often hear them referred to in dealing with various programs on the Apple. In fact, by looking at various reference books available for the Apple, you'll observe quite a number of these byte pairs used by Applesoft BASIC, the Monitor, ProDOS and just about everything on the Apple. Pointers are used to keep track of all sorts of continually changing things, like where the program is, the locations of strings and other variables, and many other nifty items. Pointers find such frequent use because of the tremendous power of indirect addressing.

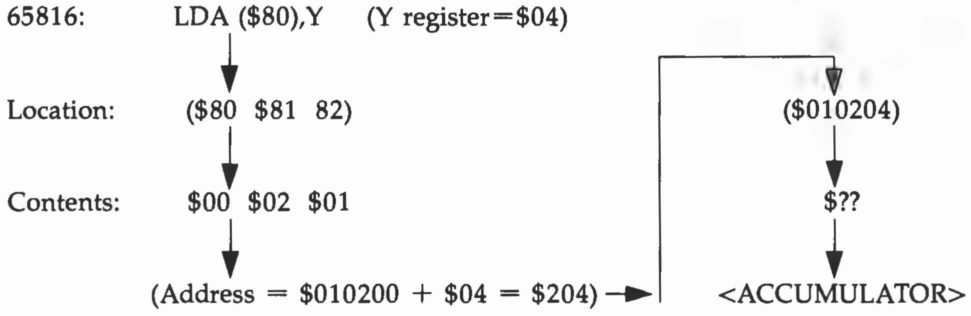
If you want to simulate the LDA $200,X command with the indirect mode, you first store #$00 in $80 and #$02 in $81 (00 and 02 are the low and high order bytes of the address $200). Then you use the command LDA ($80),Y.

Indirect long addressing mode. There is a long addressing mode for indirect indexed addressing, also. In that case, *three* bytes are retrieved starting at the direct page address. Long direct page addressing is indicated in the assembly source listing by using the square brackets instead of parentheses:

```
LDA [$80],Y
```

In this situation, data is loaded into the accumulator from the long address pointed to by $80,81,82, and the Y register is added to this data, as shown in Figure 10-2.

Figure 10-2. Indirect Long Addressing



You don't *have* to define the pointer as three bytes just because the 65816 only uses three bytes to determine the final address. In fact, doing so would create problems trying to load and store bytes there using the usual LDA/STA method. This is because the load/store of the low-order word would have to be in 16-bit mode, and the high-order word would have to be in 8-bit mode. The other alternative would be to do all three load/store operations in 8-bit mode.

A better solution is to just define *four* bytes in your source listing equates. Then it will be much easier to just to do two load/store operations in the 16-bit mode to maintain a pointer.

There is also a special case of indirect indexed addressing, simply called *indirect.* Because there are times when you just want to examine a variable memory location, without necessarily scanning an entire table, you can omit the use of the Y register in the instruction

```
LDA  ($80)
```

This is equivalent to the instructions

```
LDY  #$00
LDA  ($80),Y
```

but it saves an instruction and does not affect the Y register. This mode may also be used for long addresses:

```
LDA  [$80]
```

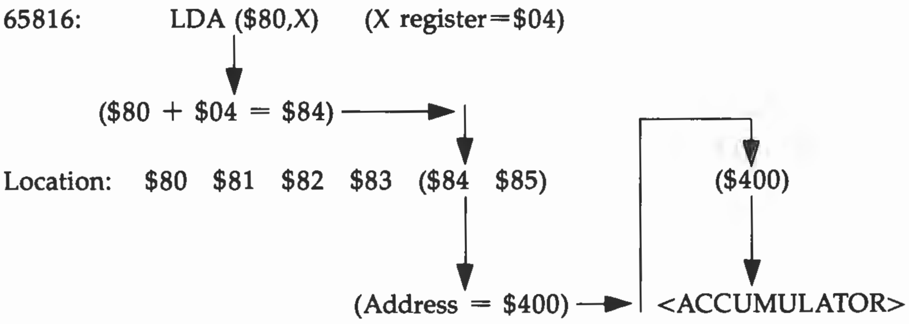
Use of the X and Y index registers. You may have noticed that the X register was used in one case and the Y register in the other. It turns out that the X and Y registers cannot always be used interchangeably. The difference shows up depending on what actual instruction and which addressing mode you're using. As it happens, indirect indexed addressing can *only* be done using the Y register. To know what is legal, you should make use of Appendix A to see which addressing modes can be used with any given command.

Indexed indirect addressing. The last addressing mode, *indexed indirect,* is probably the most unusual. In this case, the contents of the X register (Y cannot be used for this mode) are used at the *beginning* of the address calculation.

In the case of the sample instruction in the chart, if the X register held 0, a LDA ($80,X) would go to $80 and $81 for the two-byte address, and *then* load the Accumulator with the contents of the indicated location. If instead the X register held a 04, the memory address would be determined by the contents of $84 and $85.

Usually, then, the X register is loaded with multiples of 2 to access a series of continuous pointers in zero page.

Figure 10-3. Indexed Indirect Addressing


65816: LDA ($80,X) (X register=$04)
($80 + $04 = $84)
Location: $80 $81 $82 $83 ($84 $85)
($400)
(Address = $400)
<ACCUMULATOR>

The most common use of this command is for creating tables of entry address for subroutines. You might at first think that since the location of subroutines in your programs or in the Monitor seem to be fixed, such a process would not be necessary. Consider, however, the case of jumping to a routine on an interface card such as a printer card. There are also routines in the mouse firmware that may move in future revisions to the Apple IIGS. Because of this, it is handy to have a way to execute a JMP or JSR using an indirect address.

This addressing mode also provides for an elegant command processor. Assume for a moment that your program will have an input of the values 1, 2, or 3, depending on a menu choice from the user. One method of handling the commands is to do a number of CMP and conditional branch instructions, like this:

```
CHECK  LDA   CMD        ; VALUE FOR COMMAND
                        ; ASSUME = "1", "2" OR "3"
       CMP   #"1"
       BNE   CHK2
       JSR   CMD1       ; LOC OF ROUTINE #1
       JMP   NEXT       ; GO TO NEXT PART OF PROGRAM

CHK2   CMP   #"2"
       BNE   CHK3
       JSR   CMD2       ; LOC OF ROUTINE #2
       JMP   NEXT       ; GO TO NEXT PART OF PROGRAM

CHK3   CMP   #"3"
       BNE   AGAIN      ; CMD NOT HERE . . . TRY AGAIN
       JSR   CMD2       ; LOC OF ROUTINE #2
       JMP   NEXT       ; GO TO NEXT PART OF PROGRAM

NEXT   NOP              ; MORE OF YOUR PROGRAM HERE. . .
```

An alternative approach uses a table of all your subroutine entry points, and the indexed indirect addressing mode. Before you can see exactly how it's done, though, you'll need to know how to have the assembler create a data table in the first place.

Assembler Data Storage Pseudo-Ops

Before all this can be put to work, there is still one more question to answer: How do you store just pure data within a program?

All the commands discussed so far are actual commands for the 65816. There is no data command, as such. What is available are the *pseudo-ops* of your particular assembler. You'll recall that *directives* are commands used by the assembler itself (such as ORG and EQU) during the assembly of a source listing to tell the assembler to do something, like save a file to disk, or set the default BLOAD address.

Pseudo-ops are assembler commands that look very much like assembly language instructions. The difference is that instead of generating a specific 65816 instruction, they create a group of bytes which are not necessarily executable instructions—they're usually data.

Assembler directives and pseudo-ops are also a little like porpoise and dolphin, or assembly language and machine language: Although they technically have different meanings, the words are used rather interchangeably by many people.

The rule-of-thumb is: Pseudo-ops generate assembled bytes of object code; directives tell the assembler to save a file, to print a new page, or to do some other housekeeping (but non–code generating) operation.

Specific directives and pseudo-ops vary from one assembler to another, so you'll have to consult your own manual to see how your assembler operates.

In general, the most common use of pseudo-ops is for data storage. The general procedure is to define a block of one or more bytes of data, and then either to put that data at the end of the program or to skip over that block with a branch or jump instruction when executing your program. Data can usually be entered either as hex bytes or as the ASCII characters you wish to use. The assembler will, in that case, automatically translate the ASCII characters into the proper hex numbers.

Printing a String of Characters

To print a string of characters on the screen, like Hello there, you'll need to use both an indirect addressing mode and an assembler pseudo-op to define some data.

In the *Merlin* assembler, there is a HEX command for directly entering the hex bytes of a data table. Program 10-1 is a sample program using the indexed address mode.

Program 10-1. Print Demo 1

```
                        1  ***********************************************
                        2  *       SAMPLE 'PRINT' PROGRAM #1             *
                        3  *             MERLIN ASSEMBLER                *
                        4  ***********************************************
                        5
                        6              ORG   $300
                        7
            =FDED       8  COUT        EQU   $FDED
                        9
000300: A2  00          10 BEGIN       LDX   #$00          ; START WITH X = 0
                        11
000302: BD  13  03      12 LOOP        LDA   DATA,X        ; READ A BYTE OF DATA
000305: 20  ED  FD      13             JSR   COUT          ; PRINT ASCII CHARACTER
000308: E8              14             INX                 ; X = X + 1
000309: E0  0B          15             CPX   #11           ; DONE WITH LIST
00030B: 90  F5  =0302   16             BCC   LOOP          ; X < 11 MEANS NO . . .
00030D: A9  8D          17             LDA   #$8D          ; #$8D = CARRIAGE RETURN
00030F: 20  ED  FD      18             JSR   COUT          ; PRINT IT
                        19
000312: 60              20 DONE        RTS
                        21
000313: C8  E5  EC  EC  22 DATA        HEX C8,E5,EC,EC,EF,A0,F4,E8,E5,F2,E5
000317: EF  A0  F4  E8
        E5  F2  E5
                    23
                        24 * DATA = 'Hello there'

--End Merlin-16 assembly, 30 bytes, Errors: 0
```

The hex values in the data table are the ASCII values for each letter plus $80. This sets the *high bit* of each number, which is what the Apple expects to have the letter printed out properly when using COUT.

This program uses the X register as both a counter for the number of characters to print and as a pointer to the place in the data block from which the next character will be read. COUT does not affect the X register, so you don't have the concern about it being altered, as we did with the accumulator and COUT in the last chapter.

Line 10 starts the program by setting the X register to 0. The main loop then uses the indexed addressing mode to add the value of the X register to the address of the DATA table at $313. As X is incremented after each character is printed, it's checked against the number of character to be printed—the number of characters in the string. Notice that line 15 compares against the *decimal* value 11 by not using the dollar sign in front of the number. The pound sign is still needed to show it's an immediate mode value.

Note that there are 11 characters in the string, but the use of 11 in the CPX instruction is almost coincidence. Remember that the first character read from the table is done with X starting at 0. On this basis, when X has reached 10, it has reached the last character of the string. In the program, however, X is incremented *before* the check. Thus, X will be 11 after the last character has been printed.

When writing programs you must keep *all* of the following in mind: the starting value of the indexed register, which test you want to use to determine the end of the loop (BCC, BEQ, BNE, BCS, or another test), and whether the test occurs before or after an increment or decrement has been done.

After printing, the program ends with a carriage return. Remember that in assembly language you must usually do everything yourselves. This means you cannot assume an automatic carriage return at the end a printed string.

You'll notice the data table is put at the end of the program. This is because the computer, as such, can't tell the difference between data and a program. It's up to you to keep your data tables from being executed as a program. For a closer look, BLOAD the assembled file and list it from the Monitor.

```
*300L
1=m   1=x   1=LCbank (0/1)
00/0300: A2 00          LDX  #00
00/0302: BD 13 03       LDA  0313,X
00/0305: 20 ED FD       JSR  FDED
00/0308: E8             INX
00/0309: E0 0B          CPX  #0B
00/030B: 90 F5          BCC  0302 {-0B}
00/030D: A9 8D          LDA  #8D
00/030F: 20 ED FD       JSR  FDED
00/0312: 60             RTS
00/0313: C8             INY
00/0314: E5 EC          SBC  EC
00/0316: EC EF A0       CPX  A0EF
00/0319: F4 E8 E5       PEA  E5E8
00/031C: F2 E5          SBC  (E5)
```

Notice that after the RTS at $312, the data table lists as instructions also. This is because the Monitor disassemble command (like the 65816 while running a program) has no way of knowing that the bytes from $313 to $31D are ASCII text (or any other kind of data for that matter).

Now, while still in the Monitor, type

```
300.320
```

The screen will display

```
*300.320

00/0300: A2  00  BD 13  03  20  ED  FD-".=.. m}
00/0308: E8  E0  0B  90  F5  A9  8D  20-h'..u).
00/0310: ED  FD  60  C8  E5  EC  EC  EF-m}'Hello
00/0318: A0  F4  E8  E5  F2  E5  06  D0- there.P
00/0320: 24-$
*
```

To the right of the hex values, you can see the ASCII equivalents. The Monitor dump command normally only shows as printable characters those bytes whose high bit is set (value is greater than $7F). At the beginning of the dump, the assembly language instructions do not list as any intelligible characters. At the bottom of the group you can see the phrase *Hello there.*

By using both the Monitor list and dump commands, you can sometimes tell whether the part of memory you're looking at has a program or data in it. Of course, certain opcodes (like $AD for LDX) can appear like ASCII text in a dump, and ASCII text (like $C8 = INY) can appear like an instruction. It's also possible that the data stored in a program is not necessarily ASCII text. Perhaps it's the sizes of different objects, the quantity of an item, or some other information. In general, though, a little thoughtful examination can decipher many programs, even without the source code.

Some assmblers, like the *Merlin 8/16,* also have utilities to create actual text file source listings from object code in memory. Even these, though, require thoughtful use to yield intelligent results.

Sample Print Program #1 with *APW*

Program 10-2 is the same print demo as Program 8-1 for the *APW* assembler.

The main differences with the *APW* listing are the START, END, LONGA and LONGI directives, and the way that stored data is defined with the DC pseudo-op. START and END were discussed in Chapter 5. LONGA and LONGI are directives that tell the assembler not to create object code that expects 16-bit operations.

Sixteen-bit refers to an operating mode of the 65816 where most of the registers are two bytes (16 bits) in size, instead of the 8-bit size we've been looking at so far. Because Applesoft BASIC was written on older Apples that only had one-byte registers, we've been limiting the programs written thus far to this same mode. In the *APW* assembler, you must start a source listing with

Program 10-2. Print Demo 1 for the *APW* Assembler

```
*****************************************
*   SAMPLE 'PRINT' PROGRAM #1           *
*          APW ASSEMBLER                *
*****************************************

         KEEP     D.PROG1

         ORG      $300

         LONGA    OFF
         LONGI    OFF

MAIN     START

COUT     EQU      $FDED

BEGIN    LDX      #$00          ; START WITH X = 0

LOOP     LDA      DATA,X        ; READ A BYTE OF DATA
         JSR      COUT          ; PRINT ASCII CHARACTER
         INX                    ; X = X + 1
         CPX      #11           ; DONE WITH LIST
         BCC      LOOP          ; X < 11 MEANS NO . . .
         LDA      #$8D          ; #$8D = CARRIAGE RETURN
         JSR      COUT          ; PRINT IT

DONE     RTS

DATA     DC       H'C8 E5 EC EC EF A0 F4 E8 E5 F2 E5'

* DATA = 'Hello there'

         END
```

LONGA OFF and LONGI OFF if you want the following accumulator and index register (X and Y) instructions to be compatible with Applesoft BASIC. In just a few chapters, you'll see how to use the extended register size in other programs. For the time being, though, just start any *APW* source listing with LONGA OFF and LONGI OFF.

APW doesn't have a HEX pseudo-op. Instead, it has the pseudo-op DC (for Defined Constant), which is then followed by a modifier to tell the assembler what kind of number you want to define. For our program, *H* stands for *Hex* and tells the assembler to use the values that follow to determine how many bytes of hex data to include in the data block. The single apostrophe is call a *delimiter*, and it is used to contain the list of data.

ASCII Data Pseudo-Ops

You might now be thinking that it's not very convenient to have to look up the ASCII values of each character that you want to print. It's also not much fun to have to count how many characters there are in the string. Well, you're in luck. There is a way of writing your program to eliminate both these inconveniences. Program 10-3 is the new program.

Program 10-3. Print Demo 2

```
                        1 ****************************************
                        2 *   SAMPLE 'PRINT' PROGRAM #2          *
                        3 *          MERLIN ASSEMBLER            *
                        4 ****************************************
                        5
                        6         ORG  $300
                        7
          =FDED         8 COUT    EQU  $FDED
                        9
000300: A2  00         10 BEGIN   LDX  #$00        ; START WITH X = 0
                       11
000302: BD 0E  03      12 LOOP    LDA  DATA,X      ; READ A BYTE OF DATA
000305: F0  06  =030D  13         BEQ  DONE        ; 0 = END OF STRING
000307: 20  ED FD      14         JSR  COUT        ; PRINT ASCII CHARACTER
00030A: E8             15         INX              ; X = X + 1
00030B:80  F5  =0302   16         BRA  LOOP        ; NEXT CHARACTER
                       17
00030D:60              18 DONE    RTS
                       19
00030E: C8  E5  EC  EC 20 DATA    ASC  "Hello there",8D,00
000312: EF  A0  F4  E8  E5  F2  E5  8D
00031A: 00
                       21

--End Merlin-16 assembly, 27 bytes, Errors: 0
```

This program has two improvements. First, the pseudo-op **ASC** (ASCII) is used to automatically translate the text we want to print into the proper hex bytes in memory. The *Merlin 8/16* uses quotes (") to signify bytes with the high bit on, and it uses the apostrophe to signify bytes with the high bit clear. In addition, *Merlin*'s ASC command lets us end the string of characters with any hex values, by just using commas.

We'll use this first to include the carriage return as part of the string, and then to put a zero at the end of the string that we can detect with a BEQ instruction.

You can see that, on line 13 of the program, when a character is loaded with a value of zero, the BEQ will detect it and branch to DONE. This means that we don't have to check for a specific length of a string, which makes editing the source listing much easier if you decide to change a printed message in a program.

If you're using the *APW* assembler, the equivalent source listing is shown in Program 10-4.

Program 10-4. *APW* Print Demo 2

```
******************************************
*   SAMPLE 'PRINT' PROGRAM #2     *
*          APW ASSEMBLER                *
******************************************

         KEEP    D.PROG2

         ORG     $300

         LONGA   OFF
         LONGI   OFF

         MSB     ON

MAIN     START

COUT     EQU     $FDED

BEGIN    LDX     #$00        ; START WITH X = 0

LOOP     LDA     DATA,X      ; READ A BYTE OF DATA
         BEQ     DONE        ; 0 = END OF STRING
         JSR     COUT        ; PRINT ASCII CHARACTER
         INX                 ; X = X + 1
         BRA     LOOP        ; GET NEXT CHARACTER

DONE     RTS

DATA     DC      C'Hello there',H'8D 00'

         END
```

The *APW* assembler uses C (for Character) to designate text data in the DC command. You can also mix data types on one line, so you can put the H'8D 00' bytes at the end of the string.

VTAB and HTAB in Assembly Language

Being able to print something on the screen is nice—you know how to clear the screen (HOME = $FC58) and print a string (COUT = $FDF0)—but what about positioning the cursor to control *where* the string is printed?

The easiest way, for now, is to use the Monitor routine VTAB for the vertical position, and to directly control the horizontal cursor location, CH (for Cursor Horizontal = memory location $24).

Program 10-5. Print Demo 3

```
                      1 ******************************************
                      2 *    SAMPLE 'PRINT' PROGRAM #3     *
                      3 *         MERLIN ASSEMBLER          *
                      4 ******************************************
                      5
                      6         ORG  $300
                      7
          =FC58       8 HOME    EQU  $FC58
          =FDED       9 COUT    EQU  $FDED
          =FC22      10 VTAB    EQU  $FC22       ; VTAB TO CV
          =0025      11 CV      EQU  $25         ; VERTICAL POSITION
          =0024      12 CH      EQU  $24         ; HORIZ. CURSOR
                     13
                     14
000300: 20 58 FC     15 BEGIN   JSR  HOME
000303: A9 0B        16         LDA  #11
000305: 85 25        17         STA  CV          ; CURSOR VERT. POSN.
000307: 20 22 FC     18         JSR  VTAB        ; VTAB 12
00030A: A9 09        19         LDA  #9          ; HTAB 10
00030C: 85 24        20         STA  CH          ; HORIZ. POSITION
                     21
00030E: A2 00        22         LDX  #$00        ; START WITH X = 0
                     23
000310: BD 1C 03     24 LOOP    LDA  DATA,X      ; READ A BYTE OF DATA
000313: F0 06 =031B  25         BEQ  DONE        ; 0 = END OF STRING
000315: 20 ED FD     26         JSR  COUT        ; PRINT ASCII CHARACTER
000318: E8           27         INX              ; X = X + 1
000319: 80 F5 =0310  28         BRA  LOOP        ; NEXT CHARACTER
                     29
00031B: 60           30 DONE    RTS
                     31
00031C: C8 E5 EC EC  32 DATA    ASC  "Hello there",8D,00
000320: EF A0 F4 E8 E5 F2 E5 8D
000328: 00
                     33

--End Merlin-16 assembly, 41 bytes, Errors: 0
```

As a working example, let's first create a program that will position the cursor somewhere on the screen and print a string starting at that position. Here's an equivalent Applesoft BASIC program:

```
10 HOME
20 VTAB 12
30 HTAB 10
40 PRINT "THIS IS A TEST"
50 END
```

Type in the third Print demo, Program 10-5.

This program is fairly equivalent to the earlier one, except that it first clears the screen with a JSR HOME. Then it stores the desired vertical cursor position in the part of memory that Applesoft BASIC uses for the cursor's vertical position, CV (for Cursor Vertical = $25). To put the cursor in the proper vertical position, we need to do a JSR VTAB. VTAB ($FC22) is a routine that uses the value stored in CV and puts the cursor at the corresponding vertical position on the screen. CV counts from 0 to 23 (as opposed to Applesoft BASIC's 1 to 24), so if we want the twelfth line, we must store 11 in CV.

Finally, a 9 is stored in CH to do the equivalent of HTAB 10. CH also counts starting at 0, so we must use a value that's one less than the normal position value.

From there, the rest of the program is identical to SAMPLE PRINT PROGRAM #2.

Indirect Addressing

The *indirect addressing* mode is used when you want to access one memory location depending on what you've stored in a different location, or when the range of data is greater than the 256-byte range we can access by incrementing the X register.

Let's consider the problem of clearing the screen. In this case, we want to put a space character in every memory location in the screen block ($400–$7FF). One way of doing this is shown in Program 10-6.

First, locations $06 and $07 are initializing to hold the base address of $400, the address of the first byte of the screen memory area. The label PTR is used for location $06. Line 11 shows how the assembler can use STA PTR+1 to create STA $07. Doing it this way helps the source listing remind us that locations $06,07 form a pair. The ASCII value for A is then put in the accumulator, and Y is initialized to $00 to begin the upcoming loop.

Then we enter a loop which runs the Y register from $00 to $FF. Since this is added to the base address in $06,07 ($400), this stores an $A0 (a space) in every location from $400 to $4FF. When Y is incremented from $FF, it goes back to $00, a move that's detected by the BNE on line 22. At zero, it falls through, and location $07 is incremented from $04 to $05, giving a new base address of $500.

This whole process is repeated until location $07 reaches a value of $08 (corresponding to a base address of $800), at which point we return from the routine. Notice that we don't have to reinitialize the Y register to zero for each new pass through the loop. This is because the BNE test guarantees that the Y register will be zero when the new pass is started.

Program 10-6. Clear Screen Demo 1A

```
                        1  ***********************************************
                        2  *       SCREEN CLEAR PROGRAM #1A              *
                        3  *           MERLIN ASSEMBLER                  *
                        4  ***********************************************
                        5
                        6             ORG   $300
                        7
           =0006        8  PTR        EQU   $06          ; $06,07
                        9
000300: A9 04          10  ENTRY      LDA   #$04         ; HIGH-ORDER BYTE OF $400
000302: 85 07          11             STA   PTR+1        ; SET HIGH BYTE OF PTR
000304: A9 00          12             LDA   #$00         ; LOW-ORDER BYTE OF $400
000306: 85 06          13             STA   PTR          ; SET LOW BYTE OF PTR
                       14
                       15  * SETS PTR (6,7) TO $400
                       16
000308: A9 A0          17  START      LDA   #$A0         ; ASCII FOR 'SPACE' CHARACTER
00030A: A0 00          18             LDY   #$00
                       19
00030C: 91 06          20  LOOP       STA   (PTR),Y      ; PUT 'SPACE' IN MEMORY
00030E: C8             21             INY                ; Y = Y + 1
00030F: D0 FB  =030C   22             BNE   LOOP         ; BRANCH WHILE Y = $1 TO $FF
                       23
000311: E6 07          24  NEXT       INC   PTR+1        ; PTR GOES FROM $400 TO $500, ETC.
000313: A5 07          25             LDA   PTR+1
000315: C9 08          26             CMP   #$08         ; STOP WHEN PTR = $800
000317: 90 EF  =0308   27             BCC   START        ; NOT THERE YET
                       28
000319: 60             29  EXIT       RTS
                       30
                       31

--End Merlin-16 assembly, 26 bytes, Errors: 0
```

Clear to a Character

By changing the value of the #$A0 to some other character, you can clear the screen to any character you wish. In fact, you can get the value from the keyboard as we've done in earlier programs.

Let's take this opportunity to show some new assembler tricks. Program 10-7 is the revised version.

The first change to notice is that the beginning of the screen memory area has been given a label, SCRN (line 10). In general, it's a good idea to avoid specific addresses in the body of your programs. By assigning a label, you accomplish two things. First, if you ever want to change the memory area affected, you only need to change one line, rather than many individual uses of the address. Second, you make it possible for the assembler to help you discover typing errors.

It works like this: Suppose you used the address $313 in a program in a dozen different places, and in one of those uses you accidentally typed $314. The assembler has no way of knowing this is not what you intended, and it could take a long time to track down the mistake when debugging your program. On the other hand, if you assign $313 = LABEL, and then somewhere accidentally type LABLE, the assembler will automatically generate a Label Not Defined (or similar) error, which you can quickly remedy.

Since the value of SCRN could now be almost anything, we can't use the LDA #$04 and LDA #$00 for the high and low bytes. Fortunately, the assembler will do the calculation for us. By using the < and > symbols after the pound sign and before the label, the assembler will automatically calculate the high- and low-order bytes of the address defined by SCRN, and it will use them when assembling the line (see lines 14 and 16). The low-order byte is indicated by <; the high-order byte is indicated by >.

There's another change you might not see at first glance. Notice that lines 16 and 17 now use LDY, STY. As long as you know that SCRN will start at a *page boundary* ($400, $500, and so forth), you also know that the low-order byte will always be zero. You can use this fact to save an instruction to set the Y register to zero. Since it makes no difference which register is used on line 16 and 17 to set up PTR, we can take care of the Y register at the same time.

We've also added a check for the Escape key, so you can exit the program when you wish.

If the Escape key is not pressed, the value is then temporarily held in the variable CHAR so that it can be retrieved each time after incrementing PTR in the NEXT section.

With the screen display in the 40-column mode, BLOAD this program and run it from BASIC with a CALL 768. Each keypress will clear the screen

Program 10-7. Clear Screen Demo 1B

```
                              ***********************************************
                              *      SCREEN CLEAR PROGRAM #1B               *
                              *            MERLIN ASSEMBLER                 *
                              ***********************************************

                                          ORG    $300

            =0006             PTR         EQU    $06           ; PTR = $06,07
            =0008             CHAR        EQU    $08
            =0400             SCRN        EQU    $400
            =C000             KYBD        EQU    $C000
            =C010             STROBE      EQU    $C010

000300: A9 04                 ENTRY       LDA    #>SCRN        ; HIGH-ORDER BYTE OF $400
000302: 85 07                             STA    PTR+1         ; SET HIGH BYTE OF PTR
000304: A0 00                             LDY    #<SCRN        ; LOW-ORDER BYTE OF $400 AND Y = 0
000306: 84 06                             STY    PTR           ; SET LOW BYTE OF PTR

                              * SETS PTR (6,7) TO $400

000308: AD 00 C0              READ        LDA    KYBD          ; GET KYBD CHARACTER VALUE
00030B: C9 80                             CMP    #$80          ; KEYPRESS
00030D: 90 F9    =0308                    BCC    READ          ; NO, THEN TRY AGAIN.
00030F: 8D 10 C0                          STA    STROBE        ; CLEAR KYBD STROBE.

000312: C9 9B                 CHECK       CMP    #$9B          ; ESCAPE
000314: F0 13    =0329                    BEQ    DONE          ; YES

000316: 85 08                             STA    CHAR          ; SAVE CHARACTER VALUE

000318: A5 08                 CLEAR       LDA    CHAR          ; GET CHAR TO 'CLEAR' TO

00031A: 91 06                 LOOP        STA    (PTR),Y       ; PUT CHAR IN MEMORY
00031C: C8                                INY                  ; Y = Y + 1
00031D: D0 FB    =031A                    BNE    LOOP          ; BRANCH WHILE Y = $1 TO $FF

00031F: E6 07                 NEXT        INC    PTR+1         ; PTR GOES FROM $400 TO $500, ETC.
000321: A5 07                             LDA    PTR+1         ; GET VALUE INTO ACC.
000323: C9 08                             CMP    #$08          ; STOP WHEN PTR = $800
000325: 90 F1    =0318                    BCC    CLEAR         ; NOT THERE YET

000327: 80 D7    =0300        AGAIN       BRA    ENTRY         ; GO BACK FOR MORE

000329: 60                    DONE        RTS                  ; ALL DONE!


--End Merlin-16 assembly, 43 bytes, Errors: 0
```

to a different character. The screen should also clear to the same character as the key you press, including space bar and special characters. This program shows you how fast machine language is. Clearing the screen requires over 1000 different locations to be set to the given value. In Applesoft BASIC, this would be quite slow by comparison. Here you'll find that the screen will clear to different characters just as fast as you can type them.

An interesting variation on this is to enter the graphics mode by typing in GR before calling the routine. Then the screen will clear to various colors and different line patterns.

See what other variations you can make on this, try modifying the program to clear the hi-res screen ($2000–$3FFF).

Using Indirect Indexed Addressing for a Better Screen Clear

If you multiply the number of lines on a 40-column screen (24) by the number of characters (40), you get 960 (24 * 40 = 960). This is a smaller number than the actual memory allocated to the screen memory, $400 to $7FF = $400 bytes = 1024.

It turns out that the Apple IIGS uses an unusual system of assigning each character position on the screen to a byte of memory. You might think it would have been most logical to have the first 40 bytes of the first line correspond to the first 40 bytes of memory, and so on, but that's not the way it works. It turns out that such a linear calculation would take much longer, and would be harder to implement in the hardware circuitry of the computer, than the method that is actually used. At first look, the system seems to be rather chaotic:

Screen Line	Address Range: Hex	Address Range: Decimal
1	$400–$427	1024–1063
2	$480–$4A7	1152–1191
3	$500–$527	1280–1319
4	$580–$5A7	1408–1447
5	$600–$627	1536–1575
6	$680–$6A7	1664–1703
7	$700–$727	1792–1831
8	$780–$7A7	1920–1959
9	$428–$44F	1064–1103
10	$4A8–$4CF	1192–1231
11	$528–$54F	1320–1359
12	$5A8–$5CF	1448–1487
13	$628–$64F	1576–1615
14	$6A8–$6CF	1704–1743
15	$728–$74F	1832–1871

Screen Line	Address Range: Hex	Address Range: Decimal
16	$7A8–$7CF	1960–1999
17	$450–$477	1104–1143
18	$4D0–$4F7	1232–1271
19	$550–$577	1360–1399
20	$5D0–$5F7	1488–1527
21	$650–$677	1616–1655
22	$6D0–$6F7	1744–1783
23	$750–$777	1872–1911
24	$7D0–$7F7	2000–2039

As you look at the list, a certain pattern does emerge, but it is not necessary to go into any detail about the actual mechanics of the calculations. Suffice it to say that determining these addresses is precisely the purpose of the VTAB routine used in Program 10-3.

As you study the table, you'll notice that the last eight bytes of memory used by the last eight screen lines are not used (64 bytes total). For example, the range of bytes from $478 to $47F (screen line 17) are never used in the screen display itself. These gaps in memory usage are called "screen holes," and they have been reserved for use by hardware devices assigned to each slot. The assignments are as follows:

			Slot Number				
0	1	2	3	4	5	6	7
$478	$479	$47A	$47B	$47C	$47D	$47E	$47F
$4F8	$4F9	$4FA	$4FB	$4FC	$4FD	$4FE	$4FF
$578	$579	$57A	$57B	$57C	$57D	$57E	$57F
$5F8	$5F9	$5FA	$5FB	$5FC	$5FD	$5FE	$5FF
$678	$679	$67A	$67B	$67C	$67D	$67E	$67F
$6F8	$6F9	$6FA	$6FB	$6FC	$6FD	$6FE	$6FF
$778	$779	$77A	$77B	$77C	$77D	$77E	$77F
$7F8	$7F9	$7FA	$7FB	$7FC	$7FD	$7FE	$7FF

Since there really is no slot 0 on the Apple IIGS, the first group of bytes can be used by any slot. This means that a card using these locations should not assume they will be maintained if another card also has to use them.

Generally speaking, it's a good idea to never use the first group. The groups for slots 1 through 7 are considered private memory, and cards may use these locations to store any required data. For the printer and communications ports (slots 1 and 2), this can include baud rate, parity, or other information. The 80-column firmware for example, which always looks like it's in slot 3, stores its current horizontal cursor position in location $57B.

If you write your own programs that manipulate the horizontal cursor position, as does Program 10-3, you must control the contents of $57B (CH80 is the common assembly label) in addition to $24 (CH40).

The mouse firmware make extensive use of the screen holes for storing the current *x,y* position, the clamping values, and more.

You may wonder why the slot/address assignments didn't group all bytes for a given slot together, for example, $4F8 to 4FF for slot 1. The reason was to make indexed addressing easier. A printer card, for example, could be placed in any slot.

```
TAY              ; PUT SLOT # IN Y (1-7)
LDA  $478,Y      ; GET A BYTE
STA  $4F8,Y      ; PUT IT IN ANOTHER SCREEN HOLE
LDA  $578,Y      ; AND SO ON.
STA  $5F8,Y
LDA  $678,Y
STA  $6F8,Y
LDA  $778,Y
STA  $7F8,Y
```

Based on the above, you may have noticed that Program 10-6 cleared all the invisible screen holes—not a wise thing to do. If you run the program with DOS 3.3 active and then do a CATALOG, you'll hear the disk drive grind as it starts back up and discovers some of it's information stored in the screen holes has been altered.

A better screen clear program uses the VTAB routine and indirect indexed addressing to clear just those bytes you see on the screen. Program 10-8 is the improved listing.

Notice that the VTAB routine sets up **BASL (BASe address Low byte)** with the address of the beginning of the line. We then use indirect indexed addressing to store the character at each character position on a given line.

There are two main loops in the program. Line 39 checks the Y Register to keep it in the range of 0 to 39 for the horizontal character loop. Line 44 checks to see if the current line counter has reached the bottom of the screen. Remember that the horizontal and vertical counts go from 0 to 39 and from 0 to 23, respectively. BCC is thus the proper test to use, since this will branch as long as each counter is *less than* its prescribed limit.

Program 10-8. Screen Clear Demo 1C

```
                          ************************************************
                          *      SCREEN CLEAR PROGRAM #1C                 *
                          *            MERLIN ASSEMBLER                   *
                          ************************************************

                                   ORG   $300

              =0006       LINE     EQU   $06          ; WHAT LINE WE’RE ON
              =0008       CHAR     EQU   $08
              =C000       KYBD     EQU   $C000
              =C010       STROBE   EQU   $C010

              =0025       CV       EQU   $25          ; VERTICAL CURSOR POSN
              =FC22       VTAB     EQU   $FC22
              =0028       BASL     EQU   $28          ; $28,29 = BASE ADDRESS


000300: AD 00 C0          READ     LDA   KYBD         ; GET KYBD CHARACTER VALUE
000303: C9 80                      CMP   #$80         ; KEYPRESS?
000305: 90 F9  =0300               BCC   READ         ; NO, THEN TRY AGAIN.
000307: 8D 10 C0                   STA   STROBE       ; CLEAR KYBD STROBE.

00030A: C9 9B             CHECK    CMP   #$9B         ; ESCAPE?
00030C: F0 20  =032E               BEQ   DONE         ; YES

00030E: 85 08                      STA   CHAR         ; SAVE CHARACTER VALUE

000310: 64 06             INIT     STZ   LINE         ; SET LINE = 0

000312: A5 06             FINDV    LDA   LINE         ; GET LINE VALUE
000314: 85 25                      STA   CV           ; VERTICAL CURSOR POSN
000316: 20 22 FC                   JSR   VTAB         ; CALCULATE BASE ADDRESS

000319: A5 08             CLEAR    LDA   CHAR         ; GET CHAR TO ‘CLEAR’ TO
00031B: A0 00                      LDY   #$00         ; ZERO Y REGISTER

00031D: 91 28             LOOP     STA   (BASL),Y     ; PUT CHAR IN MEMORY
00031F: C8                         INY                ; Y = Y + 1
000320: C0 28                      CPY   #40          ; END OF LINE?
000322: 90 F9  =031D               BCC   LOOP         ; NOPE: NEXT POSITION

000324: E6 06             NXTLN    INC   LINE         ; LINE = LINE + 1
000326: A5 06                      LDA   LINE
000328: C9 18                      CMP   #24          ; DONE YET?
00032A: 90 E6  =0312               BCC   FINDV        ; NOPE

00032C: 80 D2  =0300      AGAIN    BRA   READ         ; GET ANOTHER CHARACTER!

00032E: 60                DONE     RTS                ; ALL DONE!

00032F: AB                         CHK                ; CHECKSUM FOR LISTING

--End Merlin-16 assembly, 48 bytes, Errors: 0
```

Command Processing with Indexed Indirect Addressing

The final example for this chapter is a demonstration of how indexed indirect addressing can be used to easily process a command. The principle behind the operation is to use the command as the X register index into a table of entry points to the desired routines.

In the early example of indexed indirect addressing, a direct page address was used as the base address for a LDA instruction. For the JSR and JMP instructions, a complete 2-byte address can be used, like this:

```
JSR ($0300,X)
```

or

```
JMP ($0300,X)
```

What is needed now is a way to store, in the program itself, the addresses of the routines that we want to call. The program can then load the X register with the value for a command and jump directly to the subroutine. Program 10-9 is an example.

The first thing to notice is the use of a new assembler pseudo-op, **DA (Defined Address)** on lines 44–46. This instruction tells the assembler to create a pair of bytes in memory, as part of the object file, that have values equal to the label specified in the instruction. On line 44, the statement DA CMD1 tells the assembler to first evaluate the label CMD1, which in this assembly is equal to $32E (see line 48). The assembler then stores the address, low-order byte first, at the beginning of the data table, location $328. The next two DA statements store the address for CMD2 and CMD3. You can use the DA instruction in a program whenever you want to create two bytes of data that form a pointer to somewhere else in memory.

Now, let's look at the program as a whole. After first clearing the screen, the program gets a keypress and then checks for the Escape key. Lines 26–29 then check to see if the key is in the acceptable range—this program accepts keys 1, 2, and 3. The first test on lines 26, 27 compare against the value for 1. A BCC instruction will branch back if the value is less than 1.

Because the next test will be done with a BCS instruction, which tests for greater than or equal to, we need to compare with a value one larger than the last allowable value. Lines 28, 29 do this test.

At this point the accumulator holds the value $B1, $B2, or $B3. This must first be converted to a command number of 0, 1, or 2. Lines 31–33 subtract #$B1 to get a result in this range. The table is made up of two-byte groups; thus the proper entry points are stored at TABLE, TABLE+2 and TABLE+4 ($328, $32A and $32C). This means that the X register must be loaded with 0, 2, or 4 for the indirect JSR to work properly.

Lines 35,36 add the value for CMD to itself (equivalent to multiplying by 2), and then put this value in the X register. Line 40 then does the actual indirect JSR to the appropriate routine, which prints the characters A, B, or C, depending on which number key is pressed.

This may seem a little more complicated than the alternative method of a CMP and direct JSR, but for large numbers of commands you may find this method of using the indirect JSR more efficient.

***APW* user please note.** In the *APW* assembler, lines 44-46 used the defined constant pseudo-op, and should look like this:

```
DC  I2'CMD1'
DC  I2'CMD2'
DC  I2'CMD3'
```

Program 10-9. Command Processor Example

```
                          1 ******************************************
                          2 * COMMAND PROCESSOR EXAMPLE *
                          3 *        MERLIN ASSEMBLER        *
                          4 ******************************************
                          5
                          6           ORG  $300
                          7
           =C000          8 KYBD      EQU  $C000
           =C010          9 STROBE    EQU  $C010
                         10
           =FC58         11 HOME      EQU  $FC58     ; CLEAR SCREEN
           =FDED         12 COUT      EQU  $FDED
                         13
           =0006         14 CMD       EQU  $06
                         15
000300: 20 58 FC         16 ENTRY     JSR  HOME
                         17
000303: AD 00 C0         18 READ      LDA  KYBD      ; GET KYBD CHARACTER VALUE
000306: C9 80            19           CMP  #$80      ; KEYPRESS?
000308: 90 F9  =0303     20           BCC  READ      ; NO, THEN TRY AGAIN.
00030A: 8D 10 C0         21           STA  STROBE    ; CLEAR KYBD STROBE.
                         22
00030D: C9 9B            23 CHECK     CMP  #$9B      ; ESCAPE?
00030F: F0 2F  =0340     24           BEQ  DONE      ; YES
                         25
000311: C9 B1            26           CMP  #"1"      ; 1ST ALLOWABLE CHARACTER
000313: 90 EE  =0303     27           BCC  READ      ; NOPE TRY AGAIN
000315: C9 B4            28           CMP  #"4"      ; LAST CHAR + 1
```

```
000317: B0 EA =0303          BCS  READ

000319: 38                   SEC            ; GET READY TO SUBTRACT
00031A: E9 B1                SBC  #$B1      ; VALUE FOR '1'
00031C: 85 06                STA  CMD       ; SAVE CMD VALUE

00031E: 18                   CLC
00031F: 65 06                ADC  CMD       ; ACC = 2 * CMD VALUE

000321: AA                   TAX            ; PUT CMD IN X REGISTER

000322: FC 28 03     PROCESS JSR  (TABLE,X) ; GO TO APPROPRIATE ROUTINE

000325: 4C 03 03             JMP  READ      ; BACK FOR MORE!

000328: 2E 03        TABLE   DA   CMD1      ; LOC OF ROUTINE #1
00032A: 34 03                DA   CMD2      ; LOC OF ROUTINE #2
00032C: 3A 03                DA   CMD3      ; LOC OF ROUTINE #3

00032E: A9 C1        CMD1    LDA  #"A"
000330: 20 ED FD             JSR  COUT
000333: 60                   RTS

000334: A9 C2        CMD2    LDA  #"B"
000336: 20 ED FD             JSR  COUT
000339: 60                   RTS

00033A: A9 C3        CMD3    LDA  #"C"
00033C: 20 ED FD             JSR  COUT
00033F: 60                   RTS

000340: 60           DONE    RTS            ; ALL DONE!

000341: EB                   CHK            ; CHECKSUM FOR LISTING

--End Merlin-16 assembly, 66 bytes, Errors: 0
```

Chapter 11

Data Storage and Program Control

Chapter 11

Data Storage and Program Control

This chapter starts with a question: When your program does a JSR to some other part of memory, how does the 65816 microprocessor keeps track of *where* to return?

It's possible that there is some as-yet-unmentioned register in the 65816 itself that could hold the returning address, but suppose your called subroutine does a JSR itself? With room for only one stored address, the microprocessor register would already be busy keeping track of the first address, and things would come to a screeching halt.

The Stack

The answer is to set aside an area of RAM in the computer itself to store a large number of temporary values. This area is called the *stack,* and, for Applesoft BASIC and simple related routines, it occupies all of *page one* ($100–$1FF) of memory. The area can actually be reassigned anywhere in the first 64K of memory (Bank 0), but you'll see how to do that a little later.

The area is called the stack because it acts something like a physical stack of items. If you put three items in a stack, one at a time, you can't get back to the first item until you remove the last two placed there. The stack in the Apple is the same way, and is often refered to as a last in, first out stack (LIFO). If you place the value 1, then 2, then 3 on the stack in memory, you get the values back in the reverse order, 3, 2, 1.

You've already used the stack in a program by using the JSR instruction. When the 65816 encounters a JSR in a program, it first determines the address of the instruction which follows JSR. This address is then put on the stack for temporary storage, and the JSR to the target address is done. When the RTS at the end of the subroutine is reached, the 65816 takes the stored *return address* off the stack and goes back to executing the program at the instruction which follows the JSR.

The stack can be used for more than maintaining JSRs however. You can put the contents of any of the A, X, or Y registers on the stack with the appropriate push command: **PHA (PusH Accumulator)**, **PHX (PusH X)**, and **PHY (PusH Y)**. These place a copy of whatever value is in the referenced register onto the stack. Whether this consists of one or two bytes depends on the condition of the *e*, *m*, and *x* bits, which control register sizes.

To get a value off the stack, you use the corresponding *pull* instructions: **PLA (PuLl Accumulator)**, **PLX (PuLl X)**, and **PLY (PuLl Y)**.

As with the push instructions, the number of bytes removed from the stack also depend on the settings of the *e*, *m*, and *x* bits.

You don't have to use the same register to remove data from the stack as you used to put it there. The only crucial requirement is that the number of bytes put on the stack be the same as the number removed. Here's a sample program that uses the stack:

```
LDA  #"A"        ; VALUE FOR "A" IN ACCUMULATOR.
PHA              ; PUT VALUE (ONE BYTE) ON STACK.
PLX              ; RETREIVE VALUE INTO X REGISTER.
STX  $5BC        ; PUT IT ON SCREEN.
```

The program begins by loading the accumulator with the single-byte ASCII value for the letter *A*. This is then pushed onto the stack. Next, PLX pulls a single byte from the stack, and puts it in the X register. It's then stored in screen memory to make the byte visible.

Keep It Balanced

In using the stack, it's of ***critical*** importance that you keep all pushes and pulls balanced. That is, *if your routine pushes two bytes onto the stack, your routine should also remove those same two bytes before your final RTS.* All information in the stack is organized *only* by its position there. There are no labels or other identifiers. When Applesoft BASIC does a CALL to a routine, the return address for your BASIC program is put on the stack. If your program looked like these three lines, the computer will probably crash or lock up when you run it:

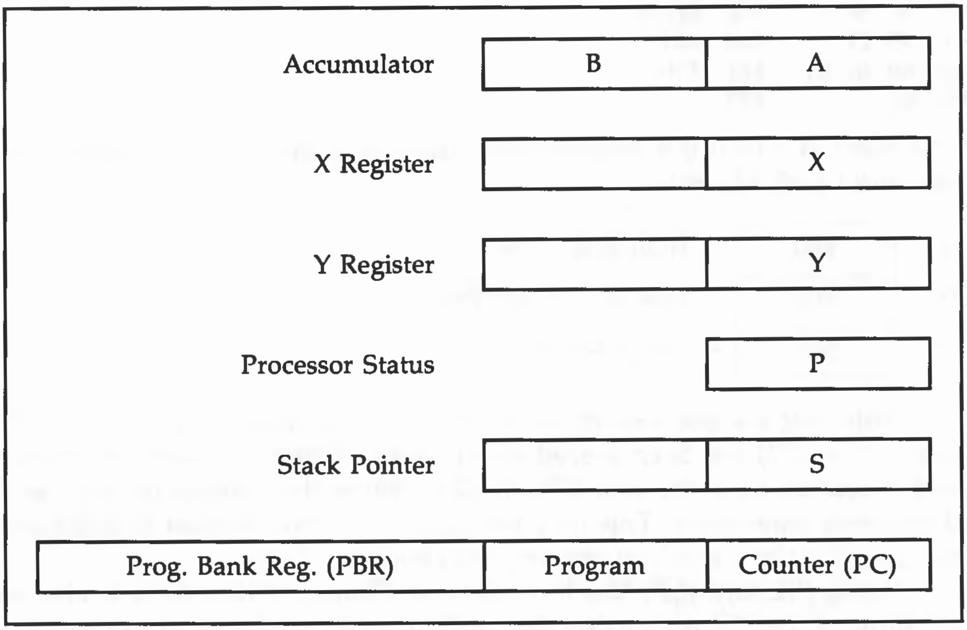
```
LDA  #"A"        ; VALUE FOR "A"
PHA              ; PUT ONE BYTE ON STACK
RTS              ; RETURN TO WHERE?
```

This is because you have left a byte on the stack that the computer will use as a return address. Remember it's expecting that the last two bytes on the stack are a return address from a JSR somewhere. You've now added a byte of your own, and have not removed it. *Likewise, if you do a PHA with m=1 (8-bit mode = 1 byte pushed on stack), and then later you do a PLA with m=0 (16-bit mode = 2 bytes removed from stack), your final RTS won't work because part of the* *return address will be missing.* Like left and right parentheses in a BASIC program, it's up to you to see that all pushes and pulls in a machine language program are balanced.

The Stack Pointer

The 65816 uses a pointer, called the *stack pointer,* to keep track of data currently on the stack. This pointer is abbreviated **S (Stack)** and is another register within the 65816 itself (see Figure 11-1).

Figure 11-1. 65816 Microprocessor Model



When the Monitor displays the registers following a BRK, or with Control-E, you can see the value of the stack pointer:

```
A=00EF X=0000 Y=0000 S=01DD D=0000 P=B0
B=00 K=00 M=0C Q=80 L=1 m=1 x=1 e=1
```

For a routine called from Applesoft BASIC, the 65816 has the *e* bit set to emulation (e = 1), and the stack is confined to page one ($100–1FF). This is done by forcing the high byte of the stack pointer to $01, and letting the low byte range from $00 to $FF.

In the native mode, however, the high byte can have any value in the range of $00 to $FF also, which means the stack can be of any size and can be located anywhere in the first 64K (Bank 0) of memory.

For efficiency purposes, the stack is operated by building *down* in memory, with the stack pointer indicating the *next* available memory location. For example, with nothing on the stack in the emulation mode (such as Applesoft BASIC routines), a diagram of the the stack would look like this:

$1FF:	$??	← S = $01FF

This shows nothing on the stack, and S is set to $1FF. At this point, the actual contents of $1FF can be anything.

Suppose now that the following program were executed:

```
8000:  20  58  FC    JSR   $FC58
8003:  A5  C1        LDA   #C1
8005:  8D  BC  05    STA   $5BC
8008:  60            RTS
```

At the point at which the program does the JSR to $FC58, for example, the stack would look like this:

$1FF:	$80	High Byte = $80
$1FE:	$02	Low Byte = $02 ($8002)
$1FD:	$??	← S = $01FD

Note that the address for the instruction following the JSR $FC58, $8003 *minus one* ($8002) has been placed on the stack. When the microprocessor resumes execution with the next RTS, it adds one to the address on the stack, and proceeds from there. This may not seem to be the cleanest possible system, but is presumably a result of the original processor design.

Using JSL and JSR. You'll recall from Chapter 3 that there is also another form of the JSR instruction that will jump to any location in memory, **JSL (Jump Subroutine Long)**. Because JSR has only a 2-byte operand, it can only jump to an address in the current bank of memory. JSL is a four-byte instruction, and it looks like this in a program:

```
JSL   $E1A55C
```

This tells the microprocessor to go to the subroutine located at address $E1A55C. It can also be expressed as location $A55C in bank $E1. A routine called by a JSL *must* be terminated by a **RTL (ReTurn from subroutine Long)**.

Whether you use a JSL or a JSR affects how many bytes are stored, and later retrieved, from the stack. For a JSL, *three* bytes are pushed onto the stack; a JSR pushes *two* bytes onto the stack. An RTL removes three; RTS removes two.

As an example, consider this program, running in Bank 0:

```
00/8000: 22  5C  A5  E1    JSL   $E1A55C
00/8004: A9  C1            LDA   #C1
```

The stack will look like this while the routine at $E1A55C is being executed:

$1FF:	$00	Bank = $00
$1FE:	$80	High Byte = $80
$1FD:	$03	Low Byte = $03 ($008003)
$1FC:	$??	← S = $01FD

Setting the stack pointer. There are a number of commands that can be used to set the stack pointer, or to transfer its value to another register for examination or manipulation. These are as follows:

TSX Transfer Stack pointer to X register.
TXS Transfer X register to Stack pointer.
TSC Transfer Stack pointer to C (full) Accumulator.
TCS Transfer C (full) Accumulator to Stack pointer.

Basically, your choices are to use the Accumulator or the X register to either receive from or send a value to the Stack pointer. For example, if, for some reason you wanted to set the Stack pointer to $1300, the following program would do it:

```
CLC
XCE                  ; SET NATIVE MODE IF NOT THERE ALREADY.
SEP   #$20           ; 16-BIT ACCUMULATOR
LDA   #$1300         ; ACC (C) = $1300
TCS                  ; SET S = $1300
```

This program assumes it is starting in emulation (e=1) mode, as would be the case if it were called from Applesoft BASIC. It's not really a very realistic example, since there's not much point to moving the stack for a routine called from Applesoft BASIC, but it shows that such a feat is possible. You could also have used the TXS command to set S to $1300 if desired.

Stack Relative Addressing

With just the push and pull instructions, once a byte was on the stack, you couldn't access it until any bytes on top of it were removed. Fortunately, there is an addressing mode specifically for the stack that lets you retrieve any of the last 256 bytes pushed on the stack. It's called the *stack relative* addressing mode, and looks like this:

```
BEGIN  LDA  #$0100      ; 16-BIT MODE
       PHA              ; PUT IT ON STACK
       LDA  #$0200      ; ANOTHER VALUE
       PHA              ; PUT IT ON STACK
GET    LDA  1,S         ; ACC WILL = $0200
       LDA  3,S         ; ACC WILL = $0100
```

In this addressing mode, you can retrieve a value off the stack by indicating the offset from the current stack pointer that you want to retrieve the data from. There are two things in particular to notice here.

The first is that the first byte stored on the stack is at relative position *one.* That is because the stack pointer itself (relative position zero) always points to the *next available* byte, not the last stored.

Second, remember to use the proper offset value. Because each push in the sample program was in the 16-bit mode, *two* bytes were put on the stack for each PHA. Therefore, the second LDA used an offset of 3 to get the second pair of bytes.

Stack Relative Indirect Indexed Addressing

There is an even more interesting addressing mode variation, called *stack relative indirect indexed.* It looks like this:

```
LDY  #2
LDA  (1,S),Y
```

This tells the 65816 to first go to the stack and get the address it finds at the first position on the stack (1,S). Then, it uses this as an indirect pointer to an address to which the offset in the Y register is added. This may seem rather convoluted, but it comes in very handy for following a JSR with data to be handled by a subroutine.

Program 11-1 demonstrates how to create a subroutine that prints whatever string follows the JSR to the routine. It works by first using the stack relative-indirect indexed mode. Because the return address for the JSR is on the stack when the print routine is called, that address can be used as a base address from which to read the characters that follow. The print loop itself is based on the print program from the last chapter. When the $00 at the end of the string is encountered, the print loop is terminated.

At this point, an RTS in the print routine would return to the byte right after the JSR, namely the beginning of the string just printed. To skip over this data, lines 36–43 add the length of the string just printed to the value for the return address. The result is then replaced on the stack so that when the RTS at

DONE is executed, program control resumes at PROGRAM, the next instruction after the end of the printed string.

This technique is not limited to just print routines. You can use this method to pass any kind of data to a subroutine. *The main restriction is that you must make sure that the subroutine has a way of knowing exactly how many bytes are passed to it.* If you add too much or too little to the return address, program control will resume either past the desired instruction or in the middle of the data to be passed, both of which will have unpredictable results.

Program 11-1. Stack Indirect Indexed Sample

```
                            ******************************************************
                            *      STACK INDIRECT INDEXED SAMPLE                 *
                            *              MERLIN ASSEMBLER                      *
                            ******************************************************

                                         ORG    $300

             =FC58          HOME         EQU    $FC58
             =FDED          COUT         EQU    $FDED
             =0006          LEN          EQU    $06


000300: 20 58 FC            BEGIN        JSR    HOME

000303: 20 41 03            PRINT1       JSR    PRINT
000306: D4 C8 C9 D3                      ASC    “THIS IS THE FIRST STRING“,8D,00
00030A: A0 C9 D3 A0     D4 C8            C5     A0
000312: C6 C9 D2 D3     D4 A0            D3     D4
00031A: D2 C9 CE C7     8D 00

000320: EA                  PROGRAM      NOP                  ; MISC. PROGRAM STUFF HERE...

000321: 20 41 03            PRINT2       JSR    PRINT
000324: D4 C8 C9 D3                      ASC    “THIS IS THE SECOND STRING“,8D,00
000328: A0 C9 D3 A0     D4 C8            C5     A0
000330: D3 C5 C3 CF     CE C4            A0     D3
000338: D4 D2 C9 CE     C7 8D            00

00033F: EA                  PROGRAM      NOP                  ; MORE PROGRAM STUFF HERE...

000340: 60                  EXIT         RTS


000341: A0 01               PRINT        LDY    #$01          ; ADD 1 TO RETURN ADDRESS

000343: B3 01               LOOP         LDA    (1,S),Y       ; GET A CHARACTER TO PRINT
000345: F0 06   =034D                    BEQ    FIX           ; 0 = END OF STRING
000347: 20 ED FD                         JSR    COUT          ; PRINT ASCII CHARACTER
00034A: C8                               INY                  ; Y = Y + 1
```

```
00034B: 80  F6  =0343            BRA   LOOP        ; NEXT CHARACTER

00034D: 84  06           FIX     STY   LEN         ; SAVE LEN OF STRING
00034F: A3  01                   LDA   1,S         ; GET LOW BYTE OF RETURN ADDRESS
000351: 65  06                   ADC   LEN         ; ADD TO LENGTH OF STRING
000353: 83  01                   STA   1,S         ; PUT BACK IN PLACE

000355: A3  02                   LDA   2,S         ; GET HIGH BYTE OF RETURN ADDRESS
000357: 69  00                   ADC   #$00        ; ADD CARRY IF NEEDED
000359: 83  02                   STA   2,S         ; PUT BACK IN PLACE

00035B: 60               DONE    RTS               ; RETURN TO END OF STRING + 1!



—End Merlin-16 assembly, 92 bytes, Errors: 0
```

Push Effective Instructions

Along with the push instructions already described, there is a special group of instructions that push address data, rather than register contents, onto the stack. These instructions are **PEA (Push Effective Address)**, **PEI (Push Effective Indirect address)**, and **PER (Push Effective Relative address)**.

PEA pushes an absolute address onto the stack. It can also be used to push a data value. PEA always pushes two bytes onto the stack no matter what the setting of the *e* and *m* bits are (8-or 16-bit mode).

The following instructions would push the values $0100 and $0200 onto the stack:

```
PEA  $0100
PEA  $0200
```

This is equivalent to:

```
LDA  #$0100      ; 2 BYTES IN 16-BIT MODE
PHA              ; PUSH BOTH BYTES
LDA  #$0200
PHA
```

PEA can be used to pass any constant or address to a subroutine using the stack. Notice that in the PEA instruction, the pound sign (#) is not used in front of the value pushed on the stack.

PEI uses the *contents* of the indicated direct page locations as the data to put on the stack. This instruction:

```
PEI   ($06)       ; PUSH TWO BYTES ON STACK
```

Is equivalent to:

```
LDA  $07          ; GET HIGH BYTE BYTE
PHA               ; PUSH ON STACK
LDA  $06          ; GET LOW BYTE
PHA               ; PUSH ON STACK
```

Notice that PEI pushes the high byte (LABEL+1) first, then the low-order byte (LABEL). Like PEA, PEI always pushes two bytes, regardless of the condition of *e* and *m*.

PER is the most exotic of the three instructions. It pushes a relative offset from the current point in the program to the referenced address. This is very much like the calculation done for a branch instruction. In your source listing, you specify the target address. However, the assembler calculates a relative distance, and uses this as the operand of PER in the actual assembly.

PER can be used to reference data when you don't know exactly where in memory your program will run. In previous chapters, we discussed the impact of JMPs and JSRs to absolute addresses in a program. If a program has a JSR, for example, to $340, and that program is moved to $8000, then the JSR $340 will jump to a non-existent program at that point. Likewise, load and store instructions like LDA and STA that address absolute memory location will access non-existent data if the program is moved from its original location.

One solution to this problem is to use the stack relative indexed indirect addressing mode and to use PER to put the correct address on the stack. Program 11-2 is another print program that will run at any location in memory.

On line 12, the 65816 first uses the offset value in the operand of PER and adds that to the current program counter, such as the address of that instruction. The result, namely the current address of DATA, is then pushed on the stack. Line 15 can then access that pointer on the stack.

When using any of the push instructions, you must remember to keep the number of bytes pushed and pulled from the stack balanced. Lines 21, 22 provide the balancing pulls in this example program.

Program 11-2. PER Sample Print Demo

```
                           *********************************************
                           *     ‘PER’ SAMPLE PRINT PROGRAM            *
                           *            MERLIN ASSEMBLER               *
                           *********************************************

            =FC58          HOME     EQU  $FC58
            =FDED          COUT     EQU  $FDED


008000: 20 58 FC           BEGIN    JSR  HOME

008003: 62 10 00           PRINT    PER  DATA         ; PUSH ADDRESS OF ‘DATA’
008006: A0 00                       LDY  #$00         ; POSN OF 1ST CHARACTER

008008: B3 01              LOOP     LDA  (1,S),Y      ; GET A CHARACTER TO PRINT
00800A: F0 06   =8012               BEQ  FIX          ; 0 = END OF STRING
00800C: 20 ED FD                    JSR  COUT         ; PRINT ASCII CHARACTER
00800F: C8                          INY               ; Y = Y + 1
008010: 80 F6   =8008               BRA  LOOP         ; NEXT CHARACTER

008012: 68                 FIX      PLA               ; FIX STACK (PULL 1 BYTE)
008013: 68                          PLA               ; PULL SECOND BYTE

008014: EA                 PROGRAM  NOP               ; MISC. PROGRAM STUFF HERE...

008015: 60                 EXIT     RTS

008016: D4 C8 C9 D3        DATA     ASC  “THIS IS A TEST“,8D,00
00801A: A0 C9 D3 A0 C1 A0 D4 C5
008022: D3 D4 8D 00


—End Merlin-16 assembly, 38 bytes, Errors: 0
```

The Direct Page Register: D

In the previous chapter, we noted that although the direct page is usually the first $100 bytes from $00 to $FF, this area can be reassigned by a running program for its own use. This means that there can be several different programs in the computer at the same time, each with its own direct-page area, thus eliminating potential memory-use conflicts.

Several programs in the computer at the same time may seem rather exotic, but even a running Applesoft BASIC program fits this category. Not only is Applesoft BASIC active, but usually ProDOS and certain Monitor routines are active, as well. These three were designed before the 65816 (for the 6502 microprocessor), so each was designed to specifically avoid using bytes used by one of the others. With the Apple IIGS, you can design new programs without

Program 11-3. PHD Example 1

```
SAVE     PHD              ; PUSH DIRECT PAGE ON STACK
         PLA              ; GET LOW BYTE (ASSUMES 8-BIT MODE)
         STA  TEMP        ; SAVE IT SOMEWHERE
         PLA              ; GET HIGH BYTE
         STA  TEMP+1      ; SAVE IT

         LDA  #>PAGE      ; GET HIGH BYTE OF NEW LOCATION
         PHA              ; PUT IT ON STACK
         LDA  #<PAGE      ; GET LOW BYTE OF NEW LOCATION
         PHA

         PLD              ; SET NEW DIRECT PAGE LOCATION

         NOP              ; YOUR PROGRAM HERE...

RESTORE  LDA  TEMP+1      ; GET OLD DIRECT PAGE LOC. HI BYTE
         PHA              ; PUT IT ON STACK
         LDA  TEMP        ; GET OLD DP LOW BYTE
         PHA

         PLD              ; RESTORE DP LOCATION

EXIT     RTS              ; DONE
```

having to worry about what direct-page bytes may be used by someone else.

There is a specific 65816 command, **PLD (PuLl Direct page register)**, that lets the programmer reassign the direct page to any location in the first 64K of memory ($0000 to $FFFF). This command can be very useful because page zero is heavily used by Applesoft BASIC, the Monitor, and ProDOS. There aren't very many free bytes left. The example programs shown so far have used locations $06–$09 because these happen to be free, but what happens if you need more bytes? Using the PLD command is a way to define an entirely new direct page for your program's own use, thus allowing 256 bytes just for you.

In the 65816 itself, there is a register, called the *Direct Page Register*, abbreviated *D*, that keeps track of the current direct-page location. This defaults to $0000, which indicates the range from $00 to $FF, but you can change D to define a new direct page any time you'd like (see Figure 11-1).

There is a hazard, however. Remember that, if you're calling your routine from Applesoft BASIC, you must restore the direct page back to page zero when you're finished or before you call any Applesoft BASIC, Monitor, or ProDOS 8 routine.

You can determine the current direct page at any time by using the command **PHD (PusH Direct page register)**. This pushes two bytes onto the stack that correspond to the current direct-page setting. For example, the program segment shown in Program 11-3 assumes that the routine is operating in the 8-bit mode (e and m = 1), as would be the starting case for a ProDOS 8 program or a routine called from Applesoft BASIC. However, if your program has shifted to the 16-bit mode (e and m = 0), the process is somewhat simpler as shown in the segment Program 11-4.

Program 11-4. PHD Example 2

```
SAVE     PHD            ; PUSH DIRECT PAGE ON STACK
         PLA            ; GET DP LOC (ASSUMES 16-BIT MODE)
         STA   TEMP     ; SAVE IT SOMEWHERE

         LDA   #PAGE    ; GET NEW LOCATION
         PHA            ; PUT IT ON STACK

         PLD            ; SET NEW DIRECT PAGE LOCATION

         NOP            ; YOUR PROGRAM HERE...

RESTORE  LDA   TEMP     ; GET OLD DIRECT PAGE LOCATION
         PHA            ; PUT IT ON STACK

         PLD            ; RESTORE DP LOCATION

EXIT     RTS            ; DONE
```

The Data Bank and Program Bank Registers: B and K

In previous chapters, we've mentioned that the 65816 can run a program and access data in any of the memory banks. Remember that the bank is the first byte of the full three-byte address for a memory location. For example:

```
01/0300
```

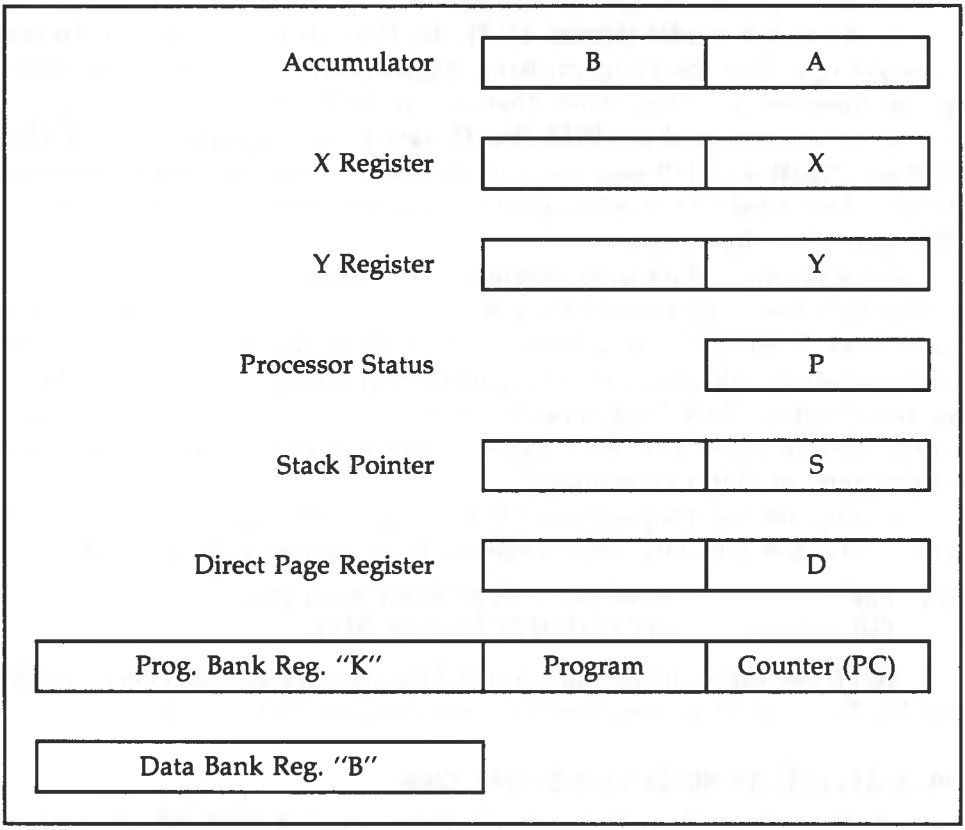
would signify bank 1, address $300. For a running program, the Program Counter includes the Program Bank Register to make up the complete address for where the 65816 is currently executing an instruction (see Figure 11-2).

The Program Bank Register is a single byte register that determines which bank the currently active program is in. When the Monitor prints out the registers, like this:

```
A=00EF X=0000 Y=0000 S=01DD D=0000 P=B0
B=00 K=00 M=0C Q=80 L=1 m=1 x=1 e=1
```

the Program Bank is abbreviated *K*. The display here indicates the Program Bank Register is set to bank 0. The Program Bank Register is only modified when a JML, JSL, or RTL is executed. You can, however, determine it's current

Figure 11-2. 65816 Microprocessor Model



setting with a stack instruction, **PHK (PusH program banK register)**. This instruction always pushes a single byte, namely the current Program Bank value, onto the stack.

The main purpose for the PHK command is to condition another important register, the Data Bank Register.

The Data Bank Register: B

So far, whenever you had a pair of instructions like

```
LDA  MEM1
STA  MEM2
```

it was taken for granted that the bytes accessed would all be in the same bank. In every program so far, this has been limited to bank 0. This need not be the case, however. By changing the Data Bank Register, B, your program can run in one bank and manipulate data in another.

In the 65816 model (Figure 11-2), the Data Bank Register can be seen to be a single byte, like the Program Bank Register. Unlike the Program Bank Register, however, the Data Bank Register can be both read *and set* at any time. The two commands used are **PHB (PusH data Bank register)** and **PLB (PulL data Bank register)**. PHB puts the current value of the data bank register on the stack. This would be used to save the current setting, so your program could restore it before it quit.

For a routine called from Applesoft BASIC, BRUN, or a ProDOS 8 System file, both the Program and Data Bank Registers are already set to the default of bank 0. However, in a ProDOS 16 System file, the program can be loaded anywhere into memory. This means that when your program starts running, the Program Data Bank most likely *won't* be set to the correct value. Fortunately, you do know that the Program Bank Register is correct—otherwise your program wouldn't be running.

A program can properly set the Data Bank Register with the PLB command, which sets the Data Bank Register, B, by pulling a value off the stack:

```
BEGIN  PHK            ; PUSH PROGRAM BANK VALUE ON STACK
       PLB            ; SET DATA BANK TO SAME VALUE
```

You'll see these instructions at the beginning of almost every ProDOS 16 program. ProDOS 16 is described in more detail in Chapter 14.

Bank 1 Access: An 80-Column Screen Clear

If you try the Screen Clear Program 1C, Program 10-8, with 80 columns active, you'll notice it only clears every-other character on the screen. That's because the 80-column screen is made up of *two* $400-byte blocks—the first in bank 0, and the other (in the same address range) in bank 1. Thus, the 80-column screen is made up from memory with the addresses $00/400 to $00/7FF and $01/400 to $01/7FF. Screen Clear 1C only clears the memory in bank 0.

To create an 80-column screen clear, we can use the Data Bank Register to change which bank is being cleared (see Program 11-5). The main difference between Program 11-5 and Screen Clear 1C, Program 10-8, is on lines 42–56. Line 42 first pushes the current Data Bank value on the stack. Even though we know it's equal to bank 0 for a routine called from Applesoft BASIC, this illustrates the technique for saving it if the need should arise. It also illustrates how the stack itself can be used to save a value temporarily. The value to be saved is pushed onto the stack, and then is pulled off later (see line 56) to restore it.

Lines 43–46 push the value 1 on the stack so the Data Bank Register can be set with a PLB. At this point, all 16-bit address access will be done in bank

1—not where the program is running in bank 0. It's important to notice that we're dealing with 16-bit addresses. What this means is that direct page and stack references are still in bank 0. This makes sense because the stack and direct page *can only* be in bank 0, so the Data Bank Register has no effect on these addresses or on instructions like LDA ($80),Y that reference them.

Because the Accumulator was used to push the value on the stack, the value for the character to clear to is no longer there. Line 48 resets the Accumulator to the proper value. Line 49 resets the Y register to 0. Because it has just fallen through the test on 39, the Y register is equal to 40 without the reset.

Lines 51–54 duplicate the loop used for bank 0, after which the Program Data Bank value is restored to its original value on line 56.

More About Multi-Bank Access

The Data Bank Register is not the only way to access other banks of memory from a running program. You've already seen how the LDA and STA instructions can use a long address to access any byte directly. As an exercise, you should try rewriting Screen Clear Program 1D using the Indirect Indexed Long instruction, STA [BASL],Y, to clear bank 0. Instead of using the Data Bank Register, modify BASL+2 to be the bank byte.

Program 11-5. Screen Clear Demo 1D

```
                          1 *******************************************
                          2 *   SCREEN CLEAR PROGRAM #1D     *
                          3 *          MERLIN ASSEMBLER      *
                          4 *******************************************
                          5
                          6          ORG  $300
                          7
         =0006            8 LINE     EQU  $06        ; WHAT LINE WE'RE ON
         =0008            9 CHAR     EQU  $08
         =C000           10 KYBD     EQU  $C000
         =C010           11 STROBE   EQU  $C010
                         12
         =0025           13 CV       EQU  $25        ; VERTICAL CURSOR POSN
         =FC22           14 VTAB     EQU  $FC22
         =0028           15 BASL     EQU  $28        ; $28,29 = BASE ADDRESS
                         16
                         17
000300: AD 00  C0        18 READ     LDA  KYBD       ; GET KYBD CHARACTER VALUE
000303: C9 80            19          CMP  #$80       ; KEYPRESS?
000305: 90  F9  =0300    20          BCC  READ       ; NO, THEN TRY AGAIN.
000307: 8D 10  C0        21          STA  STROBE     ; CLEAR KYBD STROBE.
                         22
```

```
00030A:C9 9B         CHECK  CMP  #$9B       ; ESCAPE?
00030C:F0 31   =033F        BEQ  DONE       ; YES

00030E:85 08                STA  CHAR       ; SAVE CHARACTER VALUE

000310:64 06         INIT   STZ  LINE       ; SET LINE = 0

000312:A5 06         FINDV  LDA  LINE       ; GET LINE VALUE
000314:85 25                STA  CV         ; VERTICAL CURSOR POSN
000316:20 22 FC             JSR  VTAB       ; CALCULATE BASE ADDRESS

000319:A5 08         CLEAR  LDA  CHAR       ; GET CHAR TO 'CLEAR' TO
00031B:A0 00                LDY  #$00       ; ZERO Y REGISTER

00031D:91 28         LOOP1  STA  (BASL),Y   ; PUT CHAR IN MEMORY
00031F:C8                   INY             ; Y = Y + 1
000320:C0 28                CPY  #40        ; END OF LINE?
000322:90 F9   =031D        BCC  LOOP1      ; NOPE: NEXT POSITION

000324:8B            BANK1  PHB             ; SAVE CURRENT DATA BANK (0)

000325:A9 01                LDA  #$01       ; BANK 1 VALUE
000327:48                   PHA             ; PUT IT ON STACK
000328:AB                   PLB             ; SET DATA BANK = 1

000329:A5 08                LDA  CHAR       ; PUT CHAR IN ACC AGAIN . . .
00032B:A0 00                LDY  #$00       ; ZERO Y REGISTER AGAIN . . .

00032D:91 28         LOOP2  STA  (BASL),Y   ; PUT CHAR IN MEMORY
00032F:C8                   INY             ; Y = Y + 1
000330:C0 28                CPY  #40        ; END OF LINE?
000332:90 F9   =032D        BCC  LOOP2      ; NOPE: NEXT POSITION

000334:AB                   PLB             ; RESTORE ORIG. DATA BANK (0)

000335:E6 06         NXTLN  INC  LINE       ; LINE = LINE + 1
000337:A5 06                LDA  LINE
000339:C9 18                CMP  #24        ; DONE YET?
00033B:90 D5   =0312        BCC  FINDV      ; NOPE

00033D:80 C1   =0300 AGAIN  BRA  READ       ; GET ANOTHER CHARACTER

00033F:60            DONE   RTS             ; ALL DONE

000340:0C                   CHK             ; CHECKSUM FOR LISTING

—End Merlin-16 assembly, 65 bytes, Errors: 0
```

Chapter 12

Adding Machine Language Programs

Chapter 12

Adding Machine Language Programs

One of the first useful applications of your knowledge of assembly language programming can be the enhancement of your existing Applesoft programs. Such a combination of two languages is sometimes called a hybrid program, and many commercial programs are written by combining modules written in a variety of languages. In this way, particular functions in a program can be written in the language best suited to the task.

For example, if you had to write a program that asked the user for 10 names, just about the fastest way to do it would be with a short and simple Applesoft program that looked like this:

```
10 FOR I = 1 TO 10
20 INPUT N$(I)
30 NEXT I
```

This is much simpler than the equivalent program in assembly language. In cases where the tools already exist in Applesoft BASIC, and blinding speed is not a requirement, Applesoft BASIC is a completely acceptable solution.

However, if you had to sort a list of 1000 names, speed would become a concern, and it would be worth considering whether the job could best be done in assembly language.

As you've seen in previous chapters, it's possible to call a single machine language routine from within an Applesoft BASIC program with the CALL command. All of the example programs presented in this book so far assume that you're testing them with a CALL from Applesoft BASIC. As you have seen, by using the CALL statement, you can jump to any address in memory you want, and the routine there can perform virtually any function, subject only to the design of the routine.

Why Add Anything to Applesoft BASIC?

You might ask, "Why add any routines at all to Applesoft BASIC?" You might think that there are only two choices when writing a program: Write the entire program in Applesoft BASIC, or write the entire program in assembly language. As you've seen, though, there is another option. By adding special machine language routines to your Applesoft BASIC programs, you can solve those problems that Applesoft BASIC can't quite manage.

There are two fundamental reasons to add new functions to a BASIC program: speed and simpler programming. Applesoft BASIC has a little more than 100 commands like PRINT, VTAB, HOME, and so on. What happens when you want to sort a list? You have to combine a large number of these simpler commands to create a sort function. Usually, the resulting subroutine is not as fast as you'd like it.

To be fair, it's not that BASIC itself is really slow. As first discussed in Chapter 1, when your program has a statement like PRINT 5 * 3, the command is ultimately executed at machine language speed, because Applesoft BASIC *is* a collection of machine language routines. It's when things slow down that you have to put together hundreds of these commands to do a complete subroutine like sort a list, format dollars and cents numbers, and so forth.

If there were a way to replace all those BASIC commands with a machine language routine that sorted an array, and a way to add a command named SORT to BASIC, it would be just as fast as a pure machine language program—because it would be in machine language. Best of all, your BASIC program listing would look simpler itself, since all you'll see is a single CALL statement to do the sort or whatever. This isn't to say, of course, that you won't still have to write hundreds of lines of *assembly language* source code to create your sort subroutine—it just won't be visible as part of your BASIC program.

Passing Data Between Applesoft BASIC and Machine Language

All of the sample programs you've seen so far are independent of any Applesoft BASIC program that calls them. That is to say, there is no data in the form of variables passed either to or from the machine language routine that is called.

To create any really useful routines, you'll want to be able to pass variables back and forth between Applesoft BASIC and the machine language subroutines. The only problem is, how? You should suspect by now that an Applesoft BASIC program does not run, nor store data, in the same way as a machine language program. Then how can they talk to one another and share data?

Remember for a moment that at some point Applesoft BASIC executes a machine language routine to carry out a BASIC command, so it seems only logical that routines must already exist within Applesoft BASIC to convert the

Applesoft BASIC variables like X and A$ to a form that a machine language routine can deal with. To see how this is done, let's first take a brief look at how an Applesoft BASIC program is actually stored in memory.

The Internal Structure of Applesoft BASIC

Consider this simple program:

```
10 HOME: PRINT "HELLO"
20 END
```

An interesting question arises: How does the computer actually store, and then later execute this program?

To answer that, we'll have to go to the Monitor and examine the program data directly. Type in the BASIC program exactly as shown, then go to the Monitor with a CALL -151.

The first question to answer is, exactly where in the computer is the program stored? This can be found by entering the Monitor and typing in:

```
67 68 AF B0  (and pressing RETURN)
```

The computer should respond with:

```
00/0067:01-.
00/0068:08-.
00/00AF:19-.
00/00B0:08-.
*
```

The first pair of numbers is the pointer for the program beginning, bytes reversed of course. They indicate that the program starts at $801.

(You should be able to put this observation together with what you just learned about indirect addressing, and see why almost every important address value—like the beginning of a program, a variable list, and so forth—is stored as a pair of zero-page bytes. This allows us to access the data table, program, and so on with LDA ($67),Y, for example. By seeing how other programs are written, including Applesoft BASIC itself, you will get ideas about how to structure programs of your own.)

The second pair of bytes is the program end pointer, and they show it ends at $818. Using this information, let's examine the program data by typing in:

```
801L
```

You should get:

```
1=m  1=x  1=LCbank (0/1)

00/0801: 10  08            BPL   080B {+08}
```

```
00/0803: 0A              ASL
00/0804: 00  97          BRK  97
00/0806: 3A              DEC
00/0807: BA              TSX
00/0808: 22  48  45  4C  JSL  4C4548
00/080C: 4C  4F  22      JMP  224F
00/080F: 00  16          BRK  16
00/0811: 08              PHP
00/0812: 14  00          TRB  00
00/0814: 80  00          BRA  0816 {+00}
00/0816: 00  00          BRK  00
00/0818: 00  8C          BRK  8C
00/081A: E2  28          SEP  #28
00/081C: 31  37          AND  (37),Y
00/081E: 35  29          AND  29,X
00/0820: C8              INY
00/0821: 32  35          AND  (35)
00/0823: 36  CA          ROL  CA,X
00/0825: E2  28          SEP  #28
*
```

Although at first you might think this looks like a machine language program, those BRK instructions are a clue that it's really not directly executable code. Now type in:

```
801.819
```

This will give:

```
00/0801: 10  08  0A  00  97  3A  BA-.....::
00/0808: 22  48  45  4C  4C  4F  22  00-"HELLO".
00/0810: 16  08  14  00  80  00  00  00-........
00/0818: 00  00-..
```

To understand this, let's break it down one section at a time. When the Apple stores a line of BASIC, it encodes each keyword as a single byte *token*. Literally, a token is any single marker of a larger quantity. In this case, the token is a single byte that stands for the five or six bytes that make up the Applesoft BASIC command. Thus, the word PRINT is stored as a $BA. This does wonders for conserving space. In addition, there is some basic overhead associated with packaging the line, namely a byte at the end to signify the end of the line, and a few bytes at the beginning of each line to hold information related to the length of the line, and also the line number itself.

To be more specific:

```
00/0801: 10  08  0A  00  97  3A  BA-.....::
00/0808: 22  48  45  4C  4C  4F  22  00-"HELLO".
```

```
00/0810: 16 08 14 00 80 00 00 00-........
00/0818: 00 00-..
```

The first two bytes of every line of an Applesoft BASIC program are an *index* to the address of the beginning of the next line. At $801,802 we find the address $810 (bytes reversed). This is where line 20 starts. At $810 we find the address $816. This is where the next line would start, if there were one. The double *00* at $816 tells Applesoft BASIC that this is the end of the BASIC listing.

The next information within a line is the line number itself:

```
00/0801: 10 08 0A 00 97 3A BA-.....::
00/0808: 22 48 45 4C 4C 4F 22 00-"HELLO".
00/0810: 16 08 14 00 80 00 00 00-........
00/0818: 00 00-..
```

The *0A 00* is the two-byte form of the number 10, the line number of the first line of the Applesoft BASIC program. Likewise, the *14 00* is the data for the line number 20. The bytes are again reversed. After these four bytes, we see the actual tokens for each line.

```
00/0801: 10 08 0A 00 97 3A BA-.....::
00/0808: 22 48 45 4C 4C 4F 22} 00-"HELLO".
00/0810: 16 08 14 00 80 00 00 00-........
00/0818: 00 00-..
```

All bytes with a value of $80 or greater are Applesoft BASIC keywords in token form. Bytes less than $80 represent normal ASCII data (letters of the alphabet, numbers, and so forth). Examining the data here, we see a $97 followed by $3A—$97 is the token for *HOME*, and $3A is the token for the colon. Next, $BA is the token for *PRINT*. This is followed by the quote ($22) and the text for HELLO (48 45 4C 4C 4F) and the closing quote ($22). Last of all, the *00* indicates the end of the line.

In line number 20, the $80 is the token for *END*. As before, the line is terminated with *00*.

Again, remember how indirect addressing worked: Applesoft BASIC limits the length of each stored line to 255 bytes. This is so the Y register can be incremented from 0 to $FF as it scans the line in memory. The 0 at the end is used so that a BEQ test will detect the end of the line. If you were writing your own Applesoft BASIC interpreter, the code shown in Program 12-1 would be a good place to start.

When a program is executed, the interpreter scans through the data. Each time it encounters a token, such as the PRINT token, it looks up the value in a table to see what action should be taken. In the case of PRINT, this would be to output the characters following the token, namely HELLO.

Program 12-1. Interpreter

```
BEG    EQU  $67        ; $67,68
PTR    EQU  $06        ; $06,07
NXTLN  EQU  $08        ; $08,09

LINE   LDA  BEG
       STA  PTR
       LDA  BEG+1
       STA  PTR+1      ; PTR = ADDR OF 1ST LINE

READ   LDY  #$00       ; START AT BEG OF LINE
       LDA  (PTR),Y    ; GET LO BYTE OF NEXT LINE ADDR.
       STA  NXTLN      ; SAVE IT
       INY             ; INCREMENT Y TO NEXT BYTE
       LDA  (PTR),Y    ; GET HI BYTE OF NEXT LINE ADDR.
       STA  NXTLN+1    ; SAVE IT
       INY
       INY             ; SKIP LINE # BYTES

LOOP   LDA  (PTR),Y    ; READ 1ST TOKEN
       BEQ  NEXT       ; 0 = END OF LINE
                       ; DO SOMETHING WITH IT ( )
       INY             ; INCREMENT Y TO NEXT BYTE
       BNE  LOOP       ; READ NEXT TOKEN

NEXT   LDA  NXTLN      ; LO BYTE OF LINE #
       STA  PTR        ; SET PTR = ADDR OF NEW LINE
       LDA  NXTLN+1    ; HI BYTE OF LINE #
       STA  PTR+1

CHECK  LDA  NXTLN      ; CHECK FOR ADDR = 0
       BNE  READ       ; NOPE - GO FOR NEXT LINE
       LDA  NXTLN+1    ; GET HI BYTE OF ADDRESS
       BNE  READ       ; NOPE - GO FOR NEXT LINE

DONE   RTS             ; ONLY GET HERE IF (NXTLN) = 0
```

This constant translation is the reason for the use of the term *interpreter* for Applesoft BASIC.

Machine code, on the other hand, is directly executable by the 65816 microprocessor so is much faster since no table lookups are required.

In Applesoft BASIC, a SYNTAX ERROR is generated whenever a series of tokens is encountered that is not consistent with what the interpreter expects to find.

Take the time to look over the program that reads an Applesoft BASIC line. You have learned all the commands and addressing modes necessary to write a program like this, and taking a moment to make sure you understand what it's doing will help reinforce what you've learned already. And it will cement the new facts about Applesoft BASIC in place.

As another aside, armed with what you've already learned, and a chart of the Applesoft BASIC tokens, you could write a number of interesting programs, including a utility to renumber the line numbers in an Applesoft BASIC program or one to make a list of all the variable names used in a program.

Passing Variables from Applesoft BASIC to Machine Language

The easiest way to pass data to a machine language routine is to simply POKE the appropriate values into unused memory locations, and then to retrieve them when you get to your machine language routine. To illustrate this, we'll use the speaker location ($C030) and your knowledge of loops to write a simple tone routine.

To use this, enter and assemble Program 12-2, and BLOAD the final object code at $300. Then enter the accompanying Applesoft BASIC program, Program 12-3.

Program 12-2. Sound Routine 1

```
                        **********************************************
                        *            SOUND ROUTINE #1                *
                        *            MERLIN ASSEMBLER                *
                        **********************************************

                                     ORG   $300

           =0006        PITCH        EQU   $06
           =0007        DURTN        EQU   $07
           =C030        SPKR         EQU   $C030

000300: A6 07           BEGIN        LDX   DURTN

000302: A4 06           LOOP         LDY   PITCH       ; STARTING VALUE FOR PITCH
000304: AD 30 C0                     LDA   SPKR        ; CLICK SPEAKER

000307: 88              DELAY        DEY               ; COUNTDOWN DELAY (PITCH)
000308: D0 FD  =0307                 BNE   DELAY

00030A: CA              DRTN         DEX               ; COUNTDOWN DURATION
00030B: D0 F5  =0302                 BNE   LOOP        ; CONTINUE NOTE

00030D: 60              DONE         RTS

—End Merlin-16 assembly, 14 bytes, Errors: 0
```

This Applesoft BASIC program is used to call it:

Program 12-3. Sound Routine 1 Loader

```
10 INPUT "PITCH, DURATION ";P,D
20 POKE 6,P: POKE 7,D
30 CALL 768
40 PRINT
50 GOTO 10
```

The Applesoft BASIC program works by first requesting values for the pitch and duration of the tone from the user. These values are then POKEd into locations 6 and 7, and the tone routine is called. The tone routine uses these values to produce the desired sound, and then it returns to the calling program for another round (or sound).

The tone is created by two loops, one within the other. The outer loop, from LOOP to DURTN, controls how many times the entire note-producing cycle will last, thus controlling the length, or duration of the note. The inner loop, at DELAY, cycles through the delay loop to waste a little time each time the speaker is clicked. The faster you click the speaker, the higher the pitch of the note played. The two loops together create a system where you can control both the pitch of the note and its duration.

The technique used for passing the variables for pitch and duration works fine for limited applications, but having to POKE all the desired parameters into various corners of memory is not very flexible, and strings are nearly impossible. There must be an alternative.

Better Variable Passing

The key to passing variables to your own machine language routines is to work with Applesoft BASIC in terms of routines already present in the machine. That way, you can name the variable you're dealing with right in the CALL statement.

The secrets here are the identities of two components of the Applesoft BASIC interpreter: **TXTPTR** (TeXT PoinTeR) and **CHRGET** (CHaRacter GET). TXTPTR and CHRGET are names given to pointers and routines already present in the computer, like COUT. It's a good idea to use these names yourself in your own listings, but it's not required to have the program work.

TXTPTR is the two-byte pointer ($B8, B9) that points to the next token to be analyzed. This is equivalent to the pointer PTR ($06,07) in the example line-scanning listing earlier. CHRGET ($B1) is a very short routine that actually resides on the zero page, and which will read a given token into the Accumulator. This is equivalent to the line-scanner itself. In addition to occasionally being called directly, many other routines use CHRGET to process a string of data in an Applesoft BASIC program line.

Program 12-4 is the revised tone routine; Program 12-5 is its Applesoft BASIC loader.

Program 12-4. Sound Routine 2

```
                        *********************************************
                        *            SOUND ROUTINE #2               *
                        *            MERLIN ASSEMBLER               *
                        *********************************************

                                     ORG   $300

            =0006       PITCH        EQU   $06
            =0007       DURTN        EQU   $07
            =C030       SPKR         EQU   $C030

            =E74C       COMBYTE      EQU   $E74C

000300: 20  4C  E7      GETVARS      JSR   COMBYTE    GET COMMA & EXPRESSION
000303: 86  06                       STX   PITCH      STORE VALUE < 256
000305: 20  4C  E7                   JSR   COMBYTE    GET NEXT COMMA & EXPRESSION
000308: 86  07                       STX   DURTN      ; STORE VALUE < 256

00030A: A6  07          BEGIN        LDX   DURTN

00030C: A4  06          LOOP         LDY   PITCH      ; STARTING VALUE FOR PITCH
00030E: AD  30  C0                   LDA   SPKR       ; CLICK SPEAKER

000311: 88              DELAY        DEY              ; COUNT DOWN DELAY (PITCH)
000312: D0  FD  =0311                BNE   DELAY

000314: CA              DRTN         DEX              ; COUNT DOWN DURATION
000315: D0  F5  =030C                BNE   LOOP       ; CONTINUE NOTE

000317: 60              DONE         RTS


End Merlin-16 asembly, 24 bytes, Errors: 0
```

Pogram 12-5. Sound Routine 2 Loader

```
10 INPUT "PITCH, DURATION ";P,D
20 CALL 768,P,D
30 PRINT
40 GOTO 10
```

This is a much more elegant way of passing the values, and it also doesn't require miscellaneous memory locations as such (although for purposes of simplicity the tone routine itself still uses the same zero page locations).

The secret to the new technique is the use of another new routine,

COMBYTE ($E74C = COMma and BYTE processor). This is an Applesoft BASIC routine which checks for a comma and then evaluates whatever expression follows the comma in the Applesoft BASIC statement. It then returns the result as a single-byte value between $00 and $FF (0–255) in the X register.

It's normally used for evaluating commands such as POKE, HCOLOR=, and others, but it does the job very nicely here. It also leaves TXTPTR pointing to the end of the line (or to a colon if there was one) by using CHRGET to advance TXTPTR appropriate to the number of characters following each comma. Note also that any legal expression such as (X−5)/2 can be used to pass the data.

To verify the importance of managing TXTPTR, try putting a simple RTS ($60) at $300. Calling this, you'll get a SYNTAX ERROR—upon return Applesoft BASIC's TXTPTR will be on the first comma, and the phrase ",P,D" is not a legal Applesoft BASIC expression.

Now what about two-byte quantities (values greater than 256), or strings? There are other routines in Applesoft BASIC that can be used for these, as well.

The most concise way to explain the basic routines you'll need is with another example, Program 12-6.

Program 12-6. Passing Variables

```
**************************************************
* BASIC TO ASSEMBLY LANGUAGE                     *
* VARIABLE PASSING DEMO.                         *
*                                                *
* &N1,N2,N$                                      *
* where N = Real variable,                       *
* with value up to 65535,                        *
* N2 is < 256, and N$ is any                     *
* string.                                        *
*                                                *
* Note that N1, N2 and N$ can                    *
* also be expressions.                           *
*                                                *
* Merlin 8/16 Assembler                          *
*                                                *
**************************************************

BUFFER  EQU   $280          ; INPUT BUFFER FOR WORK AREA
MEM     EQU   $270          ; SOME STORAGE BYTES ($270-272)

FRMNUM  EQU   $DD67         ; EVALUATE NUMERIC EXPRESSION
GETADR  EQU   $E752         ; CONVERT FAC TO INTEGER
LINNUM  EQU   $50           ; $50,51

FRMEVL  EQU   $DD7B         ; EVALUATE ANY EXPRESSION
FRESTR  EQU   $E5FD
INDEX   EQU   $5E           ; $5E,5F
```

```
                    ILDIR    EQU  $E306         ; CHECK FOR DIRECT MODE

                    COMBYTE  EQU  $E74C         ; GET COMMA AND VALUE < 256

                    CHRGOT   EQU  $B7
                    CHKCOM   EQU  $DEBE         ; CHECK FOR COMMA


8000:  20  06  E3   BEGIN    JSR  ILDIR         ; MAKE SURE WE'RE NOT IN IMMED MODE
8003:  20  B7  00            JSR  CHRGOT        ; CHECK CHAR AT TXTPTR
8006:  C9  2C                CMP  #','          ; CHECK FOR COMMA
8008:  D0  03                BNE  REAL          ; NO COMMA
800A:  20  BE  DE            JSR  CHKCOM        ; ADVANCE TXTPTR

800D:  20  67  DD   REAL     JSR  FRMNUM        ; EVALUATE EXPRESSION
8010:  20  52  E7            JSR  GETADR        ;CONVERT TO INTEGER
8013:  A5  50                LDA  LINNUM        ; LOW BYTE OF RESULT
8015:  8D  70  02            STA  MEM           ; STORE IT
8018:  A5  51                LDA  LINNUM+1      ; HI BYTE OF RESULT
801A:  8D  71  02            STA  MEM+1         ; STORE IT

801D:  20  4C  E7   SINGLE   JSR  COMBYTE       ; CHECK COMMA AND EVALUATE
8020:  8E  73  02            STX  MEM+3         ; STORE IT

8023:  20  BE  DE   STRING   JSR  CHKCOM        ; CHECK FOR NEXT COMMA
8026:  20  7B  DD            JSR  FRMEVL        ; EVALUATE STRING EXPRESSION
8029:  20  FD  E5            JSR  FRESTR        ; MAKE SURE IT'S A STRING AND
                                                ; SET UP POINTERS

802C:  A8           COPY     TAY                ; PUT LEN IN Y REG
802D:  88                    DEY                ; FIX LEN FOR XFER LOOP
802E:  B1  5E       LOOP     LDA  (INDEX),Y     ; GET CHAR OF NAME STRING
8030:  99  80  02            STA  BUFFER,Y      ; PUT IT IN NEW BUFFER
8033:  88                    DEY
8034:  C0  FF                CPY  #$FF          ; DONE WITH LOOP
8036:  D0  F6                BNE  LOOP          ; NOPE

8038:  60           DONE     RTS                ; ALL DONE!

8039:  84           CHK           ;CHECKSUM
                                  FOR LISTING

—End assembly, 58 bytes, Errors: 0
```

This program will read a large (greater than 255) floating-point number stored in a real variable, convert it to a two-byte integer, and then store it somewhere. We'll also read a string and a number value less than 256, and will store the data of these variables as well.

Program 12-7. Passing Variables, Applesoft BASIC Loader

```
10 PRINT CHR$(4);"BLOAD VARIABLE.1.DEMO,A$768"
15 POKE 1014,0: POKE 1015,3: REM ($3F6,3F7) = $300
20 N1 = 513: N2 = 127: N$ = "TEST"
30 & N1,N2,N$
40 PRINT PEEK (624) + 256 * PEEK (625)
45 PRINT PEEK (627)
50 FOR I = 0 TO 3
55 PRINT CHR$ ( PEEK (640 + I) );
60 NEXT I: PRINT
```

Program 12-7 includes a few new concepts. The first is to have the BASIC program automatically BLOAD the object code file when it first runs. This isn't really all that new—Chapters 4 and 5 showed how to manually BLOAD a file after assembling it and saving the object code to disk. This program just adds the ProDOS BLOAD command as the first line of the program so you don't have to load it manually each time you run the program. This is a good idea for programs that use added machine language routines.

Using &

The other new feature of the BASIC program is using the ampersand character (&). This is actually just a *very* limited version of the CALL command that you've already been using. The only differences are that the ampersand *always* does the equivalent of a CALL 1014 whenever it's encountered in a program, and, because the ampersand always CALLs 1014, you must remember to POKE the proper destination address at 1014, 1015 before the ampersand is first used. Location 1014 is equivalent to $3F5, and if you go to the Monitor and list starting at $3F5, you see the following:

```
00/03F5: 4C 03 BE   JMP  BE03
00/03F8: 4C 00 BE   JMP  BE00
00/03FB: 4C 59 FF   JMP  FF59
```

You can see that all there is at $3F5 is a JMP command that you're rewriting with your POKEs. This JMP is called a *vector,* and is used to direct the running machine language program to a new place in memory. After running the BASIC program, go to the Monitor again, and you'll see $3F5 has changed to point to $300:

```
00/03F5: 4C 00 03   JMP  0300
00/03F8: 4C 00 BE   JMP  BE00
00/03FB: 4C 59 FF   JMP  FF59
```

The only advantage of using the ampersand is that it saves a few keystrokes compared to typing CALL 768 each time you call your routine. Other than that, it's identical to a CALL statement.

The BASIC program itself simply loads the demo assembly language routine at $300 and then sets the ampersand vector to point to $300.

A Closer Look

Let's look at the assembly language program itself. In order of appearance, starting on line 36, here are the routines that are called, with a brief explanation:

Applesoft BASIC almost always uses the memory range from $200 to $2FF, called the *input buffer,* to store the characters you're typing as part of an INPUT, or when you're entering a new line of your program. Because any INPUT command writes into this area, you can't store anything there, but it is available as a temporary area for your routines.

We'll use this in our program as a temporary place to work with some string data, but the first thing to do is to make sure we're not in immediate mode, typing in the very area we want to store to. JSR ILDIR ($E306 = check for ILlegal DIRect error) does this. It will generate an Applesoft BASIC ILLEGAL DIRECT ERROR if our routine is not being called from within a running program.

When the ampersand is first called on line 30, the memory pointer (TXTPTR) is pointing to the first variable (or character) following the ampersand.

First, because a comma follows the CALL statement, TXTPTR must be advanced past the comma. However, because you might later decide to use the ampersand, we can't be sure a comma will always be there. Therefore, the routine is made more versatile by beginning it with a call to the routine CHRGOT ($B7 = CHaRacter GOT). This is similar to CHRGET in that the accumulator is loaded with whatever character is pointed to by TXTPTR, but TXTPTR is not advanced after the read. This means you can check to see what's there before putting everything in motion.

In this case, we check for a comma. If it's there, we advance TXTPTR using CHKCOM ($DEBE = CHecK for COMma), which moves TXTPTR past a comma and at the same time checks to make sure that it was in fact a comma being skipped. If there isn't a comma there (as will be the case if the routine is called with the ampersand syntax), it leaves everything alone and goes directly to the actual routine on line 36. All of this is so that you have the option of calling the routine either with a statement like CALL 768,N1,N2,N$ or &N1,N2,N$. Remember, if you use the CALL method, you don't have to set up the ampersand vector.

FRMNUM ($DD67 = evaluate a FoRMula for a NUMber) is a routine which will evaluate any numeric value, variable, or expression, and which will return the result in the Floating Point Accumulator (FAC). You don't have to deal with the FAC directly, however, because there is another routine, GETADR ($E752 = GET ADdRess), that will convert a floating-point number in the FAC into a two-byte integer, placing the result in LINNUM, LINNUM+1 ($50,51 = LINeNUMber). You might correctly guess that these two routines are used by Applesoft BASIC for handling line numbers and addresses.

Our program then stores these two bytes in MEM, MEM+1 ($270,271). During the evaluation, FRMNUM advances TXTPTR to the next character after the expression, in this case a comma before the next variable. FRMNUM will produce an automatic TYPE MISMATCH ERROR if you should try to use a string expression instead of a numeric expression in the first position.

Sometimes you may want to pass a relatively small number (less than 256); in this case you can use COMBYTE ($E74C) to check the comma, advance TXTPTR, and then evaluate any numeric expression (remember an expression can be just single numbers and variables). It then returns the result in the X register. If the result is greater than 255, it will automatically generate an ILLEGAL QUANTITY ERROR in the calling Applesoft BASIC program. This saves you *a lot* of testing and message printing in the BASIC program. The result is stored at MEM+3 just to set it off from the first two data bytes stored earlier.

Finally, starting on line 52, we again check for an expected comma, but now we call the routine FRMEVL ($DD7B = general FoRMula EVaLuation). FRMEVL is like FRMNUM, except that it will evaluate *any* expression, string or numeric. To check for a string, we need to call FRESTR ($E5FD = FREe STRing), which checks to make sure we just evaluated a string and also leaves us with a pointer to the string data in INDEX, INDEX+1 ($5E,5F) and the length of the string in the accumulator.

Lines 57 through 63 then use this information to copy the string to the middle of the input buffer (BUFFER = $280), just to demonstrate how the data can be moved or manipulated.

Passing Variables from Machine Language to Applesoft BASIC

Now that you can send any kind of information you want to a machine lanuage routine, how will that routine send its answers or other information back to Applesoft BASIC? The answer, again, is to use built-in routines. Since the statement X = Y + 2 * (5/2) exists in Applesoft BASIC, there must be routines that, after doing the calculation, convert the result to the Applesoft BASIC variable X.

Program 12-8 is a demonstration program that sends data from a machine language program back to an Applesoft BASIC program as real, integer, and string variables. Program 12-9 is the Applesoft BASIC loader used with Program 12-8.

Program 12-8. Passing Variables to an Applesoft BASIC Program

```
                         ************************************************
                         *                                              *
                         * MACH. LANG. TO FP VAR DEMO                   *
                         * SYNTAX: CALL 768,X%,Y,Z$                     *
                         * WHERE:                                       *
                         * X% = VALUE AT $270,271                       *
                         * Y = VALUE AT $272,273                        *
                         * Z$ = STRING AT $280+                         *
                         *                                              *
                         * MERLIN 8/16 ASSEMBLER                        *
                         *                                              *
                         ************************************************

          =0085           FORPNT   EQU  $85         ; $85,86
          =0280           STR      EQU  $280        ; STRING BUFFER
          =0270           DATA1    EQU  $270        ; 1ST VALUE
          =0272           DATA2    EQU  $272        ; 2ND VALUE

          =00B7           CHRGOT   EQU  $B7
          =DEBE           CHKCOM   EQU  $DEBE
          =DFE3           PTRGET   EQU  $DFE3
          =DD6C           CHKSTR   EQU  $DD6C
          =E3E9           MAKSTR   EQU  $E3E9
          =DA9A           SAVD     EQU  $DA9A
          =E306           ILDIR    EQU  $E306

          =DD6A           CHKNUM   EQU  $DD6A
          =EB9D           GIVAYF2  EQU  $EB9D
          =EBF2           QINT     EQU  $EBF2
          =0011           VARTYPE  EQU  $11         ; STR$=$FF, NUM=$00
          =0012           NUMTYPE  EQU  $12         ; INT =$80, REAL = $00
          =DA63           LET2     EQU  $DA63
          =DA6B           LET3     EQU  $DA6B
          =009D           FAC      EQU  $9D


008000: 20 06 E3          BEGIN    JSR  ILDIR       ; MAKE SURE WE'RE NOT IN IMMED MODE
008003: 20 B7 00                   JSR  CHRGOT      ; CHECK CHAR AT TXTPTR
008006: C9 2C                      CMP  #','        ; CHECK FOR COMMA
008008: D0 03   =800D              BNE  SEND1       ; NO COMMA
00800A: 20 BE DE                   JSR  CHKCOM      ; ADVANCE TXTPTR

00800D: 20 E3 DF          SEND1    JSR  PTRGET      ; FIND OR CREATE VARIABLE
008010: 20 6A DD                   JSR  CHKNUM      ; VAR = NUM
008013: 85 85                      STA  FORPNT      ; FOR USE BY LET2/LET3
008015: 84 86                      STY  FORPNT+1    ; AS ADDR OF VARIABLE DATA

```

```
008017: AC 70 02                 LDY  DATA1      ; LO BYTE OF RETURN VALUE
00801A: AD 71 02                 LDA  DATA1+1    ; HI BYTE
00801D: 85 9E                    STA  FAC+1
00801F: 84 9F                    STY  FAC+2
008021: A2 90                    LDX  #$90
008023: 25 12                    AND  NUMTYPE
008025: 20 9D EB                 JSR  GIVAYF2
008028: A5 12                    LDA  NUMTYPE
00802A: 30 06 =8032              BMI  S1A        ; INTEGER VARIABLE
00802C: 20 63 DA                 JSR  LET2       ; MAKE A REAL VAR
00802F: 18                       CLC
008030: 90 06 =8038              BCC  SEND2      ; ALWAYS BRANCH

008032: 20 F2 EB        S1A      JSR  QINT       ; XVERT TO INTEGER
008035: 20 6B DA                 JSR  LET3       ; THAT'S ALL.

008038: 20 BE DE        SEND2    JSR  CHKCOM     ; MOVE TXTPTR PAST COMMA
00803B: 20 E3 DF                 JSR  PTRGET     ; FIND OR CREATE VARIABLE
00803E: 20 6A DD                 JSR  CHKNUM     ; VAR = NUM
008041: 85 85                    STA  FORPNT     ; FOR USE BY LET2/LET3
008043: 84 86                    STY  FORPNT+1   ; AS ADDR OF VARIABLE DATA

008045: AC 72 02                 LDY  DATA2      ; LO BYTE OF RETURN VALUE
008048: AD 73 02                 LDA  DATA2+1    ; HI BYTE
00804B: 85 9E                    STA  FAC+1
00804D: 84 9F                    STY  FAC+2
00804F: A2 90                    LDX  #$90
008051: 25 12                    AND  NUMTYPE
008053: 20 9D EB                 JSR  GIVAYF2
008056: A5 12                    LDA  NUMTYPE
008058: 30 06 =8060              BMI  S2A        ; INTEGER VARIABLE
00805A: 20 63 DA                 JSR  LET2       ; MAKE A REAL VAR
00805D: 18                       CLC
00805E: 90 06 =8066              BCC  SENDSTR    ; ALWAYS BRANCH

008060: 20 F2 EB        S2A      JSR  QINT       ; XVERT TO INTEGER
008063: 20 6B DA                 JSR  LET3       ; THAT'S ALL.


008066: 20 BE DE        SENDSTR  JSR  CHKCOM     ; MOVE PAST COMMA
008069: 20 E3 DF                 JSR  PTRGET
00806C: 20 6C DD                 JSR  CHKSTR
00806F: 85 85                    STA  FORPNT
008071: 84 86                    STY  FORPNT+1

008073: A9 80                    LDA  #<STR      ; LOC OF STRING BUFFER
008075: A0 02                    LDY  #>STR
008077: A2 0D                    LDX  #$0D       ; TERMINATOR CHARACTER

008079: 20 E9 E3                 JSR  MAKSTR     ; CREATE STRING DESCRIPTOR
00807C: 20 9A DA                 JSR  SAVD       ; PUT DATA AT A,Y INTO VARIABLE

```

```
00807F: 60              100 DONE     RTS
                        101
008080: A5              102          CHK                   ; CHECKSUM FOR LISTING
```

—End Merlin-16 assembly, 129 bytes, Errors: 0

Program 12-9. Applesoft BASIC Loader

```
0 REM ML TO FP VAR DEMO
5 PRINT CHR$ (4);"BLOAD VARIABLE.2.DEMO,A$300"
10 A% = 200
20 B = 45123
30 C$ = "THIS IS A TEST"
40 POKE 624,A% - INT (A% / 256) * 256: REM LO BYTE
45 POKE 625, INT (A% / 256): REM HI BYTE
50 POKE 626,B - INT (B / 256) * 256: REM LO BYTE
55 POKE 627, INT (B / 256): REM HI BYTE
60 FOR I = 1 TO LEN (C$)
65 POKE 639 + I, ASC ( MID$ (C$,I,1) )
70 NEXT I
75 POKE 639 + I,13: REM 'RETURN'
100 REM DISPLAY & CONVERT DATA
105 PRINT "ORIGINAL DATA: A% = ";A%,"B = ";B
110 PRINT "C$ = ";C$: PRINT
115 CALL 768,X%,Y,Z$
120 PRINT "NEW DATA: : X% = ";X%,"Y = ";Y
125 PRINT "Z$ = ";Z$: PRINT
130 END
```

Just for variety, Program 12-9 uses the CALL method and shows how the variables follow a the CALL statement and a comma.

A Detailed Look

As with the first variable passing example, we first check for a comma, and move TXTPTR past it, if necessary.

Then, PTRGET ($DFE3 = PoinTeR GET), first called on line 43 of the listing, locates the variable in the Applesoft BASIC calling line. If a variable with that name has not yet been defined in the calling program, PTRGET creates one. The JSR CHKNUM ($DD6A = CHecK for NUMber) on line 44 verifies that this variable is a numeric—not a string—variable.

At this point, PTRGET has left the address of the variable data in the Accumulator and Y register, and lines 45 and 46 store this address in an Applesoft BASIC pointer, FORPNT ($85,86 = FORmula PoiNTer), to be used later when the variable data is actually sent back.

Lines 48 and 49 transfer the data, which for this demo has already been stored at locations $270, 271 into the Floating Point Accumulator (FAC = $9D). The remaining lines (52–62) identify whether the receiving variable was an integer or a real variable type, and then they send the data back using the appropriate internal Applesoft BASIC routines accordingly.

For the purposes of this demo, the data is arbitrarily placed in memory by the Applesoft BASIC program. But, under normal circumstances, this data would have been already created by your assembly language program and could be located anywhere in memory.

Lines 64–84 basically duplicate the same variable passing procedure for the second variable. You might think the program should be written to send only integers back to the first variable, and only reals back to the second. In practice, however, you should use the routine as presented here so that you don't have to remember whether to use a specific numeric variable type. The Applesoft BASIC demo uses both integers and reals just to prove it works, but the assembly language routine shown sends data to any numeric variable.

Lines 87–98 assume that string data, ending with a carriage return ($0D = 13), is in memory starting at $280. Again, PTRGET is used to identify the proper variable in the calling Applesoft BASIC program. This time, CHKSTR ($DD6C = CHecKSTRing) is used to make sure it's a string variable. Sending the data back to Applesoft BASIC is even easier than it was for numbers—you need only load A and Y with the address of the beginning of the string, and X with the terminator character, and then call MAKSTR ($E3E9 = MAKe STRing). MAKSTR assumes that FORPNT has already been set up with the address of the variable data (lines 83 and 84), and it creates the preliminary string descriptor that SAVD ($DA9A = SAVe Descriptor) ultimately turns into a true Applesoft BASIC string variable.

The Applesoft BASIC program (Program 12-9) is designed only to prove the routine works. Lines 10–30 define three variables, lines 40–75 POKE the data into memory so our routine will have something to work with, and line 115 actually does all the work of returning the data, in the form of three new Applesoft BASIC variables, back to the calling program.

In normal practice, this data would have been created by the machine language subroutine itself, and no POKEs would be used.

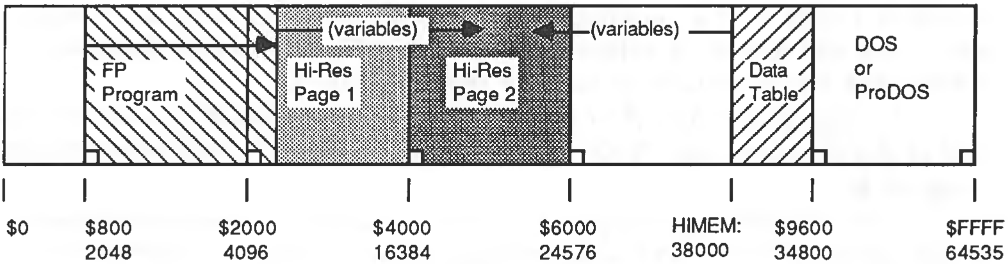
How to Add Your Own Routines

Our examples so far have all loaded the routines at $300. This is because the area from $300 to $3CF is not used by Applesoft BASIC or ProDOS for anything, so is available for short routines.

As you create your own subroutines and programs, you'll have to decide where you want them to be located in the machine. Where you put them depends on how big the routine is (number of bytes), how many routines you're using (there may be room for one short routine at $300), and whether the routine *has* to be put at a specific location in memory to work properly. Most large routines that are listed in computer magazines have to be loaded at a certain spot, and the article that explains them will give instructions on how to set things up.

However, if you write the routine yourself, or you want to move a published routine to a new location, you'll have to decide where to put it. First, let's look at how a normal Applesoft BASIC program sits in memory (see Figure 12-1).

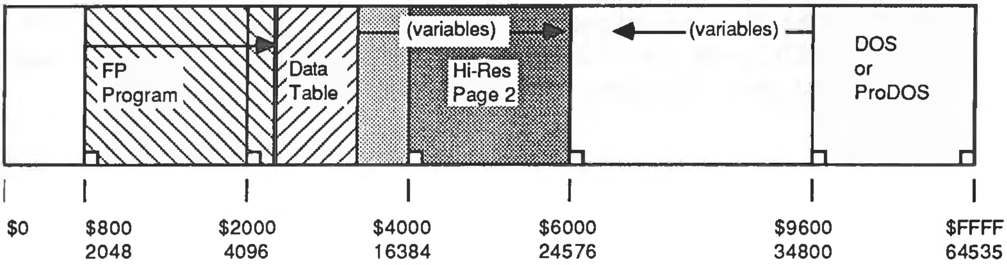
Figure 12-1. Normal Applesoft BASIC Program Memory Map



When an Applesoft BASIC program is running, it uses all of the memory from $800 (2048 decimal) to $9600 (38400 decimal). The program itself starts at $800. LOMEM: defaults to the end of the BASIC program and determines where Applesoft BASIC will start storing all the variable names and numeric variable data that your program uses. HIMEM: defaults to just below the part of memory used by ProDOS (usually $9600), and the bytes for string data start here in memory, building down as new strings are defined. As more data is defined in the program as a whole, the two groups, numeric and string data, grow toward the middle of memory.

If you want to add a routine to the system, there are three usual places to put it, as shown in Figure 12-2.

Figure 12-2. Applesoft BASIC with Routines Memory Map



If the routine is less than 200 bytes long, you can put it at $300 (768). Starting at $3D0 are some important ProDOS pointers, so your program can't be larger than the space between $300 and $3D0 if you want to put it here.

Another option is to find the end of your program in memory, to BLOAD the routine there, and to set LOMEM: to a larger value to create a gap for your program. The listing for a BASIC program that did this might look like this:

```
10 PRINT CHR$(4);"BLOAD ROUTINE,A";
   PEEK(175) + 256 * PEEK(176)
20 REM ASSUME ROUTINE IS 200 BYTES LONG...
30 LOMEM: PEEK(175) + 256 * PEEK(176) + 200
```

Note that no variables are used in the calculations. Since you'll be changing LOMEM:, no variables may be used before LOMEM: is changed, since they will lose their values as soon as LOMEM: is moved (Applesoft BASIC won't know where to look for the old values).

Locations 175, 176 ($AF,B0 hex) are Applesoft BASIC's pointer to the end of the program, and PEEKing here tells us where the end of the BASIC program is.

This last technique requires that your program is position independent (there are no JMPs or JSRs in the program to other parts of itself). You'll recall from the discussion in Chapter 6 that if there is a JMP or JSR in the program to another location within the program, and you move the program's position in memory to any other location other than the ORG address, it will crash when you try to run it.

If you want to write programs that are not position independent, you can always pick an arbitrarily large memory address for the ORG and BLOAD, like $6000 (the top of hi-res page two), and set LOMEM: to, say, 28672 ($7000 hex). $1000 hex is about 4000 bytes, which should be enough room for many routines. You just have to make sure your BASIC program never gets so large as to go past $6000, or that your machine language routine isn't larger than $1000 bytes.

All this might seem like a lot to learn at once, but you'll find that including the lines necessary to pass variables back and forth fairly simple to use, once you try them a few times.

By using these techniques in your own subroutines that work with Applesoft BASIC programs, I think you'll find it's a lot easier to use what you've learned about assembly language right away.

Chapter 13

ProDOS

Chapter 13

ProDOS

ProDOS, which stands for *Professional Disk Operating System*, is a set of routines loaded into RAM when the computer first starts up from the disk. The routines are responsible for opening and reading files and for writing data to the disk. Without a disk operating system in the machine, the Apple IIGS doesn't inherently know how to read a disk. You can prove this to yourself by turning on the computer with no disk in the drive, and then pressing RESET to go to Applesoft BASIC without starting up a disk. If you type CATALOG at this point, you'll get a SYNTAX ERROR because the computer, without a DOS loaded, doesn't know anything about talking to the disk.

There are two main versions of ProDOS, ProDOS 8 and ProDOS 16. ProDOS 8 was originally designed for the Apple IIe and IIc, which use the 65C02 microprocessor. In this processor, the Accumulator, registers, and memory are always accessed one byte at a time, so these are called 8-bit machines. ProDOS 8 will also run on the Apple IIGS, and is the required disk operating system for Applesoft BASIC.

ProDOS 16 is the latest incarnation of ProDOS, and it's designed specifically for the Apple IIGS. It will not run on a IIe or IIc, nor with Applesoft BASIC. Fortunately, the user doesn't have to worry about which operating system is required by a given program, because the Apple IIGS automatically loads the correct operating system when a program is loaded.

ProDOS 8

To get an idea of how ProDOS 8 is set up in the computer, let's first consider a hypothetical disk, with ProDOS 8 (named PRODOS), BASIC.SYSTEM, and an Applesoft BASIC program named STARTUP on the disk. This disk can be booted on either a IIGS, IIe, or IIc.

When the disk is first booted, the disk drive hardware is preprogrammed to read in the first two blocks of data on the disk (blocks 0 and 1) and to execute this data as a program. This very small program then reads in more information, and the process continues until an entire application program (in this case STARTUP) is loaded and running. To the original designers of disk systems, this process of one bit of code loading some more that loads even more had an almost magical feeling to it, reminding them of the phrase *pulling yourself up by your bootstraps*. This inspired the term *booting* for starting up a disk.

The entire ProDOS 8 boot process goes like this: First, the code stored on the disk in blocks 0 and 1 is loaded and run. This miniprogram looks for a file in the main (root) directory named PRODOS. If it can't find exactly that name, or if some other problem occurs while it's trying to load and run that file, you'll get the Unable to Load ProDOS error message.

On our hypothetical disk, the file PRODOS is ProDOS 8, and the disk operating system itself is loaded into the computer. This isn't the end, though. ProDOS 8 doesn't understand CATALOG either. In fact, it has no user interface at all, let alone a friendly one. It has various routines that access the disk, but they all expect to be called with a JSR from some machine language program. Many Applesoft BASIC programs, on the other hand, are written with statements like PRINT CHR$(4);"CATALOG", that the programmer expects will make something happen.

ProDOS 8 is called a *kernel*, in that it's a central part of the operating computer, but it contains none of the niceties that make up a complete program. To bridge this gap, ProDOS 8 on our disk loads and runs BASIC.SYSTEM, which in turn looks for a file called STARTUP that is an Applesoft BASIC file.

BASIC.SYSTEM need not be run. ProDOS 8 in general just looks for the first file in the main directory whose name ends in .SYSTEM and whose file type is SYS ($FF). Although BASIC.SYSTEM was the system file on our hypothetical disk, it need not be. A program like *AppleWorks*, or any other application program, has its own system file as the first system file on the disk, and it doesn't need BASIC.SYSTEM or any Applesoft BASIC program at all on the disk.

Writing .SYSTEM Files

So, how do you write your own stand-alone program that's a SYSTEM file under ProDOS 8? It's actually quite simple. There are only a few things you need to know:

1. SYSTEM files are automatically loaded starting at memory location $2000. If your program is not totally position independent (if it has even *one* internal address reference), it must be assembled with an ORG $2000.
2. The filetype of the object file must be $FF (SYS). In *Merlin*, the DSK and TYP directives will take care of this. In *APW*, you must use the MAKEBIN and FILETYPE commands.
3. Instead of ending with an RTS, you must execute a call (JSR) to ProDOS, telling it you're finished. This Quit Call lets ProDOS return control to a program selector or any other program that started your application. You should

never end a program by telling the user to reboot, or, worse yet, by clearing memory and forcing a reboot.

The discussion that follows assumes you're familiar with ProDOS directory structure (root directories and subdirectories), the meaning of different file types, and so forth. This discussion will briefly introduce you to some of the basic rules for working with ProDOS, and it will give you an idea of what's involved in dealing with ProDOS from assembly language.

The Machine Language Interface: MLI

To make using ProDOS from machine language as easy as possible, the designers came up with a standard procedure to make any given call (JSR) to ProDOS. This common calling point (and way of using ProDOS) is called the *Machine Language Interface* (MLI). The general procedure is:

1. Call the MLI entry point. This is always done with a JSR $BF00.
2. The JSR is immediately followed by three bytes that encode the desired ProDOS command. The first byte is the command code itself, followed by two more bytes that form a pointer to a larger block called the *parameter list* or *parameter table* (parm table). The parameter list may contain things like the name of the file to open, and how many bytes to read. When the ProDOS call returns, it always resumes execution immediately *after* these three bytes. Program 11-1, the Stack Indirect Indexed Sample, showed a way of displacing the return address after a JSR, and this is similar to what ProDOS does with an MLI call.
3. After the three data bytes, there is usually a BCS ERROR instruction. ProDOS sets the Carry if an error occurs, and it stores the error code in the Accumulator. The BCS test will then branch to your own error routine to take appropriate action. If no error occurs, the carry will be clear and your program will continue. Notice that you are on your own now, and no longer enjoy the support of Applesoft BASIC and BASIC.SYSTEM to handle errors and print messages. If you want a CATALOG in your own SYSTEM type program, you'll have to write it yourself.

The Simplest Program

The first SYSTEM program (Program 13-1) we'll write that uses ProDOS 8 will be just about the simplest possible: It will clear the screen, ask for a keypress, and then do the Quit Call. The command code for a Quit is $65.

Program 13-1 can be tested by going to a program selector like the Apple Program Launcher, DeskTop, or your favorite program selector, and then choosing P8.SYSTEM in the selector menu. When you press a key, you automatically should be returned to the selector program. The name of this file, P8.SYSTEM, has no connection to the file P8 on your Apple IIGS System Disk, other than we are just using the characters P8 in these examples to indicate that a ProDOS 8 file is being used.

Notice that every ProDOS 8 SYSTEM file starts up in the total 8-bit mode, just as would a routine you were calling from Applesoft BASIC.

Looking at the source listing, lines 14 and 15 show how to create a file with a specific file type in *Merlin*. The assemble-to-disk feature was described in Chapter 4. The **TYP (file TYPe)** directive on line 15 should immediately follow the DSK directive; it tells *Merlin* what the file type of the object file should be. For a SYS file, this should be $FF. Other ProDOS file types are listed in Table 13-1. Remember that when assembling to disk, you no longer have to save the object file manually at the main menu of the *Merlin* assembler. Of course, you will still have to save the source file after you've typed it in.

The program itself starts by clearing the screen, printing a message, and then waiting for a keypress. I used the BIT instruction (see Chapter 9) more for variety than necessity.

On line 30 is the JSR to MLI (defined with an Equate at the beginning as $BF00). The DFB $65 on line 31 is a *Merlin* pseudo-op that assembles as only a *single* byte, in this case the $65 for the Quit command. **DFB (DeFine Byte)** is a data storage pseudo-op, similar to HEX, and is used whenever you want to put a single byte, whose value may be defined by a label, in your program. Line 32 uses the DA pseudo-op, first mentioned in Chapter 10, that stores *two* bytes in address form (low-order byte first). In this case the address is a pointer to the parameter list (PARMTBL at $2021). These bytes are followed by a BCS to an error routine, which, if everything is assembled correctly, will never be taken. The BRK instruction on line 34 is likewise unused since a no-error Quit will never actually return. In an assembly listing, it is best to use the instruction BRK $00 (although just BRK with no operand is legal). This is because the monitor always lists a BRK plus the byte which follows. If you use just BRK, you'll have trouble listing your programs with the monitor. The purpose of the BRK is to halt the program if something is wrong. In this case, the only probable cause is if you mistyped the quit instruction, and ProDOS returned an error code for some other command.

The structure of all ProDOS parameter lists, such as PARMTBL on line 36, follow a general pattern. The first byte in the table indicates the number of parameters in the list, *not* the number of bytes. Since Quit, or any other

ProDOS command, already knows how many parameters it requires, this first byte is mainly for internal error checking by the MLI handler.

The byte on line 37 is a single-byte code for the type of quit call being made. For the standard, no-frills ProDOS 8 quit call, this should be zero. This will return you to the program launcher (if one is used) directly. There is also another type of quit, called the ProDOS 8 Enhanced Quit, that can be used if you boot ProDOS 16 first. In our example of the disk where PRODOS *is* ProDOS 8, this is not an option. The next five bytes are not used for a standard ProDOS 8 quit, so are set to zero.

It is *essential* that you use precisely the ***correct number of bytes,*** and appropriate values, in the complete MLI call. If you use a DA on line 31 or a DFB on line 32, or if you use the incorrect structure in the parameter list, very strange and definitely unpredictable things will happen. Ninety percent of all ProDOS programming errors stem from incorrect MLI calls. Consider yourself warned.

***APW* users.** If you're using *APW*, Program 13-2 is the corresponding listing for P8.SYSTEM. After the ASML assembly (see Chapter 5), first type MAKEBIN P8.SYS. This will convert the output EXE file into a binary file that loads at $2000. Then type FILETYPE P8.SYSTEM SYS to change the filetype to $FF (SYS). The file can then be launched from a program selector as described earlier.

The main differences between the *APW* version and the *Merlin* listing are as follows: First, to make sure the high bit is set on the print statements, the *APW* has the assembler directive **MSB ON**. *APW* also assumes that everything starts off in 16-bit mode. Since this is a ProDOS 8 file, we must include the directives LONGA OFF and LONGI OFF to tell the assembler that the microprocessor will be in the 8-bit mode. If this step is omitted, LDY #$00, for example, would be assembled as A0 00 00 (three bytes) instead of A0 00 (two).

Finally, *APW* doesn't have the DA or DFB pseudo-ops, but instead uses the generic DC instruction, which is qualified by the leading characters in front of the operand. Leading characters I1 tell it to assemble a single byte; I2 specifies two bytes. Be very careful when constructing your MLI calls—it is very easy to use the wrong byte length and mess up the entire call.

The *APW*'s assembly is two bytes longer than *Merlin*'s. This is because *APW* assembled the BRK instructions as two-byte instructions, whereas *Merlin* assembled them as just one byte. Because a BRK stops program execution no matter what follows it, the use of one or two bytes is pretty much a programmer preference. You can force a two-byte BRK instruction in *Merlin* by including the byte you want used as the second byte, as in

```
BRK $00
```

Program 13-1. Simple P8 System File

```
                         ********************************************
                         *          SIMPLE P8 SYSTEM FILE           *
                         *           MERLIN ASSEMBLER               *
                         ********************************************

              =BF00      MLI      EQU  $BF00
              =FDF0      COUT     EQU  $FDF0
              =FC58      HOME     EQU  $FC58
              =C000      KYBD     EQU  $C000
              =C010      STROBE   EQU  $C010

                                  ORG  $2000

                                  DSK  P8.SYSTEM
                                  TYP  $FF          ; SYSTEM FILE TYPE

002000: 20 58 FC         START    JSR  HOME         ; CLEAR SCREEN

002003: A0 00            PRINT    LDY  #$00         ; INIT Y-REG
002005: B9 2B 20         LOOP     LDA  MSSG,Y       ; GET CHAR TO PRINT
002008: F0 06  =2010              BEQ  GETKEY
00200A: 20 F0 FD                  JSR  COUT         ; PRINT IT
00200D: C8                        INY               ; NEXT CHAR
00200E: D0 F5  =2005              BNE  LOOP         ; WRAPAROUND PROTECT

002010: 2C 00 C0         GETKEY   BIT  KYBD         ; KEYPRESS?
002013: 10 FB  =2010              BPL  GETKEY       ; NOPE
002015: 2C 10 C0                  BIT  STROBE       ; CLEAR KEYPRESS

002018: 20 00 BF         QUIT     JSR  MLI          ; DO QUIT CALL
00201B: 65                        DFB  $65          ; QUIT CODE
00201C: 22 20                     DA   PARMTBL      ; ADDRESS OF PARM TABLE
00201E: B0 09  =2029              BCS  ERROR        ; NEVER TAKEN
002020: 00 00                     BRK  $00          ; SHOULD NEVER GET HERE . . .

002022: 04               PARMTBL  DFB  4            ; NUMBER OF PARMS
002023: 00                        DFB  0            ; QUIT TYPE: 0 = STD QUIT
002024: 00 00                     DA   $0000        ; NOT NEEDED FOR STD QUIT
002026: 00                        DFB  0            ; NOT USED AT PRESENT
002027: 00 00                     DA   $0000        ; NOT USED AT PRESENT

002029: 00 00            ERROR    BRK  $00          ; WE'LL NEVER GET HERE?

00202B: D0 CC C5 C1      MSSG     ASC  "PLEASE      PRESS A KEY ->",00
00202F: D3 C5 A0 D0
002033: D2 C5 D3 D3
002037: A0 C1 A0 CB
00203B: C5 D9 A0 AD
```

```
00203F: BE 00

002041: D2                 CHK               ; CHECKSUM FOR LISTING

End Merlin-16 assembly, 66 bytes, errors: 0
```

Program 13-2. Simple P8 System File for *APW*

```
0000                    ********************************************
0000                    *        SIMPLE P8 SYSTEM FILE             *
0000                    *           APW ASSEMBLER                  *
0000                    ********************************************
0000
0000                              KEEP      P8.SYSTEM
0000                              MSB       ON
0000
0000                              LONGA     OFF
0000                              LONGI     OFF
0000
0000                              ORG       $2000
0000
0000                    MAIN      START
0000
0000                    MLI       EQU       $BF00
0000                    COUT      EQU       $FDF0
0000                    HOME      EQU       $FC58
0000                    KYBD      EQU       $C000
0000                    STROBE    EQU       $C010
0000
0000
0000  20 58 FC          ENTRY     JSR       HOME
0003
0003  A0 00             PRINT     LDY       #$00         ; INIT Y-REG
0005  B9 2B 00          LOOP      LDA       MSSG,Y       ; GET CHAR TO PRINT
0008  F0 06                       BEQ       GETKEY       ; END OF MSSG.
000A  20 F0 FD                    JSR       COUT         ; PRINT IT
000D  C8                          INY                    ; NEXT CHAR
000E  D0 F5                       BNE       LOOP         ; WRAPAROUND PROTECT
0010
0010  2C 00 C0          GETKEY    BIT       KYBD         ; KEYPRESS?
0013  10 FB                       BPL       GETKEY       ; NOPE
0015  2C 10 C0                    BIT       STROBE       ; CLEAR KEYPRESS
0018
0018  20 00 BF          QUIT      JSR       MLI          ; DO QUIT CALL
001B  65                          DC        I1'$65'      ; QUIT CODE
001C  22 00                       DC        I2'PARMTBL'  ; ADDRESS OF PARM TABLE
001E  B0 09                       BCS       ERROR        ; NEVER TAKEN
0020  00 00                       BRK       $00          ; SHOULD NEVER GET HERE . . .
0022
0022  04                PARMTBL   DC        I1'4'        ; NUMBER OF PARMS
0023  00                          DC        I1'0'        ; QUIT TYPE: 0 = STD QUIT
0024  00 00                       DC        I2'0000'     ; NOT NEEDED FOR STD QUIT
```

```
0045 0026  00                     DC     I1'0'        ; NOT USED AT PRESENT
0046 0027  00  00                 DC     I2'0000'     ; NOT USED AT PRESENT
0047 0029
0048 0029  00  00       ERROR     BRK    $00          ; WE'LL NEVER GET HERE?
0049 002B
0050 002B  D0  CC  C5  C1  MSSG   DC     C'PLEASE PRESS A KEY >'
0051 0040  00                     DC     I1'0'
0052 0041
0053 0041                         END
```

The Enhanced ProDOS 8 Quit

If ProDOS 8 has been started up by the normal ProDOS-16 boot process (described in greater detail in the next chapter), there is another quit option available, called the ProDOS 8 Enhanced Quit. In this command, you can specify the pathname of the program you wish to quit to. In this way, your program itself becomes a program launcher. The specified program can be either a ProDOS 8 or ProDOS 16 system file (SYS or S16).

The only changes that need to be made to our original program to demonstrate this are to change the quit type code from $00 to $EE, and to change the two bytes following to a pointer to the pathname for the program we want to run next. In the next example, program 13-3, we'll assume the you have the file P8.SYSTEM, which you assembled earlier, on the disk in the same directory as P8.LAUNCHER.

When you start up this program from a program selector, it will first prompt you for a keypress and then will quit by running P8.SYSTEM. Then, when P8.SYSTEM does its quit call, control will return back to the program selector that launched P8.LAUNCHER.

Notice that lines 46–48 define a string with a leading length byte. ProDOS uses a standard protocol that expects every string it deals with to begin with a length byte. This is sometimes also called a PASCAL-format string, from an obvious heritage.

P8.LAUNCHER should give you some ideas as to how you could create your own ProDOS menu program that presented the user with a list of programs to run. By changing the pointer on line 38, or by rewriting the string itself, you can create the pathname for any file you wish.

Program 13-3. ProDOS 8 Launcher Demo

```
                    1  **********************************************
                    2  *      PRODOS 8 'LAUNCHER' DEMO              *
                    3  *           MERLIN ASSEMBLER                 *
                    4  **********************************************
                    5
      =BF00         6  MLI        EQU   $BF00
      =FDF0         7  COUT       EQU   $FDF0
```

```
               =FC58      8 HOME     EQU  $FC58
               =C000      9 KYBD     EQU  $C000
               =C010     10 STROBE   EQU  $C010
                         11
                         12          ORG  $2000
                         13
                         14          DSK  P8.LAUNCHER
                         15          TYP  $FF           ; SYSTEM FILE TYPE
                         16
002000: 20 58 FC         17 START    JSR  HOME          ; CLEAR SCREEN
                         18
002003: A0 00            19 PRINT    LDY  #$00          ; INIT Y-REG
002005: B9 29 20         20 LOOP     LDA  MSSG,Y        ; GET CHAR TO PRINT
002008: F0 06    =2010   21          BEQ  GETKEY
00200A: 20 F0 FD         22          JSR  COUT          ; PRINT IT
00200D: C8               23          INY                ; NEXT CHAR
00200E: D0 F5    =2005   24          BNE  LOOP          ; WRAPAROUND PROTECT
                         25
002010: 2C 00 C0         26 GETKEY   BIT  KYBD          ; KEYPRESS?
002013: 10 FB    =2010   27          BPL  GETKEY        ; NOPE
002015: 2C 10 C0         28          BIT  STROBE        ; CLEAR KEYPRESS
                         29
002018: 20 00 BF         30 QUIT     JSR  MLI           ; DO QUIT CALL
00201B: 65               31          DFB  $65           ; QUIT CODE
00201C: 21 20            32          DA   PARMTBL       ; ADDRESS OF PARM TABLE
00201E: B0 08    =2028   33          BCS  ERROR         ; NEVER TAKEN
002020: 00               34          BRK  $00           ; SHOULD NEVER GET HERE . . .
                         35
002022: 04               36 PARMTBL  DFB  4             ; NUMBER OF PARMS
002023: EE               37          DFB  $EE           ; QUIT TYPE = PRODOS 8 ENHANCED
002024: 4C 20            38          DA   NAME          ; POINTER TO PATHNAME TO LAUNCH
002026: 00               39          DFB  0             ; NOT USED AT PRESENT
002027: 00 00            40          DA   $0000         ; NOT USED AT PRESENT
                         41
002029: 00               42 ERROR    BRK  $00           ; WE'LL NEVER GET HERE?
                         43
00202B: D0 D2 C5 D3      44 MSSG     ASC  "PRESS A KEY TO LAUNCH P8.SYSTEM ->",00
00202F: D3 A0 C1 A0
002033: CB C5 D9 A0
002037: D4 CF A0 CC
00203B: C1 D5 CE C3
00203F: C8 A0 D0 B8
002043: AE D3 D9 D3
002047: D4 C5 CD A0
00204B: AD BE 00
                         45
00204E: 09               46 NAME     DFB  NAMEEND-NAME-1
00204F: D0 B8 AE D3      47          ASC  "P8.SYSTEM"
002053: D9 D3 D4 C5
002057: CD
                         48 NAMEEND
002058: 53               49          CHK                ; CHECKSUM FOR LISTING

—End Merlin-16 assembly, 89 bytes, Errors: 0
```

ProDOS File Types

Table 13-1 is a list of file types. It shows some values in use under ProDOS 8 and ProDOS 16. New file types can be defined by Apple at any time, so the list is subject to additions.

Table 13-1. ProDOS 8 Filetypes

File Type	Name	Description
$00		Uncategorized file
$01	BAD	Bad block file
$04	TXT	ASCII text file
$06	BIN	General binary file
$08	FOT	Graphics screen file
$0F	DIR	Directory file
$19	ADB	*AppleWorks* Data Base file
$1A	AWP	*AppleWorks* Word Processor file
$1B	ASP	*AppleWorks* Spread Sheet file
$1C–$AF		Reserved
$B0	SRC	*APW* source file
$B1	OBJ	*APW* object file
$B2	LIB	*APW* library file
$B3	S16	ProDOS 16 application program file
$B4	RTL	*APW* runtime library file
$B5	EXE	ProDOS 16 shell application file
$B6		ProDOS 16 permanent initialization file
$B7		ProDOS 16 temporary initialization file
$B8	NDA	New Desk Accessory
$B9	CDA	Classic Desk Accessory
$BA		Tool set file
$BB–$BE		Reserved for ProDOS 16 load files
$BF		ProDOS 16 document file
$C0–$EE		Reserved
$EF	PAS	Pascal area on a partitioned disk
$F0	CMD	ProDOS 8 CI added command file
$F1–$F8		ProDOS 8 user-defined files 1-8
$F9		ProDOS 8 reserved
$FA	INT	Integer BASIC program file
$FB	IVR	Integer BASIC variable file
$FC	BAS	*Applesoft* BASIC program file
$FD	VAR	*Applesoft* BASIC variables file
$FE	REL	Relocatable code file (*Merlin*)
$FF	SYS	ProDOS 8 system program file

Other ProDOS 8 MLI Commands

There are a total of 26 ProDOS 8 MLI commands. These are shown in Table 13-2.

Table 13-2. ProDOS 8 MLI Commands

Alloc_Interrupt	$40	Place a pointer to an interrupt-handling routine into the system-interrupt vector table.
Dealloc_Interrupt	$41	Remove pointer from system-interrupt table.
Quit	$65	Quit current program back to another system program.
Read_Block	$80	Read a data block (512 bytes) from the disk.
Write_Block	$81	Write a data block to disk.
Get_Time	$82	Read current time using ProDOS built-in routine.
Create	$C0	Create a new file or directory.
Destroy	$C1	Remove name from directory.
Rename	$C2	Change name of file.
Set_File_Info	$C3	Set file's type and all other associated information (dates an so forth).
Get_File_Info	$C4	Read directory information entry for a file.
On_Line	$C5	Get slot, drive and volume name of one or all active volumes.
Set_Prefix	$C6	Set pathname to be used as prefix.
Get_Prefix	$C7	Get current prefix.
Open	$C8	Prepare a file to be read from or written to.
Newline	$C9	Specify character that terminates a file read, such as a carriage return.
Read	$CA	Read any number of bytes into memory from a file.
Write	$CB	Write any number of bytes from memory into a file.
Close	$CC	Finish file access. Update file directory entry if necessary.
Flush	$CD	Like a close, but doesn't release file buffers.
Set_Mark	$CE	Change current byte position in file.
Get_Mark	$CF	Get current byte position in file.
Set_EOF	$D0	Set length of file.
Get_EOF	$D1	Get length of file.
Set_Buf	$D2	Assign new location of input/output buffer for file.
Get_Buf	$D3	Get current location of input/output buffer of an open file.

An assembly language program uses ProDOS by using a combination of the appropriate commands to accomplish a given task. Program 13-4 uses the ProDOS 8 MLI system. It displays the contents of a text file on the screen. It's very simplistic. It offers no way to catalog a disk or to determine the names of the volumes online. It's error handling is minimal at best. However, it does present a working example of a program that opens a file, reads and displays the data, and then closes the file and exits with the standard Quit call.

It also shows how, in the course of writing an actual application, other issues become as important as the program itself. Such issues include error handling, the user interface, and concerns about the system state when your program starts up. Anyone that has written a commerical program can tell you that the user interface and error handling can take as much or more time and program code as the primary functions of the program itself.

In addition, this program introduces quite a number of new concepts in programming style, assembler pseudo-ops, and more.

After you've typed in the program, be sure to check the checksum value generated by the assembly on line 173. The byte in your program should match the listing, CHK = $89. The program is longer than any presented so far, and verifying the checksum will help avoid program bugs caused by typographical errors.

The program operates in general by first asking for the name of the file to be dumped. If the name includes a slash (/) as the first character of the name, it will use the input as the complete pathname, and use the volume indicated. If the name doesn't include a slash, it will append in the given name to the current prefix, and it will try to open that file. If the file is not found, or there is any error in opening and reading the file, the ProDOS MLI error code will be printed, and you can try again. A Monitor routine, PRBYTE ($FDDA = "PRint BYTE"), is used to print the error code as a hex number. This routine prints the contents of the Accumulator when called.

As the file is displayed, you can start and stop the text scrolling by pressing Control-S. You can exit the program by typing QUIT for the filename.

When you run the program, it will make some difference how you actually start up the program. If you BRUN the file from BASIC without having ever specifically set the prefix from BASIC, there will be no default prefix when FDUMP.SYS runs. Hence you'll *have* to include the volume name for the file you want to examine. This is because BASIC.SYSTEM does not specifically set the internal ProDOS pathname when it runs. On the other hand, if you run FDUMP.SYS from a program selector like the Program Launcher or DeskTop, these programs will set the internal ProDOS prefix when they launch the system file, and the prefix will be set to whatever volume and directory where the file itself is located.

A Closer Look

Now let's take a closer look at Program 13-4. The first thing to notice is a new initialization routine that you'll be seeing a lot of in the remainder of the listings in this book. When you call a routine from BASIC, if something goes wrong, and the program BRKs in the Monitor somewhere, you can always press RESET or Control-C to get back to BASIC and try it again.

With a ProDOS system file, things are a little different. Now there's no way to cleanly exit back to the program launcher without executing the ProDOS Quit command. The SETQUIT routine at the beginning of this program sets up some insurance in the way of the Control-Y vector, which is set to jump to our Quit code. If your program should break in the Monitor, you may be able to recover control by pressing Control-Y while in the Monitor.

In fact, once you get this program working, you may want to try deliberately placing a BRK instruction in the listing—perhaps around line 66—and then try pressing Control-Y in the Monitor to verify that the technique works. This will come in very handy as we move into ProDOS 16 and the tools where a BRK is even more likely, and when avoiding having to reboot the entire machine will be very helpful.

Once the Control-Y vector is set up, the very next thing the program does is check a memory location, $C01F = RD80COL (ReaD 80-COLumn status), which tells it whether the 80-column display is active. When the 80-column display is active, bit 7 of RD80COL will be set (BMI will work).

The reason this is required is because it's possible to run FDUMP.SYS from a program selector that is running in 80 columns, and to have the program start up in 40 columns. This is a function of the program selector and the Apple IIGS, rather than FDUMP.SYS itself. The problem is, if a SYSTEM program is run from an 80-column display, and comes up in 40 columns, the screen width byte, $21 (WNDWDTH = WiNDow WiDTH) will still be set to 80 columns. This in turn means that text will not be printed correctly on the screen.

To prevent all of this, the program first checks to see if we're in 40 columns (80 columns not active). If we are, the program stores the correct width, 40, in WNDWDTH.

Line 36 clears the screen and prints a prompt message. You'll notice that the PROMPT section uses something new, a *local label.* Local labels are temporary labels you can use in a source listing for the destination of branches and loops so you don't have to keep thinking of new names.

In a small program, branching back to LOOP is fine. As the program gets larger, you can probably use the labels LOOP2 and LOOP3, but after awhile it's rather pointless. Readable labels exist only to add meaning to an entry point. If the meaning is obvious, you may want to consider using a local label. A local label is designated by a colon (:) followed by a number between 1 and 9. Local labels are remembered by the assembler only between real (global) labels. For example, if there is a label like CHAR on line 41, the assembler won't know where to assign the BNE :1 on line 43, because the label CHAR would be between the branch and the target local label. Restrictions and syntax for local labels vary by assembler, so you should read your assembler manual to find out all the particulars.

In the PROMPT print loop, you might also notice that we use a BNE at the bottom of the loop on line 43. As the Y register is incremented, line 40 is already testing for the end of the string, marked by a zero. Logically, we could have used a BRA or JMP on line 43. However, in the interest of possible debugging, a BNE is used instead of BRA or JMP so that if a zero was somehow left out of the string text (MSSG1), the loop would terminate when Y wrapped around to $00. If BRA or JMP were used, the loop would go forever with an omitted zero, and the program would seem to hang up.

After the prompt, line 45 uses a Monitor routine, GETLN2, which will do the equivalent of an INPUT command for you. It even supports a cursor and editing with the arrow keys. Believe me, this is not something that would be fun to have to write yourself. A JSR to the Monitor is much easier.

GETLN2 returns when the user presses Return, and the name entered is in the input buffer, $200 to $2FF. The X register contains the length.

Now for the next tricky part. Later on, we're going to tell ProDOS where the pathname typed in is located. Right now, it starts at location $200. Remember that ProDOS expects every string to begin with a length byte. What we need to do is to rewrite the pathname in the input buffer with a length byte at the beginning. Lines 46–53 illustrate a very direct solution to this. Remember that when indexing a string of bytes, the value for the length is usually one unit too large for accessing the last byte of the string.

For example, suppose starting at $200, you have the characters A at $200, B at $201, and C at $202. The string has a length of 3. Assume we'll use indexed addressing of the form LDA $200,X to access each character. You can see that if X = 3, we will be accessing byte $203 ($200 + 3), which is actually the *fourth*, and non-existent character, of the string. Normally, in a loop that just scans a string in the input buffer, the length, as such, is used as an upper limit to tell you when to stop, by going one byte too far.

Back to our routine. We can use the fact that $200,X will start at one byte past the end of the current string as a method to move the entire string to the right one byte. Line 48 reads LDA INBUF−1,X. This is a neat trick for accessing one byte *previous* to INBUF,X. The first time through the loop, LDA INBUF-1,X will pick up the last character of the string, and STA INBUF,X will move it to right one byte.

This will continue until the entire name has been shifted. At that point, location $200 is now empty; there we can store the length, which has been saved on the stack. Look this over carefully until you're confident you understand exactly how it works. It's not enough to memorize a hundred or so assembly language commands—you must also start to learn how to combine, manipulate, and use them to accomplish your own programming goals.

The next step is to see if the user typed QUIT. A quick check is made on line 55 to see if the input string was four characters long. If it wasn't, there's no reason to do an exact check. It's true that machine language is so fast that this test is more aesthetic than necessary, but it's purpose is to illustrate further techniques of programming.

CHK2 on lines 58–64 actually tests the input string to see if it's QUIT. There are a few new tricks here as well. First, look at the definition of MSSG1 on lines 160–163. Although a simple message like this could have been defined with one ASC instruction, breaking it up like this lets us assign a label to specify the word *QUIT.* Otherwise, the characters would have to be stored elsewhere a second time for the testing loop at CHK2. The LABEL-1,X addressing mode is again used. Now that the string has been moved to the right one character in the input buffer, the characters are now found at $201 to $201 + X. This is nice, because we can now test for X reaching zero as it is decremented. If it isn't immediately obvious why this is an advantage, consider the more traditional loop to scan the input buffer. In this case, we'll pretend we want to convert an input string to entirely uppercase:

```
START  JSR  GETLN2     ; GET INPUT STRING
                       ; DATA @ $200+, LEN IN X-REG.
       DEX             ; CORRECT X FOR INDEXED ADDRESS
LOOP   LDA  $200,X     ; GET A CHARACTER
       ORA  #$DF       ; CONVERT TO UPPER CASE
       STA  $200,X     ; PUT IT BACK
       DEX             ; X = X -1
       CPX  #$FF       ; WAIT FOR WRAPAROUND
       BNE  LOOP       ; STILL IN THE LOOP
DONE   RTS             ; THAT'S ALL!
```

Notice how the X register must first be decremented to make the indexed addressing work out. Then, the end-of-loop test must look for a wraparound from $00 to $FF. You can't do a BNE test, because then you'd leave out the last pass of the loop for X = 0 (first character of the buffer). You can't use a BMI (another way to test for $FF by looking for the high bit set), because if the starting length of the string is greater than $7F (127 characters), the high bit will set when you start, and you'll never loop back.

All this is avoided in the CHK2 routine, because the string has been moved up, to $201 + X. This makes it easy to pick up each character and then use a BNE loop test. The only problem now is that the data for QUIT at WORD runs from WORD to WORD+3. No problem. By addressing it as CMP WORD-1,X, the addresses will match up properly, and the check routine will work.

Now for the actual ProDOS part of the program. OPEN on line 66 calls the ProDOS Open command. The three-byte MLI data block contains $C8 (the Open command), and a pointer to PARMTBL2, where the specifics of what file to open and where to store the data are kept. Look ahead to lines 147–150 to examine this table.

Line 147 holds the value 3, for the number of parameters for the Open command. Line 148 holds the pointer to $200 where the pathname of the file to open is stored. Line 149 tells ProDOS where a 1024-byte working buffer has been assigned. It will use this to read in each block from the disk. Line 150 reserves room for a reference number byte that ProDOS will use to make sure everybody is talking about the same file.

After the call (line 70), if the Carry is set, indicating a ProDOS error has occurred, a message will be printed that includes the ProDOS MLI error code, and the program will jump back after a keypress to ask for a new pathname.

Assuming there is no error in the Open command (Table 13-3 lists the error codes), lines 69 through 74 then read in 255 bytes at a time. Because the parameter table for both a Read and Close (which will be used shortly) are so similar, the same table can be used for both calls. The only consideration that must be made is to customize the beginning number-of-parameters value at the beginning of the table for each call. Lines 69,70 do this by storing a 4, which is the number of parameters for a Read table, at the beginning of PARMTBL3.

In looking at PARMTBL3 (lines 142–146), notice that a different buffer area is used for the data to actually be read from the file. DOSBUF is a 1024-byte buffer that ProDOS uses to manage the file it's reading. The information in that buffer is not directly accessed by an application, but rather is requested using the Read command. The Read command itself must specify a separate buffer (BUFFER in this case). The buffer must be at least as large as the number of bytes specified to be read by the Read command parameter table. Our BUFFER is $100 bytes long.

The ProDOS buffer, DOSBUF, must also begin at a page boundary (even multiple of $100 such as $2000, $2100, and $2200), so we use another *Merlin* pseudo-op, DS (Defined Storage). This pseudo-op is used whenever you want to set aside a large block of bytes within your program without having to use a lot of instruction, such as HEX and DA. *Merlin* allows a special form of DS (DS followed by a **Z**) which pads the object file with empty bytes until the next page boundary. At that point ($2200 in our program), BUFFER is defined. BUFFER itself didn't have to be on a page boundary, but its length of $100 makes it compatible with sandwiching between the DSZ instruction and

DOSBUF. Notice also that DOSBUF is just a label without an associated DS (or anything for that matter). Normally, all the empty bytes specified by a DS instruction are also saved to disk when the object file is saved. Since DOSBUF is at the end, and we don't need to save the empty bytes as part of the file, line 164 accomplishes what we need: It assigns DOSBUF an address.

If there is no error on the Read command, lines 76–83 print out the characters read. At some point, an error ($4C = End of File) will be generated when the end of the file is reached. This error is specifically tested for, and a branch to CLOSE is done. Lines 90–96 rewrite the first byte of PARMTBL3 to correspond to the Close command parameter list, and then execute the Close command.

You might think that the Read command would generate an error (End-of-File error) when it reads the last few bytes of the file and reaches the end of file marker, since it will be rare when the length of the file will be an exact multiple of the number of bytes you're requesting for each read.

Fortunately, Read is a little more sophisticated than that. Part of the Read parameter table is NUMREAD, which returns the actual number of bytes read from the file. When Read reaches the end of a file, it returns the number of bytes successfully read in the NUMREAD position, and it does not generate an End-of-File error. It is only the *next* or any successive attempts to read the file that will generate an error. Thus, you don't have to worry about any special case handling to print the last few remaining characters in a file *after* an End-of-File error has occurred.

Finally, a PRESS A KEY prompt is printed, and the program goes back to the beginning.

It is important that you try to understand each part of this program. All ProDOS programming uses MLI calls and techniques like those used in this example. It may seem complicated when you're reading the explanation, but it will begin to make sense as you read and reread the source listing. Also, remember this: Assembly language programs of any substance usually involve very lengthy listings. Remember—you're trying to build skyscrapers out of very little building blocks, and it takes a lot of blocks to make a single wall, let alone the entire building. The trick is to stand back and look at the main labels for each routine and to try to get the big picture of what's going on.

Error Codes

ProDOS MLI error codes are not the same as Applesoft DOS error codes, so Table 13-3 may be helpful in testing the program.

Table 13-3

Error Code	Meaning
$01	Invalid MLI command number was used.
$04	Incorrect number of parameters in PARMTBL.
$25	ProDOS Interrupt Table is full (not relevent to this example).
$27	Disk I/O error, such as open door, or bad disk.
$28	No device connected. You removed the drive while nobody was looking.
$2E	A disk with an open file was removed from the drive.
$40	Invalid pathname syntax (illegal characters).
$42	No buffers available. Too many files open (more than eight).
$43	File not open. Wrong reference number, or you tried to read a file without opening it.
$44	Subdirectory not found. Wrong name used.
$45	Volume not found. Wrong name used.
$46	File not found. Wrong name used.
$47	Duplicate filename. You've tried to create a new file with the name that is already in use (not relevent to this example).
$48	Disk is full.
$4A	File itself is not in a ProDOS format.
$4B	File type mismatch. Since the example doesn't check for a specific file type, this isn't likely.
$4C	End of data. No more data in file. EOF.
$4D	Range error. Occurs when Set_Mark is used for a position past the end of the file.
$4E	File locked. The file access bit in the directory information won't let you in.
$50	File busy. Somebody else is already talking to that file (file open).
$51	Directory count is messed up and is different than the actual number of files in the directory.
$52	Disk is not a ProDOS format.
$53	Some parameter is out of range.
$55	Eight files on eight separate drives are open, and somebody wants still more.
$56	No buffers available. You're trying to assign a buffer to a place in memory that's already being used.
$57	Duplicate volumes. There are two disks online that have the same name.
$5A	The disk bitmap says there's a free block somewhere past the actual size of the disk itself. The volume bitmap has been damaged.

Program 13-4. P8 File Dump Demo

```
                      **********************************************
                      *     P8 FILE DUMP DEMO PROGRAM               *
                      *            MERLIN ASSEMBLER                 *
                      **********************************************

                                ORG   $2000

                                DSK   FDUMP.SYS
                                TYP   $FF           ; SYSTEM FILE TYPE

            =BF00     MLI       EQU   $BF00         ; STD. PRODOS 8 ENTRY
            =FDED     COUT      EQU   $FDED
            =FC58     HOME      EQU   $FC58
            =FD0C     RDKEY     EQU   $FD0C         ; MONITOR READ KEY ROUTINE
            =FD6F     GETLN2    EQU   $FD6F         ; MONITOR INPUT ROUTINE W/O PROMPT
            =0200     INBUF     EQU   $200          ; INPUT BUFFER
            =FDDA     PRBYTE    EQU   $FDDA         ; PRINT ACC. AS HEX NUMBER
            =C01F     RD80COL   EQU   $C01F         ; BIT 7 = 1 = 80 COLS. "ON"
            =0021     WNDWDTH   EQU   $21           ; TEXT WINDOW WIDTH
            =057B     CH80      EQU   $57B          ; 80-COL HORIZ. CURSOR POSN


002000: A9 4C         SETQUIT   LDA   #$4C          ; JMP INSTRUCTION
002002: 8D F8 03                STA   $3F8          ; CTRLY VECTOR
002005: A9 B0                   LDA   #<QUIT        ; LOW BYTE OF QUIT ADDR.
002007: 8D F9 03                STA   $3F9          ; LOW BYTE OF CTRL-Y VECTOR
00200A: A9 20                   LDA   #>QUIT
00200C: 8D FA 03                STA   $3FA          ; HIGH BYTE OF CTRL-Y VECTOR

00200F: 2C 1F C0      BEGIN     BIT   RD80COL       ; 80 COLS ACTIVE?
002012: 30 07  =201B            BMI   CLEAR         ; YES
002014: A9 28                   LDA   #40           ; WINDOW WIDTH
002016: 85 21                   STA   WNDWDTH       ; SET WIDTH, JUST IN CASE
002018: 9C 7B 05                STZ   CH80          ; SET 80 COL CURSOR H = 0

00201B: 20 58 FC      CLEAR     JSR   HOME          ; CLEAR SCREEN

00201E: A0 00         PROMPT    LDY   #$00          ; INIT Y-REG
002020: B9 ED 20      :1        LDA   MSSG1,Y       ; PRINT PROMPT MSSG.
002023: F0 06  =202B            BEQ   GETPATH
002025: 20 ED FD                JSR   COUT          ; PRINT IT
002028: C8                      INY                 ; NEXT CHAR
002029: D0 F5  =2020            BNE   :1            ; WRAPAROUND PROTECT

00202B: 20 6F FD      GETPATH   JSR   GETLN2        ; GET PATHNAME FROM USER

00202E: DA            FIX       PHX                 ; SAVE LENGTH OF INPUT STRING
00202F: BD FF 01      :1        LDA   INBUF-1,X     ; GET LAST CHAR
002032: 9D 00 02                STA   INBUF,X       ; MOVE OVER ONE BYTE
002035: CA                      DEX                 ; X = X - 1
```

```
002036: D0 F7  =202F              BNE  :1            ; NEXT CHARACTER
002038: FA                        PLX                ; RETRIEVE LENGTH
002039: 8E 00 02                  STX  INBUF         ; PUT AT BEG. OF STRING

00203C: E0 04              CHK1   CPX  #$04          ; 4 = LEN "QUIT"
00203E: D0 10  =2050              BNE  OPEN          ; IT'S NOT "QUIT"

002040: BD 00 02           CHK2   LDA  INBUF,X       ; LAST CHAR OF INPUT
002043: 29 DF                     AND  #$DF          ; CONVERT TO UPPERCASE IF NEEDED
002045: DD 09 21                  CMP  WORD-1,X      ; "QUIT"?
002048: D0 06  =2050              BNE  OPEN          ; NOPE
00204A: CA                        DEX
00204B: D0 F3  =2040              BNE  CHK2          ; NOT DONE YET
00204D: 4C B0 20                  JMP  QUIT          ; STR$ = "QUIT"

002050: 20 00 BF           OPEN   JSR  MLI
002053: C8                        DFB  $C8           ; OPEN COMMAND
002054: DF 20                     DA   PARMTBL2      ; OPEN CMD TABLE

002056: 90 09  =2061              BCC  OPEN2         ; NO ERROR

002058: 20 B8 20                  JSR  ERROR         ; PRODOS ERROR MESSAGE
00205B: 20 0C FD                  JSR  RDKEY         ; WAIT FOR A KEYPRESS
00205E: 4C 0F 20                  JMP  BEGIN         ; TRY AGAIN IF ERROR

002061: AD E4 20           OPEN2  LDA  PARMTBL2+5 ; GET REFERENCE NUMBER
002064: 8D E6 20                  STA  PARMTBL3+1 ; STORE REF NUMBER

002067: A9 04              READ   LDA  #$04          ; # OF PARMS FOR 'READ'
002069: 8D E5 20                  STA  PARMTBL3      ; MODIFY TABLE ENTRY
00206C: 20 00 BF                  JSR  MLI
00206F: CA                        DFB  $CA           ; READ COMMAND
002070: E5 20                     DA   PARMTBL3      ; READ CMD TABLE
002072: 90 07  =207B              BCC  PRINT         ; NO ERROR

002074: C9 4C              EOFCHK CMP  #$4C          ; ERROR = END OF FILE?
002076: F0 15  =208D              BEQ  CLOSE         ; YEP!

002078: 20 B8 20                  JSR  ERROR         ; PRODOS ERROR MSSG

00207B: A0 00              PRINT  LDY  #$00          ; INIT Y-REG
00207D: B9 00 22           :1     LDA  BUFFER,Y
002080: 09 80                     ORA  #$80          ; SET HIGH BIT
002082: 20 ED FD                  JSR  COUT
002085: C8                        INY
002086: CC EB 20                  CPY  NUMREAD       ; PRINT CHARS READ IN.
002089: 90 F2  =207D              BCC  :1
00208B: B0 DA  =2067              BCS  READ          ; GET ANOTHER LINE OF TEXT

00208D: A9 01              CLOSE  LDA  #$01          ; REWRITE PARMTBL3
00208F: 8D E5 20                  STA  PARMTBL3      ; # OF PARMS = 1
002092: 20 00 BF                  JSR  MLI
```

```
002095: CC                           DFB  $CC         ; CLOSE COMMAND
002096: E5  20                       DA   PARMTBL3    ; SAME TABLE AS 'READ'
002098: 90  03   =209D               BCC  DONE        ; NO ERRORS
00209A: 20  B8  20                   JSR  ERROR       ; PRODOS ERROR MSSG

00209D: A0  00           DONE        LDY  #$00        ; INIT Y-REG
00209F: B9  3D  21       :1          LDA  MSSG3,Y     ; GET CHAR TO PRINT
0020A2: F0  06   =20AA               BEQ  D2
0020A4: 20  ED  FD                   JSR  COUT        ; PRINT IT
0020A7: C8                           INY              ; NEXT CHAR
0020A8: D0  F5   =209F               BNE  :1          ; WRAPAROUND PROTECT

0020AA: 20  0C  FD       D2          JSR  RDKEY       ; GET A KEYPRESS
0020AD: 4C  0F  20                   JMP  BEGIN       ; BACK TO THE BEGINNING

0020B0: 20  00  BF       QUIT        JSR  MLI         ; DO QUIT CALL
0020B3: 65                           DFB  $65         ; QUIT CALL COMMAND VALUE
0020B4: D8  20                       DA   PARMTBL     ; ADDRESS OF PARM TABLE
0020B6: 00  00                       BRK  $00         ; SHOULD NEVER GET HERE . . .

0020B8: 48               ERROR       PHA              ; SAVE ERROR CODE
0020B9: A0  00                       LDY  #$00        ; INIT Y-REG
0020BB: B9  13  21       :1          LDA  MSSG2,Y     ; GET CHAR TO PRINT
0020BE: F0  06   =20C6               BEQ  PRCODE
0020C0: 20  ED  FD                   JSR  COUT        ; PRINT IT
0020C3: C8                           INY              ; NEXT CHAR
0020C4: D0  F5   =20BB               BNE  :1          ; WRAPAROUND PROTECT

0020C6: 68               PRCODE      PLA              ; RETRIEVE ERROR CODE
0020C7: 20  DA  FD                   JSR  PRBYTE      ; PRINT IT
0020CA: A0  00                       LDY  #$00        ; INIT Y-REG
0020CC: B9  23  21       :1          LDA  MSSG2A,Y    ; GET CHAR TO PRINT
0020CF: F0  06   =20D7               BEQ  ERDONE      ; END OF MSSG
0020D1: 20  ED  FD                   JSR  COUT        ; PRINT IT
0020D4: C8                           INY              ; NEXT CHAR
0020D5: D0  F5   =20CC               BNE  :1          ; WRAPAROUND PROTECT
0020D7: 60               ERDONE      RTS

0020D8: 04               PARMTBL     DFB  4           ; NUMBER OF PARMS
0020D9: 00                           DFB  0           ; QUIT TYPE (0 = STD. QUIT)
0020DA: 00  00                       DA   $0000       ; NOT NEEDED FOR STD. QUIT
0020DC: 00                           DFB  0           ; NOT USED AT PRESENT
0020DD: 00  00                       DA   $0000       ; NOT USED AT PRESENT

0020DF: 03               PARMTBL     DFB  3           ; NUMBER OF PARMS FOR OPEN = 3
0020E0: 00  02                       DA   INBUF       ; POINTER TO PATHNAME
0020E2: 00  23                       DA   DOSBUF      ; POINTER TO PRODOS BUFFER
0020E4: 00               REFNUM      DFB  0           ; PRODOS FILE REFERENCE NUMBER

0020E5: 00               PARMTBL     DFB  0           ; NUMBER OF PARMS FOR READ/CLOSE
0020E6: 00                           DFB  0           ; REFERENCE NUMBER
0020E7: 00  22                       DA   BUFFER      ; POINTER TO DATA BUFFER
0020E9: FF  00                       DA   255         ; 255 CHARACTERS TO READ
```

```
0020EB: 00  00          NUMREAD  DA    0              ; NUMBER OF CHARACTERS READ.


0020ED: D0  CC  C5  C1  MSSG1    ASC   “PLEASE ENTER PATHNAME: “,8D
002105: A8  CF  D2  A0           ASC   “(OR “”
00210A: D1  D5  C9  D4  WORD     ASC   “QUIT”
00210E: A7  A9  A0  8D           ASC   “”) “,8D,00

002113: 8D              MSSG2    HEX   8D             ; PRINT RETURN FIRST
002114: D0  D2  CF  C4           ASC   “PRODOS ERROR $“,00
002123: 8D              MSSG2A   HEX   8D             ; ANOTHER CARRIAGE RETURN
002124: D0  D2  C5  D3           ASC   “PRESS A KEY TO TRY AGAIN“,00

00213D: 8D              MSSG3    HEX   8D             ; PRINT RETURN FIRST . . .
00213E: 80  D2  C5  D3          ASC   “PRESS A KEY FOR NEXT FILE“,00

002158: EC              CHKSUM   CHK                  ; CHECKSUM FOR VERIFICATION

002159: 00  00  00  00           DS                   ; SKIP TO NEXT PAGE BOUNDARY
002200: 00  00  00  00  BUFFER   DS    $100           ; DATA BUFFER FOR US

                        DOSBUF                        ; 1024 BYTES FOR PRODOS BUFFER
                                                      ; NOT IN PROGRAM SO AS TO NOT
                                                      ; TAKE UP DISK SPACE . . .


End Merlin-16 assembly, 768 bytes, errors: 0
```

Chapter 14

ProDOS 16

Chapter 14

ProDOS 16

Like ProDOS 8, ProDOS 16 is a set of disk access routines designed to be called from machine language programs. Unlike ProDOS 8, there is no BASIC.SYSTEM for Applesoft. In fact, in ProDOS 16, the assumption is that Applesoft BASIC and the Monitor no longer exist. You're not entirely on your own, however. It's in the ProDOS 16 environment that the new Apple IIGS tools like super hi-res graphics, the Event Manager, the Memory Manager, and other tools become available. On the one hand, you lose many of the points of reference you're familiar with. On the other, you enter the real world of the Apple IIGS, where memory seems unbounded, and the hundreds of built-in Applesoft BASIC and Monitor routines are replaced by literally thousands of Apple IIGS Toolbox commands. Future chapters will explore those tools in detail; for now let's look at ProDOS 16.

Starting Up ProDOS 16

On a disk set up to boot ProDOS 16, such as the Apple IIGS System Disk, the boot process starts the same as it did for ProDOS 8—by reading and executing the code stored in blocks 0 and 1 on the disk. This code is the same on any ProDOS disk, regardless of whether it is set up for ProDOS 8 or 16. As before, this code begins by running the file ProDOS on the disk. Here's where things under ProDOS 16 change considerably.

On a ProDOS 16 boot disk, the file PRODOS is now just an intermediate program itself, one that is not actually *either* version of ProDOS. Instead, it's an initialization file whose job it is to determine the correct operating system (ProDOS 8 or 16) for whatever the startup application on the disk is. When the file PRODOS first runs, the first thing it does is copy part of itself and call **PQUIT (ProDOS Quit)** to a part of memory outside the first 64K, where it will remain permanently. PQUIT has two specific functions: First, it loads the appropriate operating system for whatever application is about to be run. Second, it contains a program selector of sorts, which actually starts up the application named by a path name passed to it.

After PQUIT is installed, ProDOS 16 and the *System Loader* are loaded using the file P16 in the SYSTEM subdirectory. The System Loader is a separate unit from ProDOS 16, even though they share the same file (P16) on the disk. In ProDOS 8, every application is a .SYSTEM file and is loaded into memory starting at location $2000 in bank zero. Under ProDOS 16, all of bank zero becomes very valuable, and applications are loaded almost anywhere else in the many other banks of available memory.

Because the actual final location at which a program will run is now unknown to the programmer, simple object files cannot be used. Instead, a new type of assembler-created file, called *relocatable,* must be used. A relocatable file contains not only the object file as you see it assembled, but also additional information such as all the internal reference JMPs, JSRs, and LDAs. Creating a file like this with all the additional information means the actual program bytes can be rewritten when the file is loaded into memory. This loading and rewriting is done by the System Loader (not ProDOS 16 itself).

Once ProDOS 16 and the System Loader have been installed, all the appropriate Apple IIGS supporting files in the various subdirectories of the SYSTEM folder are loaded. For example, TOOL.SETUP in the SYSTEM.SETUP folder contains a number of fixes to the Apple IIGS internal ROM routines. No system is ever perfect, and the designers of the Apple IIGS knew errors in the ROM were bound to be discovered after the machine was in production.

The solution was to design almost everything in ROM in such a way that any ROM routine could be amended, or even replaced, by a substitute routine loaded into RAM when the system was booted. Much of this was accomplished with *vectors* to the various ROM routines. You'll recall from Chapter 12 that vectors are pointers in RAM that direct control to a certain routine. By changing the vectors that correspond to a given ROM routine to a loaded RAM routine, the substitution is made.

TOOL.SETUP is not the only file loaded during the boot process. Classic Desk Accessories that may be on the disk are also loaded. Basically, any file with the file types $B6 (for example TOOL.SETUP, a permanent initialization file), $B7 (a temporary initialization file), $B8 (Classic Desk Accessories such as SDUMP), or $B9 (New Desk Accessories like CLOCK) are loaded during this startup process.

Now that everything is in place, the system looks for a $B3 type (application) file named START. Usually, this is a program selector like the Apple Program Launcher, but it can be any application you wish to write. If START is found, it is loaded and run.

If START is not found, the system then searches the main directory for the first file that is either a ProDOS 8 SYS ($FF) file whose name ends in .SYSTEM, or a ProDOS 16 application (type $B3 = S16) whose name ends in

.SYS16. Depending on which type of file is found first, the appropriate operating system is selected (P8 is loaded if necessary), and the program is run.

Ultimately, it is the PQUIT routine that selects the proper operating system and application pathname.

The Simplest ProDOS 16 Program: Quit

As with ProDOS 8, ProDOS 16 applications must end with a quit command, not an RTS (or RTL). ProDOS 16 calls are made in a fashion similar to the MLI call for ProDOS 8. For ProDOS 16, a JSL is done to location $E1/00A8; this is followed by a six-byte data block. The first two bytes define the command value, or *call number.* The next four bytes are a long-address pointer to a ProDOS 16 parameter block. Notice that in the world of ProDOS 16, everything assumes we are running in banks that can be anywhere in memory.

In general, every Apple IIGS ProDOS 16 application must meet the following requirements:

1. Have the filetype $B3 (S16). There are specialized applications that may have other file types.
2. Be created in the relocatable file format called the Object Module Format (OMF). This will be described in greater detail shortly.
3. Do a proper ProDOS 16 quit call. (No RTS, RTL or forced reset.)
4. Obtain any memory used externally to the program and its stack and direct page from the Memory Manager.

Item 4 may seem new to you. With so much memory on the Apple IIGS, it may seem like you should be able to use whatever you want. But answer these questions: How will you know how much memory the user has installed in his machine? How will you know where your program is actually running? How will you share the available memory with other programs, such as desk accessories, that may have been loaded during the boot process?

The Memory Manager

To make things as easy as possible for everyone that uses the Apple IIGS environment, the system includes a tool called the *Memory Manager.* The Memory Manager keeps track of all the things mentioned above so you can concentrate on your application. Basically, whenever you need some memory for a file buffer, a picture, or a data block, you just say, "Hey, get me 10K of memory." and the Memory Manager not only finds the memory for you, but also protects it from everybody else in the system. The bottom line is: Use the memory manager; don't blaze your own trails.

For your first ProDOS 16 program, let's write a ProDOS 16 equivalent of the P8.SYSTEM program (Program 13-1) that was presented in Chapter 13. The main differences will be:

1. ProDOS 16 does an automatic screen clear when it starts up a program, so the JSR HOME won't be needed.
2. You won't have Applesoft BASIC or the Monitor to depend on, for three reasons: Our program is now being started up in the full 16-bit mode (Accumulator and index registers); we'll undoubtedly be in a different bank than the Monitor/Applesoft BASIC routines; and we now have our own stack and direct page (automatically determined, allocated and assigned by the System Loader and Memory Manager when our program was loaded). You're on your own.
3. The quit command for ProDOS 16 is slightly different from that for ProDOS 8.

Simple System File

With all that in mind, take a look at Program 14-1, P16.SYSTEM. The *APW* version of this program is Program 14-3. (Before assembling this program, you may want to read the section on linking, below.)

Because the start-assembly default of *Merlin* is for the 8-bit mode, we must begin Program 14-1 with a new *Merlin* directive, **MX**. This is equivalent to *APW*'s LONGA and LONGI directives, and it tells the assembler what the starting condition of the *m* and *x* bits are assumed to be. To indicate the 16-bit mode, MX %00 is used. You may change *Merlin*'s startup default on an assembly to be 16-bit, thus eliminating the need for this instruction. But keeping it in the listing doesn't hurt anything and is actually a good idea if you want to avoid errors should you ever change the startup default.

Lines 8 and 9 show how to create a relocatable file ouput with *Merlin*. The **REL** directive on line 8 tells *Merlin* to create a ProDOS REL type file ($FE) on the disk during the assembly. This will be used by the *Merlin* linker to create the OMF file needed for the final application. (This is more or less equivalent to *APW*'s .ROOT output file).

Because the program is running in an indeterminant memory bank, the first thing we need to do is set the data bank register equal to the program bank register (the bank we're running in). The PHK, PLB instructions will do the trick here.

Next, the prompt message is printed to the screen. Because we can no longer use COUT, the message is printed by storing the characters directly on the screen, as was done when you first started all this in Chapter 3. Line 22 uses the **STAL (STA Long)** instruction to put the bytes on the text screen. Remember, the data bank register setting at this point means a STA $400,X would store a byte (actually, two) in *the bank you're currently running in,* not $00/$0400, where the text screen is. If the data bank were set to $00, the STA instruction would work, but not the LDA MSSG,X. One or the other must use a long addressing mode instruction.

Also because the Accumulator is in the 16-bit (two byte) mode, characters are loaded and stored *two* at at time. This means the number of characters in the string at MSSG (line 44) *must* be an even number. Also, because the Accumulator is in the 16-bit mode, two INX instructions are used to increment to the next pair of bytes. To add insult to injury, the complete 80-column display is made up by interleaving the address range from $400 to $7FF for both banks 0 and 1. Because we're only writing to bank 0, the characters only appear at every other position on the screen.

The keyboard is read in a similar manner, and is thus a little different from the ProDOS 8 version of this program. Because the LDA KYBD instruction actually loads two bytes, one each from $C000 and $C001, it is necessary to do an AND #$00FF to zero-out the high-order byte of the Accumulator.

The CMP #$0080 then checks to see if a key was pressed. (By the way, for those of you who are really deep thinkers, yes, it's true that the typed instructions AND #$FF, CMP #$80 would have been equivalent to AND #$00FF, CMP #$0080.) Leading zeros don't do any more for the assembler than they do for any other number—$000000012 is still $12. They were used in this case to make it clear in the source listing that two bytes were involved in the operation. Perhaps this isn't a bad idea for your own programs.

Now for the quit command itself: $0029 is the call number for a ProDOS quit. This follows the JSL to the ProDOS 16 common entry point, $E1/00A8. Following the call number is the 4-byte pointer to the parameter block. **ADRL (ADdRess Long)** is the *Merlin* pseudo-op for a 4-byte address pointer.

The parameter block for the ProDOS 16 quit command consists of just six bytes. The first four are a pointer to an optional pathname for the next application to be run. This is similar to the ProDOS 8 Enhanced Quit Call. In our program, this is set to zero, which tells ProDOS to just do a standard quit back to the previous program.

The next two bytes define a flag that uses the upper two bits (bits 14 and 15), to flag certain exit conditions. The options are as follows:

If bit 15 is set, it means that you would like program control to return to the program (the one doing the quit at that point), instead of going back to the starting program selector. If this bit is clear, as in our P16.SYSTEM program, or there is no pathname specified (pointer = $0), then a direct quit back to the previous program is done.

If bit 15 is set, and there is a pathname for the program to quit to, our program itself now acts like a program selector, wherein it can launch a specified application. Control will return to it when that application is finished. This is where bit 14 comes in. When you think about it, the PQUIT routine (the thing really managing all this) is going to have to rerun your program when the other one quits. The obvious way to do this is to reload it from disk. However, this is not only slow (relatively speaking), but it also requires the proper disk be in the drive.

Since all that memory is lying around, why not just keep a copy of our program in memory in a dormant state, and resurrect it when the time comes? That is just what bit 14 is for. You can tell the system which you prefer. If bit 14 is set (flag = $C000), your program will be restarted from memory. On the other hand, if you want to force a restart from disk, bit 14 can be left clear (flag = $8000).

Program 14-1. Simple P16 System File

```
                          *********************************************
                          *          SIMPLE P16 SYSTEM FILE           *
                          *             MERLIN ASSEMBLER              *
                          *********************************************


                                         MX     %00            ; FULL 16 BIT MODE
                                         REL                   ; RELOCATABLE OUTPUT
                                         DSK    P16.SYSTEM.L

          =E100A8         PRODOS         EQU    $E100A8        ; PRODOS 16 ENTRY POINT
          =C000           KYBD           EQU    $C000
          =C010           STROBE         EQU    $C010
          =0400           SCREEN         EQU    $000400        ; LINE 1 ON SCREEN

008000: 4B                ENTRY          PHK                   ; GET PROGRAM BANK
008001: AB                               PLB                   ; SET DATA BANK

008002: A2 00 00          PRINT          LDX    #$00           ; INIT X-REG
008005: BD 34 80          LOOP           LDA    MSSG,X         ; GET CHAR TO PRINT
008008: F0 08  =8012                     BEQ    GETKEY         ; END OF MSSG.
00800A: 9F 00 04 00                      STAL   SCREEN,X       ; "PRINT" IT
00800E: E8                               INX                   ; NEXT TWO CHARS
00800F: E8                               INX                   ; X = X + 2
008010: D0 F3  =8005                     BNE    LOOP           ; WRAPAROUND PROTECT

008012: AD 00 C0          GETKEY         LDA    KYBD           ; CHECK KEYBOARD
008015: 29 FF 00                         AND    #$00FF         ; CLEAR HI BYTE
008018: C9 80 00                         CMP    #$0080         ; KEYPRESS?
00801B: 90 F5  =8012                     BCC    GETKEY         ; NOPE
00801D: 2C 10 C0                         BIT    STROBE         ; CLEAR KEYPRESS

```

```
008020: 22  A8  00 E1       QUIT    JSL   PRODOS                   ; DO QUIT CALL
008024: 29  00                      DA    $29                      ; QUIT CODE
008026: 2D  80  00 00               ADRL  PARMBL                   ; ADDRESS OF PARM TABLE
00802A: B0  07  =8033               BCS   ERROR                    ; NEVER TAKEN
00802C: 00                          BRK                            ; SHOULD NEVER GET HERE...

00802D: 00  00  00  00      PARMBL  ADRL  $0000                    ; PTR TO PATHNAME
008031: 00  00              FLAG    DA    $00          ; ABSOLUTE QUIT

008033: 00                  ERROR   BRK                ; WE'LL NEVER GET HERE?

008034: D0  CC  C5  C1      MSSG    ASC   "PLEASE PRESS A KEY -> " ; EVEN NUMBER OF
                                                                     CHARACTERS'
008038: D3  C5  A0  D0  D2  C5  D3  D3
008040: A0  C1  A0  CB  C5  D9  A0  AD
008048: BE  A0
00804A: 00  00                      DA    $0000                    ; TWO ZEROS

00804C: 54                          CHK                            ; CHECKSUM FOR LISTING

--End Merlin-16 assembly, 77 bytes, Errors: 0
```

The Launcher

To show how all this works, Program 14-2 is a ProDOS 16 version of the P8.LAUNCHER (Program 13-3), called P16.LAUNCHER. The *APW* version of the launcher is Program 14-4.

This program starts off the same way as P16.SYSTEM. The main difference is that now four inputs are allowed: the number keys 0, 1, 2, and 3.

Three is the most complex example (flag = $C000). This will launch the previous program, P16.SYSTEM, from disk, and will store itself in memory. When P16.SYSTEM quites, P16.LAUNCHER will resume instantly from memory. In principle, there can be many multiple levels of different programs, or program modules, each running a successive module with control ultimately returning to the master program.

Option 2 (flag = $0) simply starts P16.SYSTEM without leaving itself in the return list. Thus, when P16.SYSTEM quits, control goes back to the previous program selector.

Option 1 is equivalent to the direct quit done by P16.SYSTEM.

Option 0 demonstrates what happens either when there is no program left in the return list to go to, or when the file specified is not found. This activates the Apple IIGS ProDOS interactive restart menu that gives you the option of rebooting, running the file named START, or specifying a startup program of your own.

By the way, you may have been wondering why we didn't just bracket the 8-bit operations in the program P16.SYSTEM in a pair of SEP and REP instructions like this:

```
       SEP  $30        ; 8-BIT MODE

PRINT  LDX  #$00       ; INIT X-REG
LOOP   LDA  MSSG,X     ; GET CHAR TO PRINT
       BEQ  GETKEY     ; END OF MSSG.
       STAL SCREEN,X   ; "PRINT" IT
       INX             ; NEXT TWO CHARS
       INX             ; X = X + 2
       BNE  LOOP       ; WRAPAROUND PROTECT
GETKEY LDA  KYBD       ; CHECK KEYBOARD
       AND  #$00FF     ; CLEAR HI BYTE
       CMP  #$0080     ; KEYPRESS?
       BCC  GETKEY     ; NOPE
       BIT  STROBE     ; CLEAR KEYPRESS

       REP  $30        ; BACK TO 16-BIT MODE
```

There are two reasons. First, to show you what alternative you may have when going to the 16-bit mode may be impractical, and second, because doing this as P16.LAUNCHER is a little impractical.

Here's why. The SEP on line 22 or so of P16.LAUNCHER would work OK, but where can we put the REP $30? At the end of the print loop, around line 30, would work, but now the GETKEY routine is still in the 16-bit mode. You could move it to somewhere near line 36, but now you're comparing an Accumulator loaded in the 8-bit mode with 2-byte ASCII codes.

If you try to move the REP $30 past the compares, you'll have to put four of them in, one for each entry point to the various quit commands.

Program 14-2. ProDOS 16 Launcher Demo

```
1  *********************************************
2  * PRODOS 16 'LAUNCHER' DEMO                 *
3  * LAUNCHES 2ND SYSTEM FILE,                 *
4  * STAYS DORMANT, THEN REVIVED               *
5  * WHEN 2ND QUITS.                           *
6  *                                           *
7  * MERLIN ASSEMBLER                          *
8  *********************************************
9
10
11           MX    %00                ; FULL 16-BIT MODE
12           REL
13           DSK   P16.LAUNCH.L       ; RELOCATABLE OUTPUT
14
```

```
            =E100A8       PRODOS   EQU   $E100A8      ; PRODOS 16 ENTRY POINT
            =C000         KYBD     EQU   $C000
            =C010         STROBE   EQU   $C010
            =0400         SCREEN   EQU   $400         ; LINE 1 ON SCREEN

008000: 4B                ENTRY    PHK                ; PUSH CODE BANK
008001: AB                         PLB                ; PULL DATA BANK

008002: A2 00 00          PRINT    LDX   #$00         ; INIT X-REG
008005: BD 85 80          LOOP     LDA   MSSG,X       ; GET CHAR TO PRINT
008008: F0 08   =8012              BEQ   GETKEY       ; END OF MSSG.
00800A: 9F 00 04 00                STAL  SCREEN,X     ; "PRINT" IT
00800E: E8                         INX                ; NEXT TWO CHARS
00800F: E8                         INX                ; X = X + 2
008010: D0 F3   =8005              BNE   LOOP         ; WRAPAROUND PROTECT

008012: AD 00 C0          GETKEY   LDA   KYBD         ; KEYPRESS?
008015: 29 FF 00                   AND   #$00FF       ; MASK UPPER BYTE
008018: C9 80 00                   CMP   #$80         ; HI BIT SET?
00801B: 90 F5   =8012              BCC   GETKEY       ; NOPE
00801D: 2C 10 C0                   BIT   STROBE       ; CLEAR KEYPRESS

008020: C9 B0 00          CHK      CMP   #"0"         ; QUIT TO ROM ROUTINE?
008023: F0 13   =8038              BEQ   QUIT0        ; YES
008025: C9 B1 00                   CMP   #"1"         ; REAL QUIT?
008028: F0 1B   =8045              BEQ   QUIT1        ; YES
00802A: C9 B2 00                   CMP   #"2"
00802D: F0 23   =8052              BEQ   QUIT2        ; LAUNCH 2ND, DON'T RETURN
00802F: C9 B3 00                   CMP   #"3"
008032: F0 2B   =805F              BEQ   QUIT3        ; LAUNCH 2ND, RETURN

008034: 5C 12 80 00       TRYAGN   JML   GETKEY       ; TRY AGAIN

008038: 22 A8 00 E1       QUIT0    JSL   PRODOS       ; DO QUIT CALL
00803C: 29 00                      DA    $29          ; QUIT CODE
00803E: 6C 80 00 00                ADRL  PARM0        ; ADDRESS OF PARM TABLE
008042: B0 40   =8084              BCS   ERROR        ; NEVER TAKEN
008044: 00                         BRK                ; WE'LL NEVER GET HERE?

008045: 22 A8 00 E1       QUIT1    JSL   PRODOS       ; DO QUIT CALL
008049: 29 00                      DA    $29          ; QUIT CODE
00804B: 72 80 00 00                ADRL  PARM1        ; ADDRESS OF PARM TABLE
00804F: B0 33   =8084              BCS   ERROR        ; NEVER TAKEN
008051: 00                         BRK                ; WE'LL NEVER GET HERE?

008052: 22 A8 00 E1       QUIT2    JSL   PRODOS       ; DO QUIT CALL
008056: 29 00                      DA    $29          ; QUIT CODE
008058: 78 80 00 00                ADRL  PARM2        ; ADDRESS OF PARM TABLE
00805C: B0 26   =8084              BCS   ERROR        ; NEVER TAKEN
00805E: 00                         BRK                ; WE'LL NEVER GET HERE??

00805F: 22 A8 00 E1       QUIT3    JSL   PRODOS       ; DO QUIT CALL
008063: 29 00                      DA    $29          ; QUIT CODE
```

```
008065: 7E 80 00 00             ADRL  PARM3                 ; ADDRESS OF PARM TABLE
008069: B0 19    =8084          BCS   ERROR                 ; NEVER TAKEN
00806B: 00                      BRK                         ; WE'LL NEVER GET HERE??

00806C: 9D 80 00 00    PARM0    ADRL  NAME0                 ; BAD PATH TO GEN ERROR
008070: 00 00          FLAG0    DA    $00                   ; ABSOLUTE QUIT

008072: 00 00 00 00    PARM1    ADRL  $00                   ; NO PATHNAME
008076: 00 00          FLAG1    DA    $00                   ; ABSOLUTE QUIT

008078: 9F 80 00 00    PARM2    ADRL  NAME1                 ; PTR TO PATHNAME
00807C: 00 00          FLAG2    DA    $00                   ; BITS 15,14 = 0: DON'T RESTART

00807E: 9F 80 00 00    PARM3    ADRL  NAME1                 ; PTR TO PATHNAME
008082: 00 C0          FLAG3    DA    $C000                 ; BITS 15,14 = 1: RESTART LATER

008084: 00             ERROR    BRK                         ; WE'LL NEVER GET HERE?

008085: D0 D2 C5 D3    MSSG     ASC   "PRESS 0, 1, 2, OR 3 ->"; EVEN NUMBER OF  CHARACTERS"
008089: D3 A0 B0 AC A0 B1 AC A0
008091: B2 AC A0 CF D2 A0 B3 A0
008099: AD BE
00809B: 00 00                   DA    $00                   ; TWO ZEROS

                       * 0 - QUIT TO ROM RE-START
                       * 1 - QUIT TO PREVIOUS PROGRAM
                       * 2 - LAUNCH "P16.SYSTEM"
                       * 3 - LAUNCH "P16.SYSTEM" AND RETURN WHEN DONE

00809D: 01             NAME0    DFB   1                     ; LEN OF ZERO
00809E: D8                      ASC   "X"                   ; WON'T FIND THIS!

00809F: 0A             NAME1    DFB   NAMEND-NAME1-1        ; LEN OF PATHNAME
0080A0: D0 B1 B6 AE             ASC   "P16.SYSTEM"          ; 2ND TEST SYS FILE
0080A4: D3 D9 D3 D4    C5 CD
                       NAMEND

0080A6: 5C                      CHK                         ; CHECKSUM FOR LISTING

--End Merlin-16 assembly, 171 bytes, Errors: 0
```

Merlin File Assembly and Linking Instructions

Linking is the process of combining several different program modules, that have already been assembled, into one or more final output object files. Remember that a relocatable file contained information about the JSRs and JMPs. It can also contain information about calls to routines in itself that other modules might want to reference.

For example, suppose there are three program modules, A, B, and C. Furthermore, let's suppose that B and C have the entry points READ and

WRITE, respectively. Program A will represent the main program, and B and C are modules that read and write files to the disk.

Program A will want to call the routines READ and WRITE in B and C, but remember these are being assembled separately. So, while the programmer is working on module A, he just tells the assembler that some other module will eventually have the *external* label READ in it. During the assembly, then, the assembler knows not to worry about the fact that READ hasn't been given a specific address yet. You may know from assembling files already that normally an assembler will generate an error if a label is used that doesn't have an address defined for it. The **EXT (EXTernal)** is used to assign external labels.

While working on B, the programmer tells the assembler that READ, which is a label in module B, is an *entry point* that other programs may want to use. This is done with another assembler directive, **ENT (ENTry point)**. Module C will have WRITE defined in a similar way.

Having assembled each of the three programs individually into its own relocatable files (type REL = $FE), this is where the linker comes in. The linker uses a list, usually a text file, of all the modules to be combined into one or more final output files. In the case of the Apple IIGS and *Merlin 16,* this will be an Object Module Format (OMF) file. The list may also contain specific commands for the Linker, telling it to save the output file, to re-assemble a file, or which file type should be used for the output file.

Such a list might look like this:

```
TYPE $B3
LINK A
LINK B
LINK C
SAVE PROGRAM
```

During the linking process, the assembler will *reconcile* the calls to the READ and WRITE entry points in modules B and C with the JSRs (or whatever) to those labels from module A. This is the purpose of linking a file.

Also notice, however, that nothing insists that more than one input file be used. If all you want to do is to create an OMF file from a REL file, a link list with one file in it will do the trick.

To assemble, link, and run P16.SYSTEM, you must first load and activate the *Merlin 16* linker. This is done from the main menu by BRUNning the file LINKER.GS on the *Merlin 16* disk. You can type -LINKER.GS as a disk command to do this. The linker need only be installed once during a session.

From then on, any program can be assembled and linked by following these steps:

1. Enter and assemble the listing, exactly as shown. Save the source file. This will give you two files on the disk, P16.SYSTEM.S and P16.SYSTEM.L (a REL file). Notice the special suffix, .L given the REL file to differentiate it from the source file and the final OMF file. The suffix was part of the name in the DSK instruction and is not added automatically by *Merlin*.
2. After assembling and saving the source file, type in NEW to clear the editor workspace. Type this in:

```
TYP    $B3            ; S16 FILE
LINK   P16.SYSTEM.L   ; CONVERT REL TO OMF
SAVE   P16.SYSTEM     ; SAVE OUTPUT FILE
```

3. Save this new file on the disk under the name P16.SYS.CMD. This is the linker command list. It *cannot* be directly assembled. Do not type ASM to execute it.
4. To do the final link, type NEW again to clear the workspace, and then type:

```
LINK "P16.SYS.CMD"
```

   and press Return.
5. When the link is complete, you'll be returned to the main menu. Your final S16 file has already been saved on the disk. Return now to your program selector and try running P16.SYSTEM. It should work as described next.

If there is only one file to be linked, *Merlin 16* also has a shortcut link command that will link the last source file *saved*, and will create an OMF file, with the type S16. To do the quick link, type LINK "=" instead of an actual filename while at the command prompt (:) in the Editor. The final object file generated by the link will be saved under the name P16.SYSTEM, assuming you use the DSK command DSK P16.SYSTEM.L as the REL type output file in the source listing itself.

This general procedure should be used to assemble, link and run all further ProDOS 16 *Merlin* programs.

APW Linking

Linking a file in *APW* will seem fairly easy, because you've already done it. Because *all* files in *APW* must be linked, the linking process is part of the **ASML** command (**ASseMble and Link**). For ProDOS 8, presumably you've been reverse-converting the files after the ASML back to a standard object file with the MAKEBIN and FILETYPE commands.

Normally, the output of the ASML command is an OMF file. After assembling with ASML, just type in FILETYPE S16. You can then quit *APW* and test the program by starting it from a program selector. Although *APW* will let you launch a program directly from within its command mode, it's better to use the program selector to avoid unexpected interactions between *APW* and your programs.

For your reference, Program 14-3 and Program 14-4 are the *APW* versions of the two programs. Since *APW* assumes a starting long mode for the Accumulator and index registers, no LONGA ON, LONGI ON instructions are needed (although, like *Merlin*, it doesn't hurt, and it makes the starting conditions for the assembly clear).

Program 14-3. *APW* Simple P16 System File

```
0000                  ***********************************************
0000                  *         SIMPLE P16 SYSTEM FILE              *
0000                  *             APW ASSEMBLER                   *
0000                  ***********************************************
0000
0000                          KEEP   P16.SYSTEM
0000                          MSB    ON
0000
0000                  MAIN    START
0000
0000                  PRODOS  EQU    $E100A8           ; PRODOS 16 ENTRY POINT
0000                  KYBD    EQU    $C000
0000                  STROBE  EQU    $C010
0000                  SCREEN  EQU    $000400           ; LINE 1 ON SCREEN
0000
0000 4B               ENTRY   PHK                      ; GET PROGRAM BANK
0001 AB                       PLB                      ; SET DATA BANK
0000
0002 A2 00 00         PRINT   LDX    #$00              ; INIT X-REG
0005 BD 36 00         LOOP    LDA    MSSG,X            ; GET CHAR TO PRINT
0008 F0 08                    BEQ    GETKEY            ; END OF MSSG.
000A 9F 00 04 00              STA    >SCREEN,X         ; "PRINT" IT
000E E8                       INX                      ; NEXT TWO CHARS
000F E8                       INX                      ;X = X + 2
0010 D0 F3                    BNE    LOOP              ; WRAPAROUND PROTECT
0012
0012 AD 00 C0         GETKEY  LDA    KYBD              ; CHECK KEYBOARD
0015 29 FF 00                 AND    #$00FF            ; CLEAR HI BYTE
0018 C9 80 00                 CMP    #$0080            ; KEYPRESS?
001B 90 F5                    BCC    GETKEY            ; NOPE
001D 2C 10 C0                 BIT    STROBE            ; CLEAR KEYPRESS
0020
0020 22 A8 00 E1      QUIT    JSL    PRODOS            ; DO QUIT CALL
0024 29 00                    DC     I2'$29'           ; QUIT CODE
0026 2E 00 00 00              DC     I4'PARMBL'        ; ADDRESS OF PARM TABLE
002A B0 08                    BCS    ERROR             ; NEVER TAKEN
```

```
0037 002C 00 00                BRK                               ; SHOULD NEVER GET HERE . . .
0038 002E
0039 002E 00 00 00 00 PARMBL   DC      I4'$0000'                 ; PTR TO PATHNAME
0040 0032 00 00       FLAG     DC      I2'$00'                   ; ABSOLUTE QUIT
0041 0034
0042 0034 00 00       ERROR    BRK                               ; WE'LL NEVER GET HERE?
0043 0036
0044 0036 D0 CC C5 C1 MSSG     DC      C'PLEASE PRESS A KEY > '; EVEN NUMBER OF
                                                                   CHARACTERS'
0045 004C 00 00                DC      I1'0,0'                   ; TWO ZEROS
0046 004E
0047 004E                      END

47 source lines
0 macros expanded
0 lines generated
```

Program 14-4. *APW* ProDOS 16 Launcher Demo

```
0001 0000              ********************************************
0002 0000              * PRODOS 16 'LAUNCHER' DEMO                *
0003 0000              * LAUNCHES 2ND SYSTEM FILE,                *
0004 0000              * STAYS DORMANT, THEN REVIVED              *
0005 0000              * WHEN 2ND QUITS.                          *
0006 0000              *                                          *
0007 0000              * APW ASSEMLER                             *
0008 0000              ********************************************
0009 0000
0010 0000                       KEEP    P16.LAUNCH
0011 0000                       MSB     ON
0012 0000
0013 0000              MAIN     START
0014 0000
0015 0000              PRODOS   EQU     $E100A8              ; PRODOS 16 ENTRY POINT
0016 0000              KYBD     EQU     $C000
0017 0000              STROBE   EQU     $C010
0018 0000              SCREEN   EQU     $400                 ; LINE 1 ON SCREEN
0019 0000
0020 0000 4B           ENTRY    PHK                          ; PUSH CODE BANK
0021 0001 AB                    PLB                          ; PULL DATA BANK
0022 0002
0023 0002 A2 00 00     PRINT    LDX     #$00                 ; INIT X-REG
0024 0005 BD 8A 00     LOOP     LDA     MSSG,X               ; GET CHAR TO PRINT
0025 0008 F0 08                 BEQ     GETKEY               ; END OF MSSG.
0026 000A 9F 00 04 00           STA     >SCREEN,X            ; "PRINT" IT
0027 000E E8                    INX                          ; NEXT TWO CHARS
0028 000F E8                    INX                          ; X = X + 2
0029 0010 D0 F3                 BNE     LOOP                 ; WRAPAROUND PROTECT
0030 0012
0031 0012 AD 00 C0     GETKEY   LDA     KYBD                 ; KEYPRESS?
0032 0015 29 FF 00              AND     #$00FF               ; MASK UPPER BYTE
0033 0018 C9 80 00              CMP     #$80                 ; HI BIT SET?
0034 001B 90 F5                 BCC     GETKEY               ; NOPE
```

```
001D 2C  10  C0                BIT    STROBE                ; CLEAR KEYPRESS
0020
0020 C9  B0  00         CHK    CMP    #'0'                  ; QUIT TO ROM ROUTINE?
0023 F0  13                    BEQ    QUIT0                 ; YES
0025 C9  B1  00                CMP    #'1'                  ; REAL QUIT?
0028 F0  1C                    BEQ    QUIT1                 ; YES
002A C9  B2  00                CMP    #'2'
002D F0  25                    BEQ    QUIT2                 ; LAUNCH 2ND, DON'T RETURN
002F C9  B3  00                CMP    #'3'
0032 F0  2E                    BEQ    QUIT3                 ; LAUNCH 2ND, RETURN
0034
0034 5C  12  00  00     TRYAGN JML    GETKEY                ; TRY AGAIN
0038
0038 22  A8  00  E1     QUIT0  JSL    PRODOS                ; DO QUIT CALL
003C 29  00                    DC     I2'$29'               ; QUIT CODE
003E 70  00  00  00            DC     I4'PARM0'             ; ADDRESS OF PARM TABLE
0042 B0  44                    BCS    ERROR                 ; NEVER TAKEN
0044 00  00                    BRK                          ; WE'LL NEVER GET HERE?
0046
0046 22  A8  00  E1     QUIT1  JSL    PRODOS                ; DO QUIT CALL
004A 29  00                    DC     I2'$29'               ; QUIT CODE
004C 76  00  00  00            DC     I4'PARM1'             ; ADDRESS OF PARM TABLE
0050 B0  36                    BCS    ERROR                 ; NEVER TAKEN
0052 00  00                    BRK                          ; WE'LL NEVER GET HERE?
0054
0054 22  A8  00  E1     QUIT2  JSL    PRODOS                ; DO QUIT CALL
0058 29  00                    DC     I2'$29'               ; QUIT CODE
005A 7C  00  00  00            DC     I4'PARM2'             ; ADDRESS OF PARM TABLE
005E B0  28                    BCS    ERROR                 ; NEVER TAKEN
0060 00  00                    BRK                          ; WE'LL NEVER GET HERE??
0062
0062 22  A8  00  E1     QUIT3  JSL    PRODOS                ; DO QUIT CALL
0066 29  00                    DC     I2'$29'               ; QUIT CODE
0068 82  00  00  00            DC     I4'PARM3'             ; ADDRESS OF PARM TABLE
006C B0  1A                    BCS    ERROR                 ; NEVER TAKEN
006E 00  00                    BRK                          ; WE'LL NEVER GET HERE??
0070
0070 A2  00  00  00     PARM0  DC     I4'NAME0'             ; BAD PATH TO GEN ERROR
0074 00  00             FLAG0  DC     I2'$00'               ; ABSOLUTE QUIT
0076
0076 00  00  00  00     PARM1  DC     I4'$00'               ; NO PATHNAME
007A 00  00             FLAG1  DC     I2'$00'               ; ABSOLUTE QUIT
007C
007C A4  00  00  00     PARM2  DC     I4'NAME1'             ; PTR TO PATHNAME
0080 00  00             FLAG2  DC     I2'$00'               ; BITS 15,14 = 0: DON'T RESTART
0082
0082 A4  00  00  00     PARM3  DC     I4'NAME1'             ; PTR TO PATHNAME
0086 00  C0             FLAG3  DC     I2'$C000'             ; BITS 15,14 = 1: RESTART LATER
0088
0088 00  00             ERROR  BRK                          ; WE'LL NEVER GET HERE?
008A
008A D0  D2  C5  D3     MSSG   DC     C'PRESS 0, 1, 2, OR 3 ->'; EVEN NUMBER OF CHARACTERS'
```

```
0087 00A0  00  00                 DC      I1'0,0'              ; TWO ZEROS
0088 00A2
0089 00A2              * 0 - QUIT TO ROM RESTART
0090 00A2              * 1 - QUIT TO PREVIOUS PROGRAM
0091 00A2              * 2 - LAUNCH "P16.SYSTEM"
0092 00A2              * 3 - LAUNCH "P16.SYSTEM" AND RETURN WHEN DONE
0093 00A2
0094 00A2  01          NAME0      DC      I1'1'                ; LEN OF ZERO
0095 00A3  D8                     DC      C'X'                 ; WON'T FIND THIS!
0096 00A4
0097 00A4  0A          NAME1      DC      I1'NAMEND-NAME1-1'   ; LEN OF PATHNAME
0098 00A5  D0  B1  B6  AE         DC      C'P16.SYSTEM'        ; 2ND TEST SYS FILE
0099 00AF              NAMEND     ANOP
0100 00AF
0101 00AF                         END

101 source lines
0 macros expanded
0 lines generated
```

Chapter 15

A Look at Memory Use on the Apple IIGS

Chapter 15

A Look at Memory Use on the Apple IIGS

First of all, congratulations for having worked so hard to reach this point in the book. Going from only a simple understanding of BASIC to being able to write programs under both ProDOS 8 and ProDOS 16 is no trivial accomplishment.

Reflect for a moment on what you've learned so far: over 75 assembly language instructions; how to input and print text to the screen; how to manipulate the hi-res screen; Boolean math; the intricacies of the direct page and the stack, and exotic addressing schemes; how to extend Applesoft BASIC with your own machine language routines; how to pass variables back and forth between Applesoft BASIC and machine language; how to use the Monitor to examine memory, write a program, and debug it; how to use an assembler; and most of all, general techniques in programming that go beyond just knowing a command or two.

What all that gets you right now is the foundation to embark on writing your own programs for the Apple IIGS that would be impossible on any other machine. You see, the Apple IIGS, with its thousands of built-in routines, can act like an amplifier of your existing talent and let you write programs today that would be a super-human accomplishment for programmers just a few years ago.

Before we start with the actual Apple IIGS Toolset, let's review the overall memory use of the Apple IIGS by the different operating systems and applications.

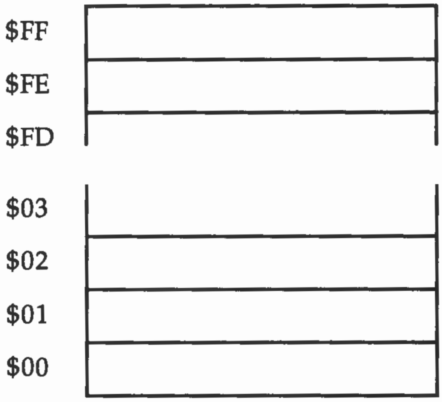
Now, with what you've learned in the previous chapters, the explanation of total memory usage on the Apple IIGS will seem easy to understand because you've already learned a lot of the most important details while you were learning about other major concepts. There will be new discoveries, like additional banks of memory, but most of this new information will be for your own background as a soon-to-be expert on the Apple IIGS. After all, you can't claim to be an expert if you've never heard of bank-switching or the alternate 4K bank of memory, now can you?

The Apple II: Past Lives

Although it's not essential to know anything about previous Apple computers (like the Apple II+, IIe and IIc) to program on the Apple IIGS, a few facts about the past will help you understand why things are the way they are today.

The original Apple II and II+ machines were 64K computers, whose memory was roughly equivalent to just bank 0 of the Apple IIGS today. Because the first bank of memory on the GS is still used in very much the same way, and because Applesoft BASIC has not fundamentally changed since the Apple II+, let's look at bank 0 first (see Figure 15-1).

Figure 15-1. Zero Page: $00 to $FF



The first 256 ($100) bytes are page zero. This is the default direct page on the Apple IIGS, and was the only possible direct page on all Apples before the Apple IIGS that used the 6502 or 65C02 microprocessors. Because of the importance of indirect and indexed addressing, this is the most important memory use in the computer.

In Applesoft BASIC, for example, every important pointer—such as to the size of the program in memory, which line is currently being executed and the character in the line which is being looked at—is stored in page zero. Even if you had no reference books whatsoever on the internal workings of the computer, quite a large amount of information could be deduced just by looking at the contents of page zero and seeing how the memory values changed as different programs were loaded and run.

This is exactly what many people did in the late 1970s, when the Apple computer was first produced, and much more technical information was to be found published by average owners of the computer who had taken the time to do a little investigation than by Apple Computer Company itself.

This tradition continues today, but the real message is that you don't always have to depend on someone else to give you the information you desire. A little work and clear deductive thought can teach you a lot about the computer.

On the Apple IIGS, the direct page can be relocated by a program by using the Direct Page Register. This is a valuable enhancement to the original Apple II design because now programs don't have to fight over the same part of memory. In the Applesoft BASIC environment, you've got Applesoft BASIC, the Monitor, ProDOS and your routine all trying to use the same 256 bytes of memory. Since the first three contenders are preprogrammed, this means you've got to be very careful choosing those zero-page bytes (we used $06–09) to not get in somebody else's way.

With the Apple IIGS, even in routines called from Applesoft BASIC, you can re-assign the direct page for your routine's use, as long as you're sure to restore it to page zero before you return to Applesoft BASIC, call the ProDOS 8 MLI, or call an internal Applesoft BASIC or Monitor routine (like COUT).

By the way, another completely acceptable approach to using page zero is to just save the contents of the bytes you want to use in your routine, and then restore them when you're done. The ProDOS MLI instructions, for example, take this approach and save the contents of $40–$4E, and then restore them when the command is finished. The main thing to be careful not to do is save the contents, use the bytes for yourself, and then call some other routine that expects the original values to be there when instead you've changed them.

For example, locations $28, 29 are used by COUT as the base address for the current text screen line being printed by the Monitor or Applesoft BASIC. If you saved the contents of these bytes, used $28,29 in your routine, and then restored them, no one would be any the wiser. However, if your routine called COUT in the middle of all this, things would really go crazy because COUT would expect the original values to still be there.

The Stack: $100 to $1FF

$100–$1FF	The Stack
$00–$FF	Zero (Direct) Page

The next page of memory, $100 to $1FF, is the default stack area. In the Applesoft BASIC environment, the stack is limited to $100 bytes, and is filled from $1FF–downward with stored return addresses for JSRs and JSLs, and values pushed on the stack by running programs.

Like the direct page, this can also be changed by a routine, by changing the Stack Pointer to any two-byte address in the first bank (bank 0) of memory. With the 65816 in the full 16-bit mode, the stack can be of any size, and it is up to the programmer to see that data in it does not collide with anything stored below it.

The Input Buffer: $200 to $2FF

$200–$2FF	The Input Buffer
$100–$1FF	The Stack
$00–$FF	Zero (Direct) Page

The area from $200 to $2FF is used by Applesoft BASIC and the Monitor to store characters as they are input from the keyboard. Certain ProDOS 8 programs also use the second half of the input buffer ($280 to $2FF) to pass pathnames between successive programs. When ProDOS is reading or writing a file from disk, a dedicated buffer defined elsewhere in memory is used, so the input buffer from $200 to $2FF is not used, although you may see the term *input buffer* used in reference to other data areas.

Because the input buffer is so heavily used on a temporary basis, it makes an excellent choice for a temporary block of memory for your own programs, especially for string operations. Just don't plan on leaving anything there after you leave your routine and expect to find it there when you come back.

Page Three

Figure 15-2 shows page three. The area from $300 to $3CF is considered an open area for user-defined machine language routines. This is the area used for most of the short demonstration programs so far in this book.

Starting at $3D0 are a number of ProDOS and system vectors that should not be changed unless you know exactly what you are doing. The existence and use of some of the vectors depend on whether you are in ProDOS 8 or 16, or are using Applesoft BASIC. Vectors like this are usually self-evident. For example, a ProDOS 16 program doesn't have to worry about the Applesoft BASIC ampersand (&) vector at $3F5–3F7.

Looking through the list, here's a brief discussion of each group of page-three bytes. A JMP instruction is held by $3D0–3D2 for the BASIC.SYSTEM warm-start entry. This is equivalent to being in the Monitor and typing Control-C. The difference is that this will reconnect ProDOS if an I/O handler has gotten things confused. The same vector is contained in $3D3–$3D5. Once upon a time, in a disk operating system called DOS 3.3, they were different.

Figure 15-2. Page Three: $300 to $3FF

$3FE–$3FF	Address for IRQ handler (interrupts).
$3FB–$3FD	JMP vector for non-maskable interrupts.
$3F8–$3FA	JMP vector Control-Y Monitor command.
$3F5–$3F7	JMP vector for BASIC & commands.
$3F4	Power-up byte. Must be EOR of contents of $3F3 with #$A5.
$3F2–$3F3	Address for a RESET restart.
$3F0–$3F1	Address of BRK handler.
$3EF	(Unused)
$3ED–$3EE	Address to go to when XFER ($C314) is called.
$3D6–$3EC	Reserved for use by a ProDOS 8 SYSTEM.
$3D3–$3D5	BASIC.SYSTEM warm-start entry vector.
$3D0–$3D2	BASIC.SYSTEM warm-start entry vector.
$300–$3CF	Free Area
$200–2FF	The Input Buffer
$100–1FF	The Stack
$00–$FF	Zero (Direct) Page.

Locations $3D6 to $3EC are reserved for use by a ProDOS 8 system program. You can use the bytes here for a vector to routines in your own program. You might wonder why you would want to do this. Suppose you're debugging a large program that has a tendency to crash. Certain entry points that could be used to restart the program after a crash may be within the body of the program itself. Instead of trying to remember that $21A7 is the current assembly's warm-start (restart without clearing variables), you could put a permanent warm-start vector of your own at $3D6-$3D8 (for example, JMP $21A7). That way, each reassembly will put the correct reentry vector at $3D6, and you only have to remember one address.

Locations $3ED and 3EE hold an address for something called the XFER (for transfer) routine. The XFER routine is derived from use on Apple IIe and IIc machines that used the 65C02 microprocessor, and could not do long-address JMPs or JSRs to other banks of memory. In the case of the IIe and IIc, there is *only* one other bank of memory (ignoring expansion RAM cards for the moment), bank 1, also called *auxiliary memory* or AUXMEM. XFER is a routine designed to transfer program control from one bank to another.

For example, if you had a program running in bank 0 at $300, and wanted to jump to $300 in bank 1, you could store the bytes $00,$03 in locations $3ED,3EE, and do a JMP $C314 (the XFER routine). The $C314 address is a clue that the routine is on a peripheral card in slot 3, and it's true. The 80-column display uses bank 1 for every-other character on the screen, and there are a number of built-in routines associated with the 80-column firmware and the extra memory in bank 1. The 80-column display routines appear as though they are on a peripheral card in slot 3. XFER is one of those routines.

Locations $3F0 and 3F1 hold the address that the computer will jump to after it has encountered a BRK instruction and has taken care of its own business with the event. The existence of this vector makes debuggers and programs that step through and trace assembly language programs possible.

Suppose we wrote a program that could keep track of a simulated program counter—where in memory a program was executing. That program could place a BRK instruction after the current instruction; then JMP to it. When the BRK was encountered after the instruction, the vector at $3F0, 3F1 would point back to our program, which would restore the byte where the BRK was and advance our own program counter to this now-current instruction. Then a new BRK would be written after this instruction, and the process would repeat. In this way, we would get control back after each and every program step in the target program. This is how a step-and-trace (or debugger) is written for the Apple computer.

The next three bytes, $3F2–3F4 are the address of where to jump to after a RESET, followed by a special checksum byte. When RESET is pressed, a number of things are reinitialized that don't include reconnecting BASIC.SYSTEM under ProDOS 8. If things were not fixed up, typing CATALOG after a RESET would just give a SYNTAX ERROR. Likewise, for a SYSTEM program of your own, it's *very* good practice to trap RESET, so that the user isn't dumped into the Monitor if RESET is pressed.

The checksum byte is used by the Monitor to make sure that the vector that's there is intended. When you first turn on the machine, *some* value has to be there. One of the ways the computer knows it has just been turned on is by doing an exclusive-OR (EOR) of the contents of location $3F3 with the constant value $A5. It then compares the result to a checksum byte stored in location $3F4. If they don't match, the computer assumes that it has just been turned on, and a total reboot is done. Needless to say, putting a zero at $3F4 is pretty much equivalent to saying you want reboot on RESET—not a friendly thing to do (but not unknown in the world of commercial software).

In the interest of completeness for this book, Program 15-1 is a short listing of a short ProDOS 8 system program (in fact, a variation on P8.SYSTEM) that traps RESET while it's waiting to do a quit.

The program should be pretty much self-explanatory. There are no new principles introduced other than the idea of saving the existing RESET vector at $3F2–$3F4 and then restoring it before the program quits. Try out the program and notice how RESET is now controlled by the system program itself.

Program 15-1. ProDOS Reset Demo

```
                  *********************************************
                  *     PRODOS 8 RESET DEMO PROG.             *
                  *          MERLIN ASSEMBLER                 *
                  *********************************************

        =BF00     MLI      EQU   $BF00
        =FDF0     COUT     EQU   $FDF0
        =FC58     HOME     EQU   $FC58
        =C000     KYBD     EQU   $C000
        =C010     STROBE   EQU   $C010
        =03F2     RESET    EQU   $3F2            ; RESET VECTOR
        =03F4     CHK      EQU   $3F4            ; CHECKSUM BYTE

                            ORG   $2000

                            DSK   P8.SYS.RESET
                            TYP   $FF             ; SYSTEM FILE TYPE

002000: 20 58 FC  START     JSR   HOME            ; CLEAR SCREEN

002003: AD F2 03  SAVE      LDA   RESET           ; GET OLD VECTOR
```

```
002006: 8D 90 20       22          STA  OLDRESET     ; SAVE IT
002009: AD F3 03       23          LDA  RESET+1
00200C: 8D 91 20       24          STA  OLDRESET+1
00200F: AD F4 03       25          LDA  CHK
002012: 8D 92 20       26          STA  OLDRESET+2
                       27
002015: A9 72          28 SET      LDA  #<HANDLER    ; OUR RESET ROUTINE
002017: 8D F2 03       29          STA  RESET
00201A: A9 20          30          LDA  #>HANDLER
00201C: 8D F3 03       31          STA  RESET+1      ; ALL SET!
00201F: 49 A5          32          EOR  #$A5         ; CHECKSUM
002021: 8D F4 03       33          STA  CHK
                       34
002024: A0 00          35 PRINT    LDY  #$00         ; INIT Y-REG
002026: B9 5C 20       36 LOOP     LDA  MSSG,Y       ; GET CHAR TO PRINT
002029: F0 06  =2031   37          BEQ  GETKEY
00202B: 20 F0 FD       38          JSR  COUT         ; PRINT IT
00202E: C8             39          INY               ; NEXT CHAR
00202F: D0 F5  =2026   40          BNE  LOOP         ; WRAPAROUND PROTECT
                       41
002031: 2C 00 C0       42 GETKEY   BIT  KYBD         ; KEYPRESS?
002034: 10 FB  =2031   43          BPL  GETKEY       ; NOPE
002036: 2C 10 C0       44          BIT  STROBE       ; CLEAR KEYPRESS
                       45
002039: AD 90 20       46 RESTORE  LDA  OLDRESET     ; GET ORIG. VECTOR
00203C: 8D F2 03       47          STA  RESET
00203F: AD 91 20       48          LDA  OLDRESET+1
002042: 8D F3 03       49          STA  RESET+1
002045: AD 92 20       50          LDA  OLDRESET+2
002048: 8D F4 03       51          STA  CHK
                       52
00204B: 20 00 BF       53 QUIT     JSR  MLI          ; DO QUIT CALL
00204E: 65             54          DFB  $65          ; QUIT CODE
00204F: 54 20          55          DA   PARMTBL      ; ADDRESS OF PARM TABLE
002051: B0 08  =205B   56          BCS  ERROR        ; NEVER TAKEN
002053: 00             57          BRK               ; SHOULD NEVER GET HERE . . .
                       58
002054: 04             59 PARMTBL  DFB  4            ; NUMBER OF PARMS
002055: 00             60          DFB  0            ; QUIT TYPE: 0 = STD QUIT
002056: 00 00          61          DA   $0000        ; NOT NEEDED FOR STD QUIT
002058: 00             62          DFB  0            ; NOT USED AT PRESENT
002059: 00 00          63          DA   $0000        ; NOT USED AT PRESENT
                       64
00205B: 00             65 ERROR    BRK               ; WE'LL NEVER GET HERE?
                       66
00205C: D0 CC C5 C1    67 MSSG     ASC  “PLEASE PRESS A KEY ->“,00
002060: D3 C5 A0 D0 D2 C5 D3 D3
002068: A0 C1 A0 CB C5 D9 A0 AD
002070: BE 00
                       68
002072: 20 58 FC       69 HANDLER  JSR  HOME         ; OUR RESET HANDLER
                       70
```

```
002075: A0  00            71  PRINT2    LDY   #$00              ; INIT Y-REG
002077: B9  93  20        72  :1        LDA   MSSG2,Y           ; GET CHAR TO PRINT
00207A: F0  06  =2082     73            BEQ   GETKEY2
00207C: 20  F0  FD        74            JSR   COUT              ; PRINT IT
00207F: C8                75            INY                     ; NEXT CHAR
002080: D0  F5  =2077     76            BNE   :1                ; WRAPAROUND PROTECT
                          77
002082: 2C  00  C0        78  GETKEY2   BIT   KYBD              ; KEYPRESS?
002085: 10  FB  =2082     79            BPL   GETKEY2           ; NOPE
002087: 2C  10  C0        80            BIT   STROBE            ; CLEAR KEYPRESS
                          81
00208A: 20  58  FC        82            JSR   HOME              ; CLEAR SCREEN
00208D: 4C  24  20        83            JMP   PRINT             ; TRY AGAIN...
                          84
002090: 00  00            85  OLDRESET  DA    $0000             ; OLD RESET VECTOR
002092: 00                86            DFB   $00               ; OLD CHECKSUM
                          87
002093: CD  C1  D9  C2    88  MSSG2     ASC   “MAYBE YOU SHOULD TRY ANOTHER KEY?”,8D
002097: C5  A0  D9  CF  D5  A0  D3  C8
00209F: CF  D5  CC  C4  A0  D4  D2  D9
0020A7: A0  C1  CE  CF  D4  C8  C5  D2
0020AF: A0  CB  C5  D9  BF  8D
0020B5: D0  D2  C5  D3    89            ASC   “PRESS A KEY TO TRY AGAIN...”,8D,00
0020B9: D3  A0  C1  A0  CB  C5  D9  A0
0020C1: D4  CF  A0  D4  D2  D9  A0  C1
0020C9: C7  C1  C9  CE  AE  AE  AE  8D
0020D1: 00
                          90
0020D3: 27                91            CHK                     ; CHECKSUM FOR LISTING

--End Merlin-16 assembly, 211 bytes, Errors: 0
```

Bytes $3F5–$3F7 hold a JMP instruction for where to go when an Applesoft BASIC program encounters the ampersand (&) character. This is a handy way of adding new commands to BASIC, and was discussed in Chapter 12.

Locations $3F8–$3FA hold a JMP instruction indicating where to go when Control-Y is pressed in the Monitor. *Merlin*, the Monitor itself, and the Classic Desk Accessory called Mangler all use this vector. It's a convenient way to re-enter any program from the Monitor.

Bytes $3FB–$3FD create the vector for what are called *nonmaskable interrupts*. Interrupts are a signal that can occur at any time to tell the computer to stop what it is doing and to execute a program somewhere else in the computer. Usually, control soon returns to the program that was interrupted. Interrupts allow the computer to seem as though it's doing more than one thing at once, and they are an essential part of the Apple IIGS environment. There are different kinds of interrupts. The BRK instruction is, in a way, a kind of interrupt. It tells the microprocessor to stop executing the program it's in, and to jump through the vector at $3F0, 3F1. This allows us to run a debugging utility at the same time as another program, namely the program being debugged.

A nonmaskable interrupt is an interrupt that can never be ignored (see maskable IRQs, next). This is usually used in dedicated microprocessor devices to detect an outside event. It is provided for in the Apple IIGS, but rarely used.

There is another kind of interrupt, called a maskable **IRQ (Interrupt ReQuest)**, that is vectored through location $3FE, 3FF. That type of interrupt can be ignored by the operating program by just using the instruction **SEI (SEt Interrupt disable)**. This tells the computer to ignore any maskable or discretionary interrupts. This type of interrupt is disabled when the disk is reading or writing to a drive, for example, because timing is very important at that point—an interruption could not be tolerated. Because interrupts are so important on the Apple IIGS, it is not advisable to ever turn them off completely. Instead, your program should only turn them off briefly, when absolutely necessary, and then restore the interrupt status to its previous state as soon as possible.

The Text Display

The memory range from $400 to $7FF in bank 0 is used for the 40-column text display (see Figure 15-3). You have seen in previous chapters how a character can be printed to the screen by storing a byte directly in this part of memory.

In this range, 64 bytes in bank 0 are also used as screen holes by certain peripheral cards, as was discussed in a previous chapter.

Figure 15-3. The Text Display: $400 to $7FF

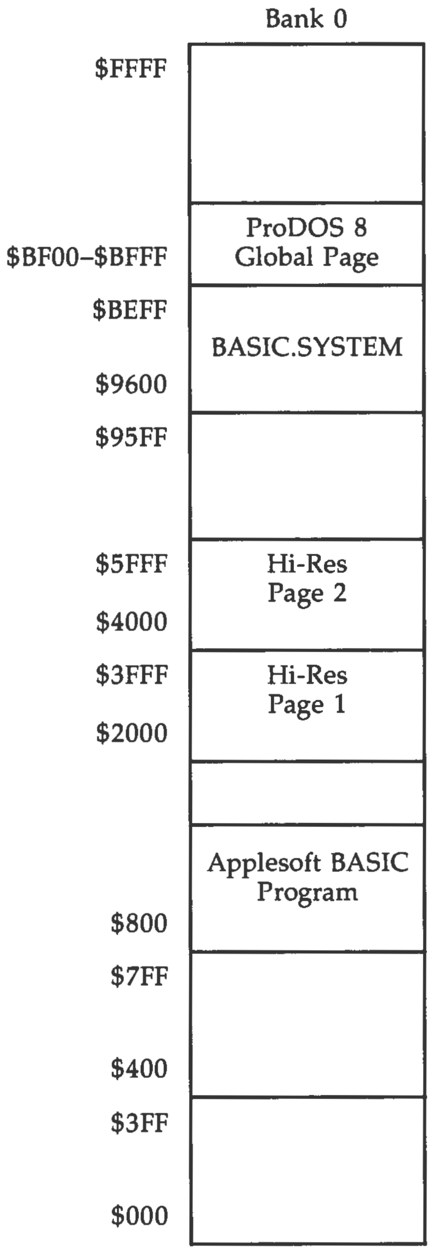
$400–$7FF	Text Display
$300–$3FF	Free Space and Vectors
$200–$2FF	The Input Buffer
$100–$1FF	The Stack
$00–$FF	Zero (Direct) Page

Applesoft BASIC

For Applesoft BASIC, a program starts in memory at $800 and grows upward in memory (see Figure 15-4). This is complicated by the fact that two hi-res displays are located in the range of $2000 to $3FFF (hi-res page one), and $4000 to $5FFF (hi-res page two). There are utility routines that will split an Applesoft BASIC program around the hi-res pages, or you can just move the entire program up above the pages in memory.

Applesoft BASIC variables are stored beginning at the end of the BASIC program itself. String data is stored at the top of memory and works downward as new strings are defined.

Figure 15-4. Applesoft BASIC Programs: $800 to $95FF



BASIC.SYSTEM: $9600 to $BEFF

The next major memory boundary occurs at $9600, which is the default lower boundary of BASIC.SYSTEM under ProDOS 8. Although BASIC.SYSTEM varies this lower boundary as files are opened and closed, this gives you a general idea of how much memory is normally available to an Applesoft BASIC program. You'll recall that BASIC.SYSTEM is used as a middleman between Applesoft BASIC and ProDOS 8. It is not required, nor is it in memory when a ProDOS system file is running.

The ProDOS Global Page: $BF00 to $BFFF

The area from $BF00 to $BFFF is called the ProDOS *global page* and is used to store information about the computer state under ProDOS that other programs may want to access. The MLI places all information that might be useful to a system program in this area of memory. You may want to consult the books specific to ProDOS 8 listed in Appendix D for more information on the ProDOS global page and other ProDOS 8 functions.

If you are running a ProDOS 8 system program, such as P8.SYSTEM, then BASIC.SYSTEM is not loaded into memory and your system file will be loaded starting at $2000. Obviously, if you intend to use the hi-res pages in such a program, you must relocate your program to some other nonconflicting part of memory. This can be done with a memory move routine in your own program, or using the 65816 memory move instructions. (See the 65816 instructions reference section in Appendix A).

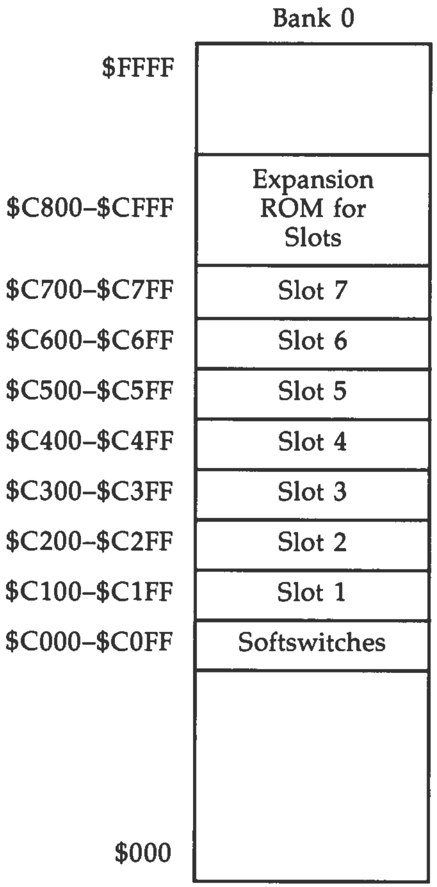
I/O ROM

The next important area of memory is that from $C000 to $CFFF. This is typically assigned totally to hardware in the form of either softswitches ($C000 to $C0FF) or ROM-based firmware on the peripheral interface cards, such as printer cards. See Figure 15-5.

The memory from $C100 to $C7FF has been allocated to the seven expansion slots (or built-in ports) in $100-byte (one page) increments. The normal implementation is for the peripheral card to have a ROM program on it, which appears in the address space corresponding to its slot. For example, the firmware for the printer port, which on the Apple IIGS appears as though it is in slot 1, appears in memory at $C100 to $C1FF. For the mouse interface, which is assigned to slot 4, the routines appear starting at $C400. When you type PR#4, for example, the computer is programmed to do a JMP to $C400. This is presumed to be an initialization routine in the ROM associated with the device assigned to slot 4.

In addition, the area from $C800 to $CFFF (2K) is a shared address space for all slots. When a device is turned on, it maps its own ROM into the complete space in this 2K area. Obviously, if two cards are active at the same time, and try to each use their own ROMs in this space, a conflict will occur. Therefore, there is a protocol for cards recognizing requests from other cards to switch in a new ROM assignment.

Figure 15-5. I/O ROM Space: $C000 to $CFFF



Bank-Switched RAM and ROM

The area from $D000 to $FFFF gets really interesting. In Applesoft BASIC, the space starting at $D000 and going up to $F7FF is assigned to the Applesoft BASIC ROM routines. And $F800 to $FFFF is the area for Monitor routines. However, there is another 16K of RAM also assigned to this space. It is accessed by the use of a softswitch which switches out the Applesoft BASIC and Monitor ROMs, and reroutes addressing to the RAM memory. This area is usually occupied by ProDOS. When a ProDOS system file (other than BASIC.SYSTEM) is running, Applesoft BASIC is not even needed, so this part of memory stays set to RAM for most, if not all, of the time.

It's pointless trying to decide which memory, RAM or ROM, is the "real" memory from $D000 to $FFFF. In fact, all of the memory in the Apple IIGS is scattered about in different physical locations. For some parts of memory, not even all the bits that make up a single byte are found in a single chip. Like the 2K of expansion ROM in the $C800–$CFFF range, this remapping is done all electronically. Memory is not actually moved, but rather, all addressing to that range is redirected to the proper physical memory (RAM or ROM).

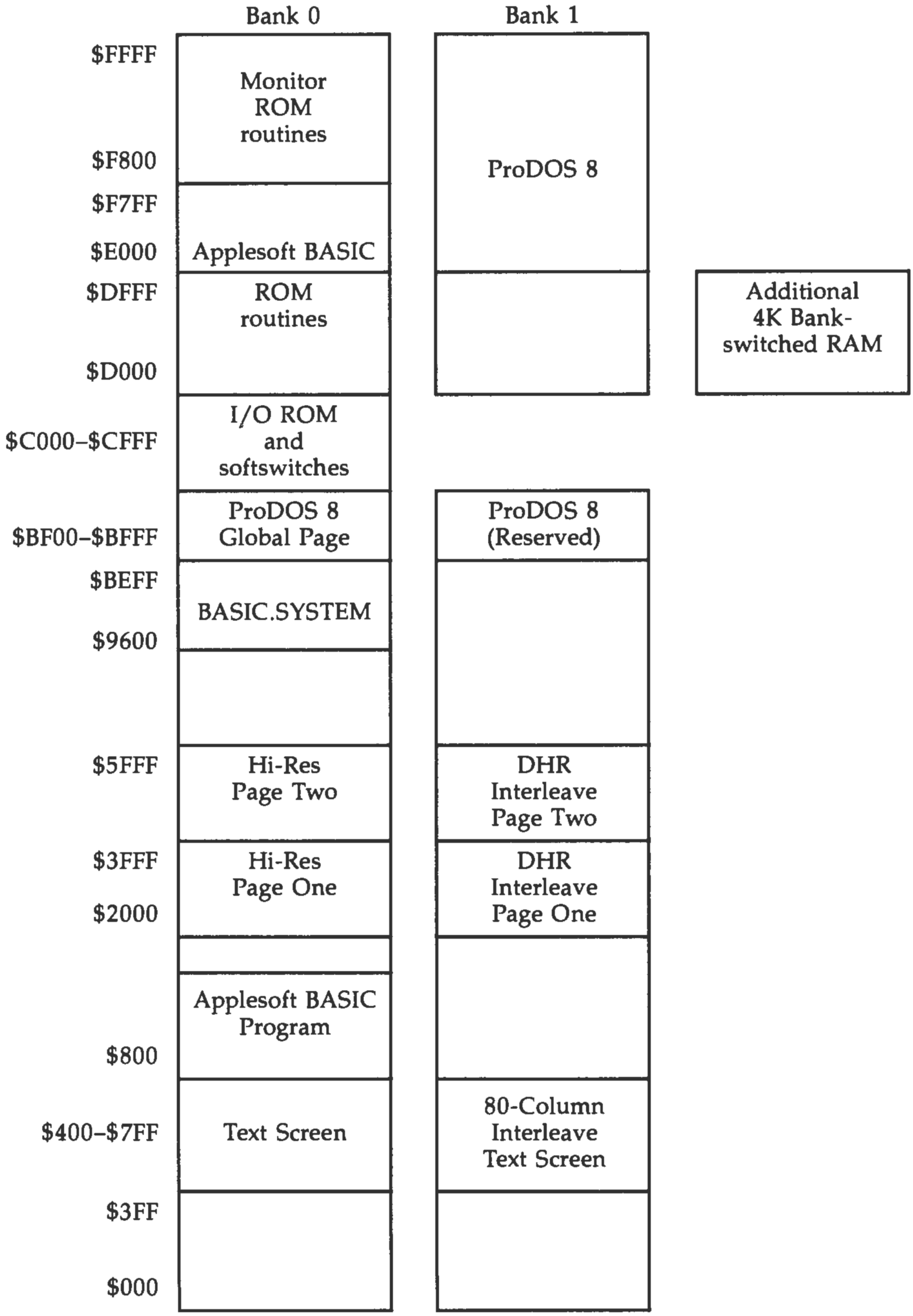
It gets even stranger though. If you recheck that address range, $D000–$FFFF, you'll see that it corresponds to only 12K ($FFFF to $D000 = $3000 = 3 * 4096 = 12288 bytes). But 16K is allocated to this area. And it is. Still another softswitch is used to switch the extra 4K of RAM from $D000 to $DFFF with the other 4K in that space. Thus, using exactly the same addresses in the range of $D000 to $DFFF, it is possible to be looking at one of three distinctly different sets of data: Applesoft BASIC ROM, RAM, or bank-switched RAM. By the way, it's in this alternate RAM bank that ProDOS 8 stores the routine ultimately called by the ProDOS quit command (called the *quit code*). By rewriting this area, programs under ProDOS 8 can establish their own quit procedures or dead-end the return process altogether (not recommended).

The actual softswitch protocols for switching between the RAM and ROM banks are varied and somewhat involved. You may wish to consult Apple IIe and Apple IIGS technical manuals for all the details on how to use bank-switched memory. Under ProDOS 16, with the long addressing modes of the 65816, bank-switching is required only for switching in and out the extra 4K (Applesoft BASIC being ignored). If it's any consolation, under ProDOS 16, it is unlikely you'll ever have to even concern yourself with this part of memory.

Two for the Price of One: The Apple IIe/IIc and Bank 1

When the Apple IIe and (later) the IIc machines were introduced, they increased the amount of memory available with a elegantly simple solution: The first 64K of memory was just doubled with matching RAM, as shown in Figure 15-6.

Figure 15-6. The First 64K



The Apple IIe and IIc are called 128K machines because memory is set up in two parallel banks of memory, each addressed from $0000 to $FFFF. This is almost like having two computers side by side. Although each has its own zero page, stack, and other areas, these areas are not really very usable as such, and are more relevant in the IIe and IIc environment. It's unlikely that you will ever have to be concerned with these functions on the Apple IIGS.

In bank 1 memory, the range from $400 to $7FF is used to augment the 40-column text display, thus creating the 80-column display (every-other character is from the alternate bank). You have seen in Chapter 10 how a character can be printed to the screen by storing a byte directly in this part of memory. Also, you saw how the identical address range in bank 1 was used to complete the 80-column display and how clearing this part of memory was required for a full 80-column screen clear. In the 80-column display, each byte from one bank is interleaved with each byte from the other. All even character-position bytes (0, 2, 4, and so on) are in bank 1 (AUXMEM), and all odd character-position bytes (1, 3, 5, and so on) are in bank 0.

Double hi-res graphics were actually discovered by accident on the Apple IIe and IIc after the implementation of the 80-column text display. It was discovered that a similar interleaving of bytes would double the graphics screen resolution of hi res from 280 pixels horizontally to 560 for double hi res.

The gap in the memory map for bank 1 is there to indicate that when you try to address, for example, $C300 in bank 1, you are actually addressing $C300 in bank 0. As mentioned earlier, it's possible, through simple wiring, to make the contents of any RAM or ROM address appear at any one, or several, addresses. It's a little like call forwarding: You can request access to an address; the computer will determine where that ultimately takes you.

The Apple IIGS: 256 for the Price of One

The Apple IIGS was designed to not only expand the capabilities of the earlier Apple IIe and IIc machines, but also to retain compatibility with software designed to run on those machines as well. The result is system that retains the underlying structure of the IIe and IIc environment, yet one that extends it in a way that makes the transition to ProDOS 16 programming very easy.

Some people try to conceptualize what goes on in the Apple IIGS between ProDOS 8 and ProDOS 16 as operating modes that are exclusive of one another. While it's true that Applesoft BASIC cannot run under ProDOS 16, many Apple IIGS tools can be called from within even an Applesoft BASIC program. You have also seen that although the *e*-bit's name, emulation bit, implies a separate and distinct operating mode, in fact, it serves mainly to enable the 16-bit width selection of data handling. Therefore, try to avoid the temptation to restrict the IIGS environment into separate operating modes, and rather realize that it is a superset, not a seperate set, of the earlier IIe and IIc computers.

The Apple IIGS has 256 ($00 to $FF) addressable (though not necessarily installed) banks of 64K memory. Banks $00 through $E1 are RAM. Banks $FE and $FF are ROM memory that include not only the Applesoft BASIC and Monitor routines, but also the Apple IIGS ROM toolset as well. The area from $F0 to $FD is reserved for expansion ROM, possibly in the form of a fast-boot ROM disk, or of permanently resident applications.

In addition, all memory except for banks $E0 and $E1 is what is called *fast memory*—all accessing to it can be done at the faster 3.1 MHz speed of the 65816, as opposed to the 1 MHz speed used to access banks $E0 and $E1.

The reason for this difference is that the video circuitry on the Apple relies on a certain timing and speed of operation to properly generate the video display. If this were arbitrarily sped up, your video monitor would no longer work. Remember that the video data areas in the Apple IIe and IIc are the text and hi-res pages in banks $00 and $01. At the same time, Apple knew people would expect that programs running in these banks would be faster because of the faster processor (clock speed) operation. Now here's a dilemma: how to speed up the program in banks 0 and 1, and leave the video display areas at a slower rate.

The solution was to do something called *shadowing,* in which data written to the video areas ($400 to $7FF and $2000 to $5FFF) of banks 0 and 1 would be automatically reproduced electronically, in the same memory range in banks $E0 and $E1. This way, as your program writes bytes to the text screen in bank 0, the data automatically appears in bank $E0. The video circuitry looks only at bank $E0, and it interacts only at the slower speed. Hence, everything works out. On the Apple IIGS, the video display you see is the contents only of banks $E0 and $E1. In fact, if you turn shadowing off, it's possible to write to the text or graphics pages in banks 0 and 1, and to have the results remain entirely invisible as the user continues to view the displays generated from banks $E0 and $E1.

Not every byte banks 0 and 1 are automatically shadowed into banks $E0 and $E1. The areas actually shadowed are controlled by a status byte at $C035, called the *shadow register.* Bits set and cleared in this byte determine which parts of memory will be automatically copied into banks $E0 and $E1 as they are written to in banks 0 and 1.

The control bits are as follows:

Bit 0	Text page one
Bit 1	Hi-res page one
Bit 2	Hi-res page two
Bit 3	Auxmem for both hi-res pages (double hi-res)

Bit 4	Super hi-res area ($2000–$9FFF) in bank 1
Bit 5	Reserved; always write as zero
Bit 6	Exchange 4K language card RAM with $C000 space (Write zero if you know what's good for you!)
Bit 7	Reserved: always write as zero

If you're wondering where the Applesoft BASIC and Monitor ROM routines are, the answer is in bank $FF. If you've gone to the Monitor and typed 00/FC58L to list the HOME routine, you probably didn't find much. That is because under ProDOS 8, FF/D000 to FF/FFFF is remapped into bank 0 when the Applesoft BASIC and Monitor ROMS are being selected by a program there. However, in the normal ProDOS 16 environment, you won't find the Applesoft BASIC routines in bank 0, but rather in bank $FF.

If you compare the size of the 4K bank-switched expansion RAM to the $C000 to $CFFF space, you'll notice that they are each 4K in size. In the Apple IIGS, it's possible to flip this expansion RAM down into the $C000 to $CFFF space in *every* bank of RAM, including bank 0. However, this is very tricky because you no longer have access to any of the softswitches or system status bytes that are so important to system control. Normally, the $C000 to $CFFF I/O area is mapped into each bank so that a program running in any bank can directly access the I/O space.

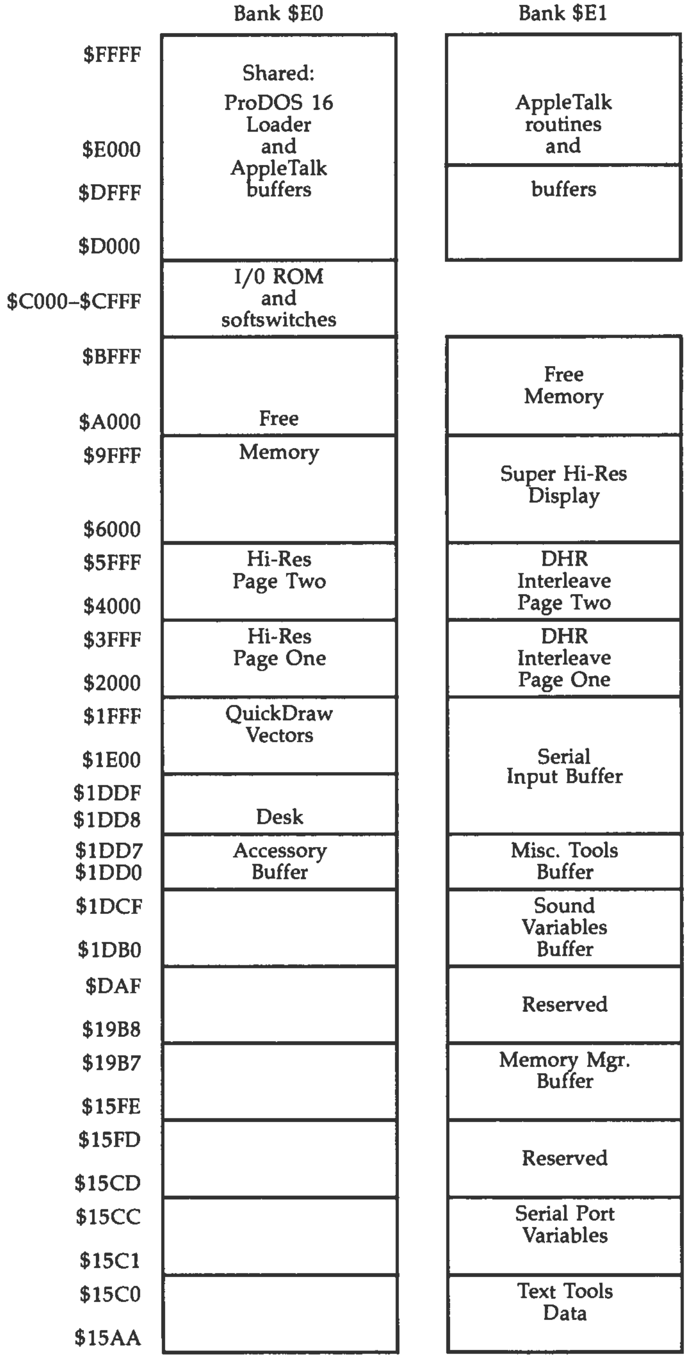
The Apple IIGS also has a new display mode, called *super hi-res graphics,* that uses the memory area in bank $E1 from $2000 to $9FFF (32K). It is possible to turn on shadowing for this display also, so that any writing to bank 1 in this memory range will automatically be copied into bank $E1 so that it will be in the video display.

Banks $E0 and $E1 are the main parts of memory used by the Apple IIGS internal system software and the system tools for such things as the super hi-res display, data storage and work areas for AppleTalk, the Miscellaneous Tool set, the Memory Manager, Text Tools, and more.

In general, it's best not to put any code directly here, but rather to use the Memory Manager, which will find and allocate memory as it's available throughout the entire computer.

For those who are curious, Figure 15-7 shows some of the memory use of banks $E0 and $E1.

Figure 15-7. Banks $E0 and $E1



$15A9 $158A		Serial Port Variables
$1589 $154A		ADB Address & attribute list
$1549 $14E2		SmartPort usage
$14E1 $1000		AppleTalk Data Storage
$FFF $FFB		Serial Port Storage
$FFA $FD6		ADB Storage
$FD5 $FD0		Misc. Tools usage
$FCF $C00		Disk Transfer Buffer
$BFF $800–$BFF $800	Text Screen Page Two	80-Column Interleave Text Screen Page Two
$7FF $400–$7FF $400	Text Screen Page One	80-Column Interleave Text Screen Page One
$3FF $3E0	↑	Clock Buffer
$3DF $3D0	Desk	ADB Interrupt Queue
$3EF $3C0	Accessory Buffer	Tool Locator Variables
$3BF $300	↓	Battery RAM Buffer
$2FF $2C0		
$2BF $2B8	Reserved	Mouse Clamp Data
$2B7 $000		User access vectors-Monitor Entry Points

Chapter 16

The Apple IIGS Toolbox

Chapter 16

The Apple IIGS Toolbox

For an assembly language programmer, one of the nicest things about the Apple IIGS is the enormous set of built-in (and loadable) routines that can be called by an application. This simplifies the programming process in that you do not have to write as many of the supporting routines to clear the screen, to use graphics, or even to catalog disks. All of these functions are available in the Apple IIGS Toolbox.

Banks $FE and $FF contain a number of the tools used most often. Others, including tools you create yourself, can be loaded in from disk.

The routines available are organized by *tool sets,* which are a group of related Toolbox commands. Each Toolbox command is called through a common vector, much the same way that ProDOS 8 and 16 commands were called. The main difference for the Toolbox commands is that information for each command is passed back and forth between the application and the command using the stack. The entry point for the Toolbox routines is at $E1/0000, and is called in the following fashion:

1. Push zeros (or anything) on the stack to make room for any results that may be returned by the routine. Nothing need be pushed on the stack if there are no results to be returned.
2. Load the X register with a two-byte value that identifies the tool set to use ($00 to $FF), and the command value ($00 to $FF). Thus, to call tool set number 5, and use command $27, you would use the instruction:

   ```
   LDX   #$2705      ; TOOL $05, COMMAND = $27
   ```

3. Do a JSL $E10000 to call the Toolbox dispatcher.
4. Pull any returned results off the stack. Not required if there are no results returned.
5. Check the carry flag for an error. The carry will be set if there was a problem executing the Toolbox command, and the Accumulator will hold the error code. If there was no error, the carry will be clear, and the Accumulator will be set to zero.

Table 16-1. The First 28 Tools

1	Tool Locator	The foundation routines that manage and locate all other tools.
2	Memory Manager	Handles the allocation of all system memory.
3	Miscellaneous Tools	Miscellaneous functions such as time and simple mouse control.
4	QuickDraw II	Super hi-res graphics routines.
5	Desk Manager	Manages classic and new desk accessories.
6	Event Manager	Reports in an organized way all input events such as the keyboard, mouse clicks, and other input devices.
7	Scheduler	Used to delay the execution of certain system commands.
8	Sound Tools	Intermediate level routines to access the sound synthesizer in the Apple IIGS.
9	Apple DeskTop Bus	Specific commands for the keyboard, mouse and other attached input devices.
10	SANE	Standard Apple Numeric Environment. Extended precision math routines.
11	Integer Math Tools	Routines for multiplication and division of integer values.
12	Text Tools	Text screen input and output routines.
13	GS System Tools	Internal tool set of the IIGS.
14	Window Manager	Routines for managing windows on the DeskTop (super hires, QuickDraw display).
15	Menu Manager	Manages entries and item selection in pull-down menus.
16	Control Manager	Routines for handling scroll bars, check boxes, and any other control device on the DeskTop.
17	Loader	ProDOS 16 System Loader.
18	QuickDraw Auxiliary	Supplemental QuickDraw routines.
19	Print Manager	Standard printer drivers.
20	Line Edit	Graphics display (DeskTop) line input and editing routines.
21	Dialog Manager	Routines for drawing and controlling dialog boxes on the DeskTop.
22	Scrap Manager	Handles common data, of either a graphics or text nature, to be transferred between applications.
23	Standard File Tools	Standardized routines for displaying disk directories, selecting a file, and so forth.
24	Disk Utilities	Commands for formatting disks and other disk functions.
25	Note Synthesizer	More advanced interface to sound synthesizer with instrument definitions.
26	Note Sequencer	Routines for playing sequences of sounds, musical performances.
27	Font Manager	Manages the many possible fonts in the graphics environment, including loading, scaling and drawing fonts.
28	List Manager	Displays lists of items with standardized routines.

There are, at this writing, 28 tool sets for the Apple IIGS. Programmers can also define their own tool sets, and more tools are sure to be released by Apple as time goes on. Table 16-1 shows the first 28 tools.

Tools 1 through 13 are ROM-based, that is, they're stored in the upper two banks of ROM memory in the Apple IIGS, banks $FE and $FF. All other tools must be loaded into memory using the Tool Locator LoadTool command.

Although it would be impossible in this book to cover every single tool in detail, we can get a good understanding of the general principles involved by exploring a half-dozen or so of the most often-used tools.

Lets start with the most important, the Tool Locator.

The Tool Locator

The Tool Locator tool set is the set of commands used to load RAM tools from disk, and to manage all the other tools currently in the system. The main entry point, $E10000 is itself part of the Tool Locator.

Generally speaking, each tool must be started up by an application when the application first runs, and then later shut down before the application does its quit command. This is so that memory used by a particular tool set may by freed for use by other tools or applications once it is no longer needed.

In practice, there are a number of tools, like the Tool Locator, that are always on because they're used by the Apple IIGS system itself. The computer itself could not function without the Tool Locator, so even if you try to shut it down, nothing actually happens. As a result, many programs do not specifically start up or shut down the Tool Locator, or tools like the Text Tools, as they probably should.

The *probably* is because, at the present, it doesn't make any difference one way or the other. However, if Apple ever changes these apparently safe tools and requires some sort of initialization, programs which don't follow the proper procedures may not work.

Table 16-2 lists some of the commands in the Tool Locator tool set.

The first six tool-set functions are a constant for every tool. Tool call $04xx, for example, will always return the version number of the tool set called, where *xx* represents its tool number. For some tools, the answer may be obvious, such as whether the Tool Locator is active (tool call $0601). The Tool Locator has to be active or the call to find out whether it was or not wouldn't work. Despite this, there is value in establishing a standard for tools whose status may not be active, and these six calls are guaranteed to be supported in every IIGS tool set.

Tool calls $0901 through $0D01 deal with internal work areas and pointers to particular tool calls. It's unlikely you'll ever need to use any of these.

Table 16-2. Selected Commands in the Tool Locator Tool Set

Command Value	Command Name	Description
$0101	BootInit	Initialized by system on boot. Not used by application.
$0201	TLStartUp	Starts up Tool Locator.
$0301	TLShutDown	Shuts down Tool Locator.
$0401	TLVersion	Returns version number of Tool Locator.
$0501	TLReset	Re-initializes Tool Locator and all other ROM-based tool sets on a system reset.
$0601	TLStatus	Indicates whether Tool Locator is active.
$0901	GetTSPtr	Get Function Pointer Table of a specified tool set.
$0A01	SetTSPtr	Set Function Pointer Table of a specified tool set.
$0B01	GetFuncPtr	Get pointer to a specified function in a tool set.
$0C01	GetWAP	Get pointer to work area for a tool set.
$0D01	SetWAP	Set pointer to work area for a tool set.
$0E01	LoadTools	Load a group of RAM-based tools from disk.
$0F01	LoadOneTool	Load a single RAM-based tool from disk.
$1001	UnloadOneTool	Release memory for a single RAM-based tool.
$1101	TLMountVolume	DeskTop (graphics) message usually for asking user to insert system disk. May be used for other messages.
$1201	TLTextMountVolume	Text screen message usually for asking user to insert system disk. May be used for other messages.
$1301	SaveTextState*	Saves current text screen and switches display to text screen. Usually for TLTextMountVolume, but could be used for other reasons.
$1401	RestoreTextState*	Restores saved state of text screen.
$1501	MessageCenter*	Allows common point to pass text data between different applications.

* Available on ProDOS 16 versions 1.2 or later.

LoadTools ($0E01) and LoadOneTool ($0F01) are used to load RAM-based tools from disk. These tools are always assumed to be in the TOOLS subdirectory of the SYSTEM folder on the boot disk.

UnloadOneTool ($1001) is used to free memory used by a RAM-loaded tool so that other applications aren't hindered by memory used by previous applications and their tools.

TLMountVolume ($1101) and TLTextMountVolume ($1201) are routines to put a message on the screen when one of the LoadTools commands can't find the system disk. One routine is for the super hi-res display, and the other is for the 40-column text screen. Note that QuickDraw and the Event Manager must have been started up already for the graphics-based TLMountVolume command to work.

If you were using the text screen, then TLTextMountVolume would destroy whatever was on the screen, so two other commands, SaveTextScreen ($1301), and RestoreTextScreen ($1401) have been provided to save and restore the screen state when you used TLTextMountVolume.

The last routine MessageCenter ($1501), is used to pass brief text data between applications. For example, suppose you had written two applications that changed back and forth between each other. MessageCenter would provide a way to communicate things like the active data disk prefix, the user's name, or whatever else you wanted, while avoiding the necessity of using a disk text file or the Scrap Manager to temporarily store the information.

The Tool Locator is actually pretty boring as far as suggesting interesting demo programs, but this is a good time to show how to call a tool from both Applesoft BASIC or ProDOS 8 and ProDOS 16 applications.

Program 16-1 is another variation on the P8.SYSTEM program that shows how to use the TLTextMountVolume command to print any message on the text screen.

Program 16-1. ProDOS 8 Tool Locator Demo

```
                     **********************************************
                     *    PRODOS 8 TOOL LOCATOR DEMO           *
                     *            MERLIN ASSEMBLER              *
                     **********************************************

        =BF00        MLI       EQU   $BF00
        =FDF0        COUT      EQU   $FDF0
        =FC58        HOME      EQU   $FC58
        =C000        KYBD      EQU   $C000
        =C010        STROBE    EQU   $C010

                               ORG   $2000

                               DSK   P8.TOOL.DEMO
                               TYP   $FF             ; SYSTEM FILE TYPE


002000: A9 4C        SETQUIT   LDA   #$4C            ; JMP INSTRUCTION
002002: 8D F8 03               STA   $3F8            ; CTRLY VECTOR
002005: A9 5C                  LDA   #<QUIT          ; LOW BYTE OF QUIT ADDR.
002007: 8D F9 03               STA   $3F9            ; LOW BYTE OF CTRL-Y VECTOR
00200A: A9 20                  LDA   #>QUIT
00200C: 8D FA 03               STA   $3FA            ; HIGH BYTE OF CTRL-Y VECTOR

00200F: 18           MODE16    CLC
002010: FB                     XCE                   ; ENABLE 16 BIT SELECT
002011: C2 30                  REP   $30             ; FULL 16 BIT MODE

002013: A2 01 02     STARTUP   LDX   #$0201          ; TLStartUp
```

```
002016: 22 00 00 E1                JSL   $E10000         ; START UP TOOL LOCATOR
00201A: 90 02  =201E               BCC   BOX
00201C: 00 00                      BRK   $00             ; TOOL ERROR (NOT LIKELY)

00201E: F4 00 00          BOX      PEA   $0000           ; PUSH SPACE FOR RESULT

002021: F4 00 00                   PEA   ^LINE1          ; HIGH WORD OF LINE1
002024: F4 6F 20                   PEA   LINE1           ; LOW WORD OF LINE1
002027: F4 00 00                   PEA   ^LINE2
00202A: F4 84 20                   PEA   LINE2
00202D: F4 00 00                   PEA   ^BUTTON1
002030: F4 9A 20                   PEA   BUTTON1
002033: F4 00 00                   PEA   ^BUTTON2
002036: F4 A9 20                   PEA   BUTTON2

002039: A2 01 12                   LDX   #$1201          ; TLTextMountVolume
00203C: 22 00 00 E1                JSL   $E10000         ; DO TOOLBOX CMD
002040: 90 02  =2044               BCC   TEST
002042: 00 00                      BRK   $00

002044: 68                TEST     PLA                   ; GET BUTTON VALUE
002045: C9 01 00                   CMP   #1              ; BUTTON 1 = QUIT
002048: F0 05  =204F               BEQ   SHUTDOWN

00204A: EE 98 20                   INC   LINE2+20        ; INCREMENT COUNTER
00204D: 80 C0  =200F               BRA   MODE16          ; TRY AGAIN . . .

00204F: A2 01 03          SHUTDOW  LDX   #$0301          ; TLShutDown
002052: 22 00 00 E1                JSL   $E10000         ; TOOL LOCATOR SHUTDOWN
002056: 90 02  =205A               BCC   MODE8
002058: 00 00                      BRK   $00

00205A: 38                MODE8    SEC
00205B: FB                         XCE                   ; BACK TO 8 BITS . . .

00205C: 20 00 BF          QUIT     JSR   MLI             ; DO QUIT CALL
00205F: 65                         DFB   $65             ; QUIT CODE
002060: 66 20                      DA    PARMTBL         ; ADDRESS OF PARM TABLE
002062: B0 09  =206D               BCS   ERROR           ; NEVER TAKEN
002064: 00 00                      BRK   $00             ; SHOULD NEVER GET HERE . . .

002066: 04                PARMTBL  DFB   4               ; NUMBER OF PARMS
002067: 00                         DFB   0               ; QUIT TYPE: 0 = STD QUIT
002068: 00 00                      DA    $0000           ; NOT NEEDED FOR STD QUIT
00206A: 00                         DFB   0               ; NOT USED AT PRESENT
00206B: 00 00                      DA    $0000           ; NOT USED AT PRESENT

00206D: 00 00             ERROR    BRK   $00             ; WE'LL NEVER GET HERE?

00206F: 14 D0 D2 CF       LINE1    STR   "PRODOS 8 TEST SYSTEM"
002073: C4 CF D3 A0
002077: B8 A0 D4 C5
```

```
00207B: D3 D4 A0 D3
00207F: D9 D3 D4 C5
002083: CD
002084: 15 D0 F2 E5   80 LINE2      STR   "Press a key. (Try #1)"
002088: F3 F3 A0 E1
00208C: A0 EB E5 F9
002090: AE A0 A8 D4
002094: F2 F9 A0 A3
002098: B1 A9
                      81
00209A: 0E D2 E5 F4   82 BUTTON1    STR   "Return to Quit"
00209E: F5 F2 EE A0
0020A2: F4 EF A0 D1
0020A6: F5 E9 F4
0020A9: 10 C5 F3 E3   83 BUTTON2    STR   "Esc to Try Again"
0020AD: A0 F4 EF A0
0020B1: D4 F2 F9 A0
0020B5: C1 E7 E1 E9
0020B9: EE
                      84
0020BA: 7A            85            CHK                     ; CHECKSUM FOR LISTING

--End Merlin-16 assembly, 187 bytes, errors: 0
```

Calling Tools from ProDOS 8

Apple IIGS tools can be called from ProDOS 8 (or even from Applesoft BASIC). The only requirement is that the accumulator and registers both be set to the 16-bit mode before any actual tool calls are done.

Lines 25–27 of Program 16-1 switch to the 16-bit mode. We could've delayed the transition, but since a tool call is the first thing the program does, the mode switch must be at the beginning. The Tool Locator tool set is then started up on lines 29 and 32.

In general, every tool used by a program should be started at the beginning of the program and shut down before the program quits. At the present time, not every tool absolutely requires this, but it is a good practice because it insures that your program will be compatible with future versions of the tools.

TLTextMountVolume has the following parameter requirements. First, each of these must be pushed onto the stack:

1. A two-byte word to make room for the result (which key is pressed).
2. A 4-byte, long-address pointer to the string that will be used as the title for the message box.
3. A 4-byte, long-address pointer to the string that will be used as the secondary line of text in the message box.
4. A 4-byte, long-address pointer to the string that will be used as the text for button 1 in the message box.

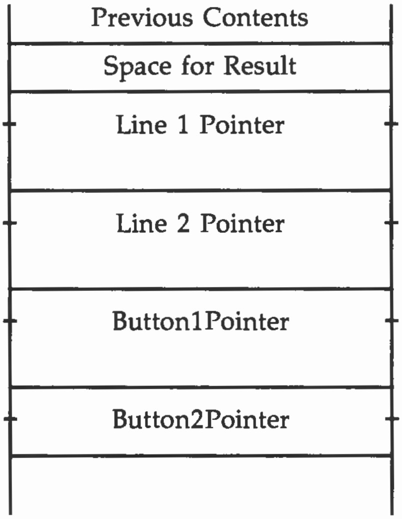
5. A 4-byte, long-address pointer to the string that will be used as the text for button 2 in the message box.

When each of these has been pushed onto the stack, the X register will load with the immediate value #$1201 (tool call $12, tool set number $01). This tool sets the display mode to the 40-column text display and draws a dialog box with two lines of text and two button indicators. The user may press the Return key for one choice and the Escape key for the other. Normally, Return accepts the request, or message, while Escape indicates the user wants to cancel.

If you've ever launched a program with the boot-up system disk not in the drive, you have probably seen this dialog box used in its intended fashion, that is, to prompt the user to insert a desired disk volume.

The tool call returns with a value on the stack equal to either 1 for button 1 pressed or 2 for button 2. This value can then be pulled off the stack. Figure 16-1 and 16-2 are diagrammatical ways of showing the input and output parameters for a tool call.

Figure 16-1. Input and Output Parameters for Tool Calls: Stack Before Call



Word: Allow space for result.

Long: Pointer to the string appear at top of box.

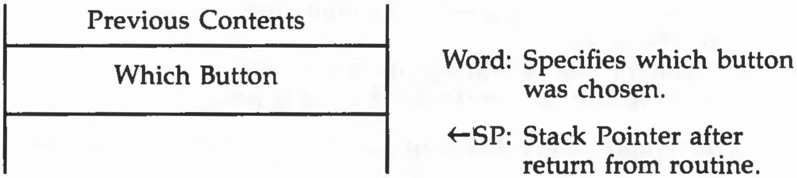
Long: Pointer to the string appear below line 2.

Long: Pointer to the string appear for Button1.

Long: Pointer to the string appear for Buton 2.

←SP: Stack pointer after setup.

Figure 16-2. Input and Output Parameters for Tool Calls: The Stack After Call


Previous Contents
Which Button
Word: Specifies which button was chosen.
←SP: Stack Pointer after return from routine.

Lines 34–43 push the needed values on the stack for the call. Remember **PEA (Push Effective Absolute address)** pushes the value of the operand on the stack (2 bytes). Line 34 pushes a zero on the stack to reserve space for the result returned by the Toolbox routine. Next, line 36 pushes the high word, or bank value, of the address of the string to be used as the title of the dialog box. Notice the use of the caret symbol (ˆ), a *Merlin 16* addressing protocol, to signify the high-order portion of the address assigned to the label LINE1. Line 37 then pushes the low-order word for the address on the stack. No special symbol is required to differentiate the low-order word. Because data may be located anywhere in memory, all Toolbox commands generally require four-byte pointers to data.

When the stack is prepared, line 45 loads the X register with the proper command value ($1201), and line 46 does the actual call to the tool function dispatcher at $E10000.

Assuming no error occurs, line 50 pulls the value for the choice off the stack and stores it for a comparison to be made shortly.

Error Codes

Then, the carry is checked to see if an error has occurred. For simplicity's sake, a BRK is used as our error handler. By examining the Accumulator in such a case, you can see what error occurred. Naturally, a more friendly error-handler is recommended for any program of your own.

There are a few particular error codes you should know about.

Error Code	= $xx01	This tool set is not available. (You haven't loaded the tool.)
	= $xx02	This tool command is not available. (You used the wrong command number.)

In addition, each tool set and routine has a variety of other individual errors that may be returned, depending on the actual call made. For example, here are some of the possible errors when using the Tool Locator:

Error Code = $0110 Version error (a tool with the minimum version number could not be found).
= $0100 Couldn't find system startup (boot) volume.
= $xxxx Any System Loader/ProDOS error is returned unchanged.

In general, error codes return the tool set that generated the error in the high-order byte, and the actual error code in the low-order byte. Not every tool call has a potential error. Some, like TLStartUp, will never generate an error.

You'll also notice that the check for the error has been done *after* any results are pulled off the stack. If you do the test first, and then branch to an error-handling routine without removing data from the stack, any subsequent RTS or RTL instructions will be executed incorrectly. You also need to be careful about forgetting to reset the microprocessor back to the 8-bit mode before doing the quit call in ProDOS 8. A common mistake is to branch past the mode switch to an error routine that then tries to return to ProDOS 8 or Applesoft BASIC in the 16-bit mode, with disasterous results.

Finally, the Tool Locator is shut down before the final ProDOS quit call is done.

ProDOS 16 Tool Locator

In ProDOS 16, the only variation is that you need not specifically set and clear the 16-bit mode, since that is the system state when your program begins. Also, don't forget to set the data bank register equal to the program bank register when you start your program. See Program 16-2.

The only other major change is that the *Merlin* directive TR ON (for *TRuncate ON*) has been added on line 81. If you compare this listing to that for the ProDOS 8 Tool Demo program, you'll see that TR ON limits the bytes printed for data blocks like those created by the STR pseudo-op to a single line. The remaining bytes are, of course, assembled—just not listed.

Program 16-2. ProDOS 16 Tool Locator Demo

```
              1  *********************************************
              2  *    PRODOS 16 TOOL LOCATOR DEMO            *
              3  *          MERLIN ASSEMBLER                 *
              4  *********************************************
              5
              6             MX    %00              ; FULL 16-BIT MODE
              7             REL                    ; RELOCATABLE OUTPUT
              8             DSK   P16.TOOL.DEMO.L
              9
=E100A8      10  PRODOS     EQU   $E100A8          ; PRODOS 16 ENTRY POINT
             11
```

```
                          **************************************************

008000: 4B                BEGIN    PHK                     ; GET PROGRAM BANK
008001: AB                         PLB                     ; SET DATA BANK

008002: E2 30             SETRES   SEP   $30               ; 8-BIT MODE
008004: A9 5C                      LDA   #$5C              ; JML (JMP LONG)
008006: 8F F8 03 00                STAL  $3F8              ; CTRLY VECTOR
00800A: C2 30                      REP   $30               ; 16-BIT MODE
00800C: A9 6F 80                   LDA   #RESUME
00800F: 8F F9 03 00                STAL  $3F9              ; $3F9,3FA
008013: A9 00 00                   LDA   #^RESUME
008016: 8F FB 03 00                STAL  $3FB              ; $3FB,3FC

00801A: A2 01 02          STARTUP  LDX   #$0201            ; TLStartUP
00801D: 22 00 00 E1                JSL   $E10000           ; START UP TOOL LOCATOR
008021: 90 02    =8025             BCC   BOX               ; NO ERROR
008023: 00 00                      BRK   $00               ; BRK IF THERE IS

008025: F4 00 00          BOX      PEA   $0000             ; PUSH SPACE FOR RESULT

008028: F4 00 00                   PEA   ^LINE1            ; HIGH WORD OF LINE1
00802B: F4 80 80                   PEA   LINE1             ; LOW WORD OF LINE1
00802E: F4 00 00                   PEA   ^LINE2
008031: F4 96 80                   PEA   LINE2
008034: F4 00 00                   PEA   ^BUTTON1
008037: F4 AC 80                   PEA   BUTTON1
00803A: F4 00 00                   PEA   ^BUTTON2
00803D: F4 BB 80                   PEA   BUTTON2

008040: A2 01 12                   LDX   #$1201            ; TLTextMountVolume
008043: 22 00 00 E1                JSL   $E10000           ; DO TOOLBOX CMD
008047: 90 02    =804B             BCC   TEST              ; NO ERROR?
008049: 00 00                      BRK   $00               ; BRK TO SEE WHAT ERROR IS...

00804B: 68                TEST     PLA                     ; RETRIEVE CHOICE VALUE
00804C: C9 01 00                   CMP   #1                ; BUTTON 1 = QUIT
00804F: F0 05    =8056             BEQ   SHUTDOWN

008051: EE AA 80                   INC   LINE2+20          ; INCREMENT COUNTER
008054: 80 CF    =8025             BRA   BOX               ; TRY AGAIN . . .

008056: A2 01 03          SHUTDOW  LDX   #$0301            ; TLShutDown
008059: 22 00 00 E1                JSL   $E10000           ; SHUT DOWN TOOL LOCATOR
00805D: 90 02    =8061             BCC   QUIT              ; NO ERROR
00805F: 00 00                      BRK   $00               ; ERROR

008061: 22 A8 00 E1       QUIT     JSL   PRODOS            ; DO QUIT CALL
008065: 29 00                      DA    $29               ; QUIT CODE
008067: 78 80 00 00                ADRL  PARMBL            ; ADDRESS OF PARM TABLE
00806B: B0 11    =807E               BCS   ERROR                 ; NEVER TAKEN
00806D: 00 00                        BRK   $00                   ; SHOULD NEVER GET HERE...

```

```
                       ************************************************

00806F: 4B             RESUME   PHK
008070: AB                      PLB                          ; SET OUR DATA BANK
008071: 18                      CLC
008072: FB                      XCE                          ; SET NATIVE MODE
008073: C2 30                   REP   $30                    ; 16-BIT MODE
008075: 4C 56 80                JMP   SHUTDOWN               ; TRY TO SHUTDOWN

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

008078: 00 00 00 00    PARMBL   ADRL  $0000                  ; PTR TO PATHNAME
00807C: 00 00          FLAG     DA    $00                    ; ABSOLUTE QUIT

00807E: 00 00          ERROR    BRK   $00                    ; WE'LL NEVER GET HERE

                                TR    ON                     ; TRUNCATE BYTES PRINTED.

008080: 15 D0 D2 CF    LINE1    STR   "PRODOS 16 TEST SYSTEM"
008096: 15 D0 F2 E5    LINE2    STR   "Press a key. (Try #1)"

0080AC: 0E D2 E5 F4    BUTTON1  STR   "Return to Quit"
0080BB: 10 C5 F3 E3    BUTTON2  STR   "Esc to Try Again"

0080CC: 63                      CHK                          ; CHECKSUM FOR LISTING

--End Merlin-16 assembly, 205 bytes, errors: 0
```

Using Macros in a Source Listing

There are times in writing an assembly language source listing that you'll find yourself typing the same sort of lines over and over again. You may even find yourself wishing there was some abbreviated way of telling the assembler to create an often-used block of code, perhaps even with certain customized aspects to it.

Let's start with a simple example: Incrementing a two-byte pointer in the 8-bit mode takes several steps in assembly language:

```
INCR    INC   $06          ; INCREMENT LOW-ORDER BYTE
        BNE   DONE         ; NO CARRY, SKIP NEXT STEP
        INC   $07          ; INCREMENT HIGH-ORDER BYTE
DONE    NOP                ; YOUR PROGRAM CONTINUES HERE
```

Assuming you have to use this routine often within a program, you can avoid retyping it by creating a *macro* definition. Macro is short for a macro-instruction, meaning a larger pseudo-instruction created out of several primary instructions. A macro can be defined in the assembler at the beginning of a source listing or in a separate file of definitions called a *macro library.* A macro library can be referenced once at the beginning of an assembly, and from then on any macro defined in the library will automatically be recognized during the assembly.

A *Merlin* macro definition looks like this:

```
INCR     MAC                 ; BEGIN MACRO DEFINITION
         INC   $06           ; INCREMENT LOW-ORDER BYTE
         BNE   DONE          ; NO CARRY, SKIP NEXT STEP
         INC   $07           ; INCREMENT HIGH-ORDER BYTE
DONE     NOP                 ; YOUR PROGRAM CONTINUES HERE
         EOM                 ; END OF MACRO DEFINITION

BEGIN    INCR                ; NEW INSTRUCTION = MACRO 'INCR'
```

A *Merlin* macro definition begins with the assembler directive **MAC.** The label used on that line will be the name assigned to the defined macro. The lines which follow define each instruction that is to be part of the macro. To terminate a macro definition, use the directive **EOM (End Of Macro)**, or, alternatively, use the characters < < < .

After the definition, the macro name can be used in the opcode field, just as though it were an assembly language instruction. When the file is assembled, all of the bytes associated with the macro definition will be created, just as though the lines of the macro had been typed at that spot in the listing. The macro definition itself at the beginning of the listing is not assembled as such. Program 16-3 shows the way the two-byte increment program would assemble.

Program 16-3. Two-Byte Increment Example

```
                           1  INCR    MAC            ; BEGIN MACRO DEFINITION
                           2          INC   $06      ; INCREMENT LOW-ORDER BYTE
                           3          BNE   DONE     ; NO CARRY, SKIP NEXT STEP
                           4          INC   $07      ; INCREMENT HIGH-ORDER BYTE
                           5  DONE    NOP            ; YOUR PROGRAM CONTINUES HERE
                           6          EOM            ; END OF MACRO DEFINITION
                           7
                           8  BEGIN   INCR
008000: E6  06             8          INC   $06
008002: D0  02   =8006     8          BNE   DONE
008004: E6  07             8          INC   $07
008006: EA                 8  DONE    NOP
                           8          EOM
                           9

--End Merlin-16 assembly, 7 bytes, Errors: 0
```

Notice that no bytes of object code are generated during the macro definition itself. Object code is generated only when the macro is actually used in the program. In the listing, you can see line 8 repeated as each line of the macro is played out. Each time INCR is used, locations $06 and $07 will be incremented.

Now, suppose that later in the listing you want to increment locations $08 and $09. Do you have to create a new macro definition? No, because you can rewrite the original definition with *variables,* like this:

```
INCR    MAC             ; BEGIN MACRO DEFINITION
        INC  ]1         ; INCREMENT LOW-ORDER BYTE
        BNE  DONE       ; NO CARRY, SKIP NEXT STEP
        INC  ]1+1       ; INCREMENT HIGH-ORDER BYTE
DONE    NOP             ; YOUR PROGRAM CONTINUES HERE
        EOM             ; END OF MACRO DEFINITION

BEGIN   INCR $06        ; INCREMENT LOCATIONS $06,07

        INCR $08        ; INCREMENT LOCATIONS $08,09
```

The characters]1 represent a variable that will be filled in with whatever value or label is in the operand field following the macro call. For example, Program 16-4 defines the macro INCR and the memory locations LOC1 as $06 and LOC2 as $08.

Program 16-4. Macro Example

```
                            1
           =0006            2 LOC1     EQU   $06        ; $06,07
           =0008            3 LOC2     EQU   $08        ; $08,09
                            4
                            5 INCR     MAC              ; BEGIN MACRO DEFINITION
                            6          INC   ]1         ; INCREMENT LOW-ORDER BYTE
                            7          BNE   DONE       ; NO CARRY, SKIP NEXT STEP
                            8          INC   ]1+1       ; INCREMENT HIGH-ORDER BYTE
                            9 DONE     NOP              ; YOUR PROGRAM CONTINUES HERE
                           10          EOM              ; END OF MACRO DEFINITION
                           11
                           12 BEGIN    INCR  LOC1
008000: E6  06             12          INC   LOC1
008002: D0  02   =8006     12          BNE   DONE
008004: E6  07             12          INC   LOC1+1
008006: EA                 12 DONE     NOP
                           12          EOM
                           13
                           14          INCR  LOC2
008007: E6  08             14          INC   LOC2
008009: D0  02   =800D     14          BNE   DONE
00800B: E6  09             14          INC   LOC2+1
00800D: EA                 14 DONE     NOP
                           14          EOM
                           15

--End Merlin-16 assembly, 14 bytes, Errors: 0
```

You can include up to 9 variables in a macro definition using the variables]1 through]9, separating each variable in the operand field with a comma. For example, here's a macro definition with three variables:

```
SWAP    MAC             ; EXAMPLE MACRO
        LDA  ]1         ; GET 1ST BYTE
        STA  ]3         ; SAVE IN TEMP LOCATION
        LDA  ]2         ; GET 2ND VALUE
        STA  ]1         ; PUT IN 1ST LOCATION
        LDA  ]3         ; GET ORIG. 1ST VALUE
        STA  ]2         ; MOVE TO POSITION 2
        EOM             ; END OF DEFINITION
```

This could then be used within the program like this:

```
PROGRAM  SWAP  $06,$08,$0A
```

or like this:

```
    SWAP  MEM1,MEM2,MEM3
```

Macro definitions are used extensively in Apple IIGS programming because the same programming procedures are used over and over again. For example, you've seen how every tool call begins with pushing data on the stack, followed by loading the X register with the command value and doing the JSL to $E10000. Apple has established a standard set of tool macros using predefined names for each tool. For example TLStartUp is defined as:

```
TLStartUp  LDX  #$0201
           JSL  $E10000
```

In a program, you'd just see:

```
BEGIN  TLStartUp
```

The *APW* assembler precedes all the tool macro names with an underscore (as in _TLStartUp), but otherwise the names are the same.

In addition to not having to type as much, macros have the advantage of conserving space in the listing and making it easier to see the big picture. It's also easier to remember the name TLStartUp for a function than the code number #$0201.

Program listings that use macros like this assume that there is a predefined macro library on the disk with the source file, and that all the reference macros have been defined.

The disadvantage is that if a listing only shows the macro name, and not the expanded lines generated, you don't see the actual lines of code. And, if you don't have the macro definition used in a program on your assembler disk, you won't be able to assemble the program without writing the macro code yourself.

Because the source listings for Apple IIGS programs that use the tools can get very large, it will be essential in the next few chapters that we make some use of macros to minimize the length of the presented listings. In addition, this will introduce you to the idea of using macros in your own programs on a regular basis. In the interest of keeping the listings short, and as clear as possible, only a half-dozen macro definitions will be used here.

Building a Macro Library

You can create this macro library yourself with either *Merlin 16* or *APW.* We'll define a standard tool call macro that includes our JSL $E10000 plus the test for an error and a BRK. Normally, you wouldn't include a BRK as an error handler in a program anyone else was going to use, but it's handy here to help debug your programs. Just be sure to include the Control-Y resume routine so you can get back to a program launcher if the program does break.

The first macro, ToolCall, will be defined as follows:

```
ToolCall    MAC                ; DEFINE THE MACRO ToolCall
            LDX   #]1          ; GET THE CALL NUMBER
            JSL   $E10000      ; DO THE CALL
            BCC   CONT         ; CONTINUE WITH PROGRAM
            BRK   $00          ; BREAK ON ERROR
CONT                           ; YOUR PROGRAM CONTINUES HERE
            EOM                ; END OF MACRO DEFINITION
```

This macro, ToolCall, will simply load the X register with the value for the call number, and then JSL to $E10000. The BCC CONT instruction will then test for an error and cause the program to continue with whatever instruction follows the BRK if no error is detected. Remember that, in *Merlin,* an instruction isn't required after a label, so this will achieve the desired result of making CONT equivalent to the address of the next instruction in the program the macro is used in. You'll see the call numbers as part of each macro, and the official name of each call will be included in the comment field, like this:

```
ToolCall $0201    ; TLStartUp
```

Because many of the Apple IIGS tools require information to be pushed on the stack prior to a call, it will also be useful to define some macros for this. For example, we can create a macro called *PushWord* that will push a two-byte word onto the stack. It would look like this in a program:

```
PushWord    LABEL
```

However, now we have a new challenge. How will you distinguish between when you want to push the contents of the location LABEL on the stack, and when you want to push the address value of LABEL itself?

The answer is to use a conditional statement in a macro. A conditional statement is just like an IF-THEN test in BASIC. It will let you test certain aspects of the inputs to the macro and generate different expansions accordingly. For example, here's a macro definition for PushWord:

```
PushWord   MAC              ; DEFINE MACRO PushWord
           IF     #,]1      ; IS 1ST CHAR OF ]1 A "#"
           PEA    #]1       ; YES, PUSH VALUE ON STACK
           ELSE             ; OTHERWISE,
           LDA    ]1        ; LOAD CONTENTS
           PHA              ; AND STORE THAT
           FIN              ; END OF CONDITIONAL PORTION
           EOM              ; END OF MACRO DEFINITION
```

The macro definition directive IF tells the assembler to look at the first character of the input variable]1. If it's the pound sign(#), signifying an immediate value, the value itself is pushed on the stack using the PEA instruction.

The ELSE directive begins the block of instructions of what to do if the test fails, which in this case is to then load the Accumulator with the contents of]1, and to push that onto the stack.

FIN defines the end of the conditional part of the macro and tells the assembler to assemble everything from that point on (or until the next IF). This is where any code to be found in both possible macro expansions would be entered (or it's before the IF at the beginning).

With this macro, you can now have two uses of PushWord:

```
PushWord #LABEL   ;PUSH VALUE OF THE LABEL ON STACK
PushWord LABEL    ;PUSH CONTENTS OF LABEL ON THE STACK
```

The same technique can be used to create a PushLong macro to push four bytes, a long address, for example, on the stack:

```
PushLong   MAC              ; DEFINE MACRO PushLong
           IF     #,]1      ; IMMEDIATE VALUE?
           PEA    ^]1       ; YES, PUSH HIGH WORD
           PEA    ]1        ; PUSH LOW WORD
           ELSE             ; OTHERWISE,
           LDA    ]1+2      ; GET HIGH WORD CONTENTS
           PHA              ; PUSH ON STACK
           LDA    ]1        ; GET LOW WORD CONTENTS
           PHA              ; PUSH ON STACK
           FIN              ; END OF CONDITIONAL PORTION
           EOM              ; END OF MACRO DEFINITION
```

In a similar manner, it would be nice to be able to pull data off the stack. In this case, the data pulled off the stack will be stored in a specified memory location. Here's two macros, *PullWord* and *PullLong* that do just that:

```
PullWord    MAC             ; DEFINE MACRO PullWord
            PLA             ; GET TWO BYTES OFF STACK
            STA   ]1        ; STORE IN MEMORY
            EOM             ; END OF MACRO DEFINITION

PullLong    MAC             ; DEFINE MACRO PullLong
            PLA             ; GET LOW WORD OFF STACK
            STA   ]1        ; STORE IT
            PLA             ; GET HIGH WORD OFF STACK
            STA   ]1+2      ; STORE IT
            EOM             ; END OF MACRO DEFINITION
```

Not every macro will be used in every program, but having these definitions in one library that we'll call UTIL.MACS will make it easy to use any of them in a given program.

Program 16-5 is an example of what a complete program using the *Merlin* Apple IIGS disk-based macro library might look like using these macros.

When you assemble Program 16-5, be sure to verify that the checksum on line 82 agrees with your own assembly. This checksum is the same for both the macro and nonmacro versions of this program.

This listing appears much longer because the contents of the macro file itself are printed at the beginning, and because each use of a macro is expanded within the listing. By using the *Merlin* directives **LST OFF** and **LST ON** on either side of the USE UTIL.MACS instruction, the listing of the macro file itself can be suppressed. There is also another *Merlin* directive, **EXP OFF** (**EXPand macros—OFF**) that will keep each macro from being expanded during the assembly.

In the interest of conserving space for the listings in the following chapters, most programs will use the UTIL.MACS macro library, and will not be expanded in the listings. If you should forget what a particular macro does in looking at a listing, you can always refer back to this chapter. Of course, in your own assemblies, you may also just omit the **LST OFF** or **EXP OFF** directives when you want a complete listing of all the assembled bytes in an object file.

Program 16-5. ProDOS 16 Tool Locator Demo with Macros

```
                      *********************************************
                      *     PRODOS 16 TOOL LOCATOR DEMO           *
                      *           --USING MACROS--                *
                      *          MERLIN ASSEMBLER                 *
                      *********************************************

                                    MX    %00           ; FULL 16-BIT MODE
                                    REL                 ; RELOCATABLE OUTPUT
                                    DSK   P16.TOOL.DEMO.L

             =E100A8  PRODOS        EQU   $E100A8       ; PRODOS 16 ENTRY POINT

                                    LST   OFF           ; DON'T LIST MACROS
                                    USE   UTIL.MACS     ; USE MACRO LIBRARY
                                    LST   ON            ; LISTING BACK "ON"

                                    EXP   OFF           ; DON'T EXPAND MACROS



008000: 4B            BEGIN         PHK                 ; GET PROGRAM BANK
008001: AB                          PLB                 ; SET DATA BANK

008002: E2 30         SETRES        SEP   $30           ; 8-BIT MODE
008004: A9 5C                       LDA   #$5C          ; JML (JMP LONG)
008006: 8F F8 03 00                 STAL  $3F8          ; CTRLY VECTOR
00800A: C2 30                       REP   $30           ; 16-BIT MODE
00800C: A9 6F 80                    LDA   #RESUME
00800F: 8F F9 03 00                 STAL  $3F9          ; $3F9,3FA
008013: A9 00 00                    LDA   #RESUME
008016: 8F FB 03 00                 STAL  $3FB          ; $3FB,3FC

                      STARTUP       ToolCall $0201      ; TLStartUP

                      BOX           PushWord #$0000     ; PUSH SPACE FOR RESULT

                                    PushLong #LINE1     ; PUSH LINE1
                                    PushLong #LINE2     ; and so on
                                    PushLong #BUTTON1
                                    PushLong #BUTTON2

                                    ToolCall $1201      ; TLTextMountVolume

00804B: 68            TEST          PLA                 ; RETRIEVE CHOICE VALUE
00804C: C9 01 00                    CMP   #1            ; BUTTON 1 = QUIT
00804F: F0 05 =8056                 BEQ   SHUTDOWN

008051: EE AA 80                    INC   LINE2+20      ; INCREMENT COUNTER
008054: 80 CF =8025                 BRA   BOX           ; TRY AGAIN . . .

```

```
                            SHUTDOWN ToolCall $0301       ; TLShutDown

008061: 22 A8 00 E1         QUIT     JSL  PRODOS          ; DO QUIT CALL
008065: 29 00                        DA   $29             ; QUIT CODE
008067: 78 80 00 00                  ADRL PARMBL          ; ADDRESS OF PARM TABLE
00806B: B0 11    =807E               BCS  ERROR           ; NEVER TAKEN
00806D: 00 00                        BRK  $00             ; SHOULD NEVER GET HERE...

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

00806F: 4B                  RESUME   PHK
008070: AB                           PLB                  ; SET OUR DATA BANK
008071: 18                           CLC
008072: FB                           XCE                  ; SET NATIVE MODE
008073: C2 30                        REP  $30             ; 16-BIT MODE
008075: 4C 56 80                     JMP  SHUTDOWN        ; TRY TO SHUTDOWN

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

008078: 00 00 00 00         PARMBL   ADRL $0000           ; PTR TO PATHNAME
00807C: 00 00               FLAG     DA   $00             ; ABSOLUTE QUIT

00807E: 00 00               ERROR    BRK  $00             ; WE'LL NEVER GET HERE?

                                     TR   ON              ; TRUNCATE BYTES PRINTED.

008080: 15 D0 D2 CF         LINE1    STR  "PRODOS 16 TEST SYSTEM"
008096: 15 D0 F2 E5         LINE2    STR  "Press a key. (Try #1)"

0080AC: 0E D2 E5 F4         BUTTON1  STR  "Return to Quit"
0080BB: 10 C5 F3 E3         BUTTON2  STR  "Esc to Try Again"

0080CC: 63                           CHK                  ; CHECKSUM FOR LISTING

--End Merlin-16 assembly, 205 bytes, errors: 0
```

APW Macros

Defining macros with the *APW* assembler is similar in concept, although different in actual procedure.

In *APW*, the macro library *must* be defined as a separate file—it cannot be included as part of the main source file itself. A macro definition in such a file begins with the directive **MACRO**. This is followed on the next line by the name of the macro. In the example below, this is **INCR** (**INCRement**). The macro definition ends with the directive **MEND** (**Macro END**).

```
         MACRO              ; DEFINE 'INCR'
         INCR
         INC     $06        ; INCREMENT $06
         BNE     DONE       ; NO WRAPAROUND
         INC     $07
DONE     ANOP
         MEND               ; END OF DEFINITION
```

The macro is then used in a source program with the directive **MCOPY** (for **M**acro **COPY**). This places a copy of the macro library specified in the list of available macro libraries. A source program that uses a macro library would look like this:

```
         MCOPY   MYMACROS
         GEN     ON

MAIN     START

PROGRAM  INCR

         END
```

The macro is invoked by using the macro name in the opcode field as though it were an assembly language instruction. The **GEN ON** directive is used if you want each macro instruction generated listed. Program 16-6 is the output of an assembly using the macro file and the source file above:

Program 16-6. Sample *APW* Program Using Macros

```
0001 0000
0002 0000                     MCOPY   MYMACROS
0003 0000                     GEN     ON
0004 0000
0005 0000           MAIN      START
0006 0000
0007 0000           PROGRAM   INCR
     0000  E6  06   +         INC     $06        ; INCREMENT $06
     0002  D0  02   +         BNE     DONE       ; NO WRAPAROUND
     0004  E6  07   +         INC     $07
     0006           +DONE     ANOP
0008 0006
0009 0006                     END

9 source lines
1 macros expanded
4 lines generated
```

It's also possible to include variables in *APW* macros as well. A macro definition that uses a variable label looks like this:

```
         MACRO                  ; DEFINE 'INCR'
         INCR     &LOC
         INC      &LOC          ; INCREMENT $06
         BNE      DONE          ; NO WRAPAROUND
         INC      &LOC+1
DONE     ANOP
         MEND                   ; END OF DEFINITION
```

The requirements are that the use of a variable label be called out on the first line of the macro definition by following the name of the macro by the expected variable list to be used when the macro is called.

The program calling the macro then follows its use of the macro name by the values or labels it wishes substituted in the macro. To increment location $06 and $07, for example, the listing would look like this:

```
            MCOPY    MYMACROS2
            GEN      ON

MAIN        START

PROGRAM     INCR     $06

            END
```

Which would generate the assembly in Program 16-7.

Program 16-7. Increment Location

```
0001 0000
0002 0000                        MCOPY    MYMACROS2
0003 0000                        GEN      ON
0004 0000
0005 0000            MAIN        START
0006 0000
0007 0000            PROGRAM     INCR     $06
     0000  E6 06     +           INC      $06           ; INCREMENT $06
     0002  D0 02     +           BNE      DONE          ; NO WRAPAROUND
     0004  E6 07     +           INC      $06+1
     0006            +DONE       ANOP
0008 0006
0009 0006                        END

9 source lines
1 macros expanded
4 lines generated
```

If a macro used several labels, the definition would look like this:

```
        MACRO                           ; DEFINE 'SWAP'
        SWAP    &LOC1,&LOC2,&LOC3
        LDA     &LOC1                   ; GET 1ST VALUE
        STA     &LOC3                   ; STORE IN TEMP LOC
        LDA     &LOC2                   ; GET 2ND VALUE
        STA     &LOC1                   ; PUT IN 1ST POSITION
        LDA     &LOC3                   ; GET ORIG. 1ST VALUE
        STA     &LOC2                   ; PUT IN 2ND POSITION

DONE    ANOP
        MEND                            ; END OF DEFINITION
```

This would be called in a program like this:

```
            MCOPY   MYMACROS3
            GEN     ON

MAIN        START

PROGRAM     SWAP    $06,$07,$08

            END
```

Which would assemble as follows:

```
0001 0000
0002 0000                       MCOPY   MYMACROS3
0003 0000                       GEN     ON
0004 0000
0005 0000             MAIN      START
0006 0000
0007 0000             PROGRAM   SWAP    $06,$07,$08
     0000  A5  06     +         LDA     $06           ; GET 1ST VALUE
     0002  85  08     +         STA     $08           ; STORE IN TEMP LOC
     0004  A5  07     +         LDA     $07           ; GET 2ND VALUE
     0006  85  06     +         STA     $06           ; PUT IN 1ST POSITION
     0008  A5  08     +         LDA     $08           ; GET ORIG. 1ST VALUE
     000A  85  07     +         STA     $07           ; PUT IN 2ND POSITION
     000C             +
     000C             +DONE     ANOP
0008 000C
0009 000C                       END

9 source lines
1 macros expanded
8 lines generated
```

The *APW* disk also contains an Apple IIGS resource macro library with macro definitions for all of the Apple IIGS tools. As with *Merlin 16,* these macros can be used to simplify a listing that uses the Apple IIGS tools.

In addition, the macro library M16.UTILITY contains the Push and Pull macros just discussed for *Merlin.* You will have to add the definition for ToolCall if you wish to use it as part of M16.UTILITY.

Chapter 17

The Memory Manager and Miscellaneous Tools

Chapter 17

The Memory Manager and Miscellaneous Tools

The multiple program operating environment of the Apple IIGS would not be possible without some supervising system to manage memory for the various applications, desk accessories, and the operating system itself. The Memory Manager tool set is a collection of routines for allocating, moving, and de-allocating blocks of memory that are used by different applications and the operating system. Even in the 64K Applesoft BASIC environment, you've seen how Applesoft BASIC, the Monitor, ProDOS and your own program all compete for the same memory in bank 0.

In the Apple IIGS, there are even more program entities such as desk accessories and the tool sets themselves—all in memory at the same time. For proper integration of all of this, it is essential that there be a central manager of all memory, to which each individual program goes to be assigned any memory it needs. This is the job of the *Memory Manager.*

The Memory Manager

As with most things, the Memory Manager is actually quite simple. When ProDOS 16 first loads a program, it asks the Memory Manager to find sufficient memory for the application from within any memory that is not already in use.

On boot up, most memory is available, and when the application is loaded, the Memory Manager marks the area occupied by the program as in use. The Memory Manager then creates two data structures to keep track of that memory. The first is an identification number, called the *User ID*. This ID number is associated with a particular application, and can then be associated with any additional blocks of memory allocated to that program. Then, when the program quits, all associated—but perhaps physically separate—blocks of memory for that application can be de-allocated and returned to the pool of available memory. The second data structure is called a *handle*, and is a pointer to the memory block while it's in use.

The ID number of a block of memory is made up of several components, or fields. These are called the *Main*, *Aux*, and *Type* fields, and are assigned to specific bit positions in the ID number (a two-byte value):

<table>
<tr><td>F</td><td>E</td><td>D</td><td>C</td><td>B</td><td>A</td><td>9</td><td>8</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td></tr>
<tr><td colspan="4"><b>Type
Field</b>
$0–$F</td><td colspan="4"><b>Aux ID
Field</b>
$0–$F</td><td colspan="8"><b>Main
ID Field</b>
$00–$FF</td></tr>
</table>

The Main ID field is assigned by the ID Manager, and ranges from $00 to $FF for each particular Type. The value $00 is reserved for the system, and so Main ID values in this field start with $01.

The Type field is an indicator of whom the ID value belongs to. The possible values, in the range of $0 to $F have been assigned as shown in Table 17-1.

Table 17-1. Type Field Indicator

0	Memory Manager use (for example, in allocating RAM disk space)
1	Application
2	Control Program
3	ProDOS
4	Tool Sets
5	Desk Accessories
6	Runtime Libraries
7	System Loader
8	Firmware
9	Tool Locator
A	Setup File
B	Undefined
C	Undefined
D	Undefined
E	Undefined
F	Undefined

For example, the first ProDOS 16 application to own memory in the system might have an ID of $1001 (application, first ID).

When ProDOS 8 is run from ProDOS 16, much of the memory in banks 0 and 1 will have already been assigned, and the ProDOS 8 program will be considered part of that memory allocation. A ProDOS 8 System file (or even an Applesoft BASIC routine requesting memory), would probably get the ID value $3001 (ProDOS, first ID).

Note that by the time your application gets control when it starts up, in either ProDOS 8 or ProDOS 16, this ID value has already been assigned to the memory your program occupies. For ProDOS 16, this will be just the memory occupied by your program, plus an additional $400 bytes given as a default direct page and stack to every ProDOS 16 program, unless otherwise directed during the assembly of the program.

For ProDOS 8, this memory is just generally assigned to the entire range of $800 to $BFFF in banks 0 and 1, and the shadowed graphics display areas in banks $E0 and $E1: $E0/2000 to $E0/5FFF for hi-res, and $E1/2000 to $E1/9FFF for double and super hi-res displays. (Yes, as a matter of fact, they did provide the option of an Applesoft BASIC or ProDOS 8 system file accessing the bank 1 super hi-res area and then shadowing this to bank $E1 to make the display visible. Try a POKE 49193,161 in Applesoft BASIC to enable the super hi-res display. You'll have to carefully type POKE 49193,33 to restore things, since you won't be able to see what you're typing.)

The $00 to $7FF and $C000 to $FFFF parts of banks 0 and 1 are marked as permanently "in use" by the memory manager, regardless of whether you're using ProDOS 8 or ProDOS 16, and need no special attention from your application.

Loading ProDOS 8 Directly

It is possible, but not advisable, to boot directly into ProDOS 8 on the Apple IIGS, as was described in Chapter 13. There are two big drawbacks to this approach. The first, and most important, is that none of the RAM patches to the built-in tool sets are loaded and activated, since the Tool.Setup file is not used in a simple ProDOS 8 boot. This means that virtually every ROM-based tool in the system is operating with known bugs, and is likely to perform less than perfectly. The whole purpose of the Tool.Setup file under ProDOS 16 is to make sure that every running Apple IIGS machine is functionally equivalent, regardless of its manufacture date, when started up with the current tool sets and setup files. If you're not using any of the Apple IIGS tools, you can boot directly into ProDOS 8. However, if you intend to use any of the routines in these chapters discussing the tools, you should always boot into ProDOS 16 first, even if you intend to ultimately end up in ProDOS 8.

The second disadvantage of booting directly into ProDOS 8 is that the Memory Manager only marks minimal areas of memory, including the ramdisk allocation, $00/0000 to $00/7FF, $00/C000 to $00/FFFF, and $01/C000 to $01/FFFF as in use (along with a very few others); thus, you must allocate your own memory in banks 0 and 1 if you want to call the Memory Manager. As a matter of interest, in such cases you can first call the Miscellaneous Tools *GetNewID* to get an ID for your itself, then use *NewHandle* ($0902) to allocate the memory your program occupies at that moment, and then finally call *MMStartUp* ($0202) to get things going (MMStartUp will give you your same User ID back). This is really not the recommended approach, though, and it does nothing to alleviate the tool bug problem.

The real moral is, if you're going to use the tools, boot ProDOS 16 first.

Auxiliary IDs

While an application is running, it may request additional memory blocks. These are usually associated with the Main ID of the application itself, and the application may then assign *auxiliary IDs* to these blocks. This is the purpose of the Aux ID field in the ID value. This field is controlled entirely by the application and is used to further classify blocks of memory.

For example, suppose an application loads two documents, each with a text and a graphics portion, for a total of four distinct blocks of memory. Let's suppose the application's Main ID, issued to it by the System Loader when it was started up, is $1001. The application itself may then generate two new sub-IDs as follows:

```
LDA  ID          ; $1001
ORA  #$0100      ; $1101
STA  SID1        ; SAVE SUB-ID #1
LDA  ID          ; $1001
ORA  #$0200      ; $1201
STA  SID2        ; SAVE SUB-ID #2
```

The application can then assign sub-ID #1 to the two blocks of memory for the first document, and the second sub-ID to the memory used by the second document.

The advantage is that the application may then later selectively de-allocate all the memory (which for some applications may be dozens of memory blocks per document) in one tool call, using the sub-ID (for example, SID2 = $1201) for the particular document. The alternative would be to create a loop to run through each data block and de-allocate it individually. The sub-ID method provides a much more efficient approach.

These sub-IDs should be used for *any* additional memory your program requires for its own use, such as additional direct-page areas or data blocks.

It's also possible, although rare, to spinoff completely separate programs from the one currently loaded. For example, suppose you had an application that wanted to install a classic desk accessory. You would want the accessory's memory to remain marked as in use even after your start up application had departed the scene.

New IDs may be obtained from within an application using the Miscellaneous tool set, specifically with the call *GetNewID* (call number = $2003). This new ID is a completely new entity and would only be required if you wanted to allocate memory for some routine or data structure that was to remain in memory after your program quit and had its own memory de-allocated by the System Loader. In the normal course of events, you should never have to call GetNewID. The Miscellaneous tool set, as its name implies, is a collection of miscellaneous tool commands that can be useful during program execution. These include not only the GetNewID routine, but also routines to read the mouse, determine the system time and others. The Miscellaneous tool set is described in greater detail below.

Handles

If a given ID number is not unique for a given memory block, that is, the same ID number may be assigned to several blocks of memory, how does the Memory Manager identify a single block? It identifies it with the second data structure created when memory is allocated, called a *handle*. A handle contains a pointer to the location of the block of memory, its size (length), and the ID number of the application to which that block of memory is assigned (the User ID), and some additional information. To reference a block of memory, most Apple IIGS tool calls use the address of the handle to a memory block, *not* the address of the block itself.

This is because the Memory Manager, from time to time, moves blocks of memory, providing they are designated as movable, from their current location to a new one. This is usually done to try to make room for another memory request, either from an application or the System Loader trying to load a new application, but it could be related to any system function that requires more memory, including desk accessories.

For this reason, the Memory Manager and most other Apple IIGS tools deal with handles as the indicator and descriptor of a particular block of memory. You can also think of a handle as a pointer to a pointer. The handles themselves are allocated in bank $E1, and are guaranteed not to move. Thus, whenever you want to access your block of memory, you give the handle address, and the system then looks there to determine where your block of memory is being kept at the moment.

Not all memory in the Apple IIGS is managed in the same way by the Memory Manager. The Memory in the Apple IIGS falls into three categories:

Normal Memory. Memory managed by the Memory Manager, this includes banks $02 through $DF and a little of banks $E0 and $E1, specifically $E0/6000 to $E0/BFFF and $E1/A000 to $E1/BFFF.

Special Memory. This is memory managed by the Memory Manager, but it has restrictions on it because it is used by programs designed for the Apple IIe and IIc. By keeping this memory restricted, the memory is more likely to be usable if the user wants to start up a ProDOS 8 or other 64K or 128K Apple II–type application. Special memory includes $00/800 to $00/BFFF, $01/800 to $01/BFFF, $E0/2000 to $E0/5FFF (the shadowed hi-res pages), and $E1/2000 to $E1/9FFF (the shadowed double and super hi-res display pages).

Unmanaged Memory. The remaining memory, the area from $00 to $800 and $C000 to $FFFF (including the 4K expansion RAM area) in banks $00, $01, $E0 and $E1, and the $800 to $1FFF areas in banks $E0 and $E1, are called *reserved memory* and are not controlled by the Memory Manager. This area is always marked as in use by the Memory Manager.

Requesting Memory

Ordinarily when requesting memory, the Memory Manager will allocate a block in nonspecial, or normal, memory. If, however, you have a specific reason for using special memory, for example using the super hi-res page directly in bank $E1, then you can include that as part of your request to the Memory Manager.

When requesting memory, there are a number of variable *attributes* that you can require of the memory block. These are controlled by a 2-byte attribute word, where certain bits are used to flag a given attribute. These are shown in Table 17-2.

Table 17-2. Variable Attributes

Bit		
0	Fixed Bank	1 = Block must be in a particular bank.
1	Fixed Address	1 = Block must start at a specific address.
2	Page Aligned	1 = Block must start at a page boundary ($100, $200, $300, and so on).
3	Special Memory	1 = Block may NOT use special memory areas
4	Bank Boundary	1 = Block cannot extend across a bank boundary (for example, from $02/F000 to $03/0100).
5–7	Unused	
8, 9	Purge Level	(0–3) = Priority level for de-allocation (purging).
10–13	Unused	
14	Fixed Address	1 = Block cannot be moved in memory.
15	Locked	1 = Block is temporarily unmovable and unpurgeable.

When the System Loader loads your program, its memory is allocated as not page aligned; it cannot cross bank boundaries (or your LDA/STAs wouldn't work); it cannot be in special memory, and it must be unmovable, locked, and with a purge level of 0 (cannot be de-allocated). A typical attribute byte for a ProDOS 16 application would be $C018 (%1100 0000 0001 1000). This is assigned automatically, more or less, but it is possible to change these attributes during the assembly and linking of an application. Ordinarily, you will not have to be concerned with controlling the attribute bytes for your application.

You'll have to specify the attribute byte for any memory your application requests from the Memory Manager. For most instances, an attribute byte of

$0014 (bank boundary limited, page aligned) or $0000 (no special requirements) is adequate.

When a ProDOS 16 application is started up by the System Loader, it is given two blocks of memory. The first block is for the program itself, the second is a $400-byte block used for that application's private stack ($300 bytes) and direct-page areas ($100 bytes) . However, many of the Apple IIGS tools, QuickDraw, for example, require that you obtain more bank 0 direct-page space for their operation. This is obtained through the memory manager, and the address of that block (not its handle) is passed to the tool when starting it up.

In those cases, you will need a fixed and locked block specifically in bank 0. The attribute byte for this type of memory is $C001. You need not memorize these values, as they will be included in the examples that follow, and you can refer to this chapter or the sample listings in the future as you need them.

Memory Allocation and Movement

When the Memory Manager allocates a block of memory, it first tries to obtain the block in available memory. If it can't locate enough memory, it first *compacts* memory. Compacting is done by trying to move all the in-use blocks into one area, to free larger sections of available memory. Movable memory is moved to the top of memory, making available areas of free memory at the bottom. Any block that is immovable remains where it stands.

The only problem is that some blocks, such as applications themselves, have already been designated as immovable, and they may reside in the middle of memory forming barriers to relocation of other blocks. In this case, the Memory Manager tries to relocate movable blocks as high in memory as possible without going past a fixed block that it may encounter. The Memory Manager will never relocate a movable block past a fixed block.

After compacting, if enough memory to satisfy the request is still not available, the Memory Manager will try to purge any blocks marked as purgeable. A priority level of 0 to 3 has been established.

3 Most purgeable (assigned by System Loader)
2 Next-most purgeable
1 Least purgeable
0 Not purgeable

When purging, the Memory Manager looks for level 3 blocks to purge first. If this is not sufficient, it starts purging blocks at level 2, and so on. Blocks at level 0 are most likely the application itself, or other important data blocks, and so are not purged. If sufficient memory cannot be found, the Memory Manager will return an insufficient memory error.

The reason for purge levels is to allow the application to set aside memory on a priority basis. For example, suppose your program has a help list that it can load from disk. Each time the user asks for help, the program has to reload the file from disk. You could get some memory from the Memory Manager and store your help list in memory, but what happens when the user's document becomes very large? It would be a shame to limit the usefulness of the program because of memory used for the help list.

The answer is to load the help list when memory is available, but to mark it as purgeable. Then, if the application's document starts growing large, the Memory Manager will automatically dispose of the help list to make room for the document. Obviously, in such schemes you've got to check to see if your data block is still in the computer whenever you want to print the help list. This is fairly simple though. Whenever the Memory Manager purges a data block, it sets the pointer within the handle to zero, but it doesn't delete the handle itself. Thus, the handle can be checked prior to use to make sure the data is still there.

Normally, this is done by *dereferencing* the handle. Dereferencing is the process of looking into the handle to see what actual memory address it points to. The actual technique of dereferencing will be described in a later demonstration program.

It is also possible to check for a *nil* (equal to zero) handle by calling *RestoreHandle* ($0B02) each time you want to access a possibly purged handle. RestoreHandle tries to re-allocate a purged block to its original size (although the data contents have presumably already been lost). For our purposes, it returns an error if the data block still contains information (the block was not really purged before), or if there is insufficient memory to re-allocate the block. You can use this call to check to see if a handle has already been purged. If the error *NotEmptyErr* ($0203) is returned, you know the data is still there. On the other hand, if you get a *MemoryErr* ($0201) or no error at all, then you know your data is long gone.

To summarize the data structures then, each block of memory has a handle and a UserID associated with it. The UserID is specific to an application, and is obtained from MMStartUp when the application starts. The application may use the Aux ID field to create sub-IDs for any additional memory it requires. Purging memory releases the memory, but does not remove the handle with the UserID embedded in it from the Memory Manager's list. Disposing of a handle both de-allocates the memory block *and* removes the handle with the UserID from the handle list of the Memory Manager. The UserID is at that point still active in the ID list (a separate function from memory handles).

When a program quits, it should first call *DisposeAll* to de-allocate any additional memory it has obtained, and then call *MMShutDown* to tell the memory manager it is finished with its memory related operations. During the ProDOS quit, the system will then de-allocate the memory for the application itself and remove the application's UserID (and any sub-IDs) from the ID list.

DeleteID, a Miscellaneous tool set call, is only required if the application has established other IDs (not sub-IDs) using GetNewID, which are separate from the main ID given the application when it first started up.

The Memory Manager Tools

The Memory Manager tool set contains a wide variety of routines for allocating, moving, and de-allocating memory, as well as routines for setting the purge levels and other attributes. Table 17-3 lists some of the routines (tool commands) available in the Memory Manager. Other commands may be added by Apple Computer at any time.

Table 17-3. Memory Manager Tools

Command Value	Command Name	Description
$0102	MMBootInit	Initialized by system on boot. Not used by application.
$0102	MMStartUp	Starts up Memory Manager.
$0302	MMShutDown	Tells Memory Manager you're finished.
$0402	MMVersion	Returns version number of the Memory Manager.
$0502	MMReset	Reinitializes MM on reset. Should not be called by an application.
$0602	MMStatus	Indicates whether MM is active.
$0902	NewHandle	Creates a new block of memory and returns handle.
$0A02	ReAllocHandle	Re-allocates a block that was purged.
$0B02	RestoreHandle	Re-allocates a handle that was purged.
$1002	DisposeHandle	Disposes of a specified memory block and its handle.
$1102	DisposeAll	Disposes of all memory and handles belonging to a specified UserID. The ID, however, remains active.
$1202	PurgeHandle	Purges a specified block.
$1302	PurgeAll	Purges all blocks for a specified ID.

$1802	GetHandleSize	Returns the size of a specified block.
$1902	SetHandleSize	Changes the size of a specified block.
$1A02	FindHandle	Returns the handle of the block containing the specified memory address.
$1B02	FreeMem	Returns the total number of free bytes of memory.
$1C02	MaxBlock	Returns size of largest free block in memory.
$1D02	TotalMem	Returns total memory size of system.
$1E02	CheckHandle	Checks to see if a given handle exists in the handle list.
$1F02	CompactMem	Forces memory compaction.
$2002	HLock	Locks a handle (cannot be purged or moved).
$2102	HLockAll	Locks all handles for a given ID.
$2202	HUnLock	Unlocks a given handle.
$2302	HUnLockAll	Unlocks all handles for a given ID.
$2402	SetPurge	Sets purge level for a block.
$2502	SetPurgeAll	Sets purge level for all blocks for a given ID.
$2B02	BlockMove	Copies a range of memory from one address to another.
$2802	PtrToHand	Copies a range of memory from one address to a block specified with a handle.
$2902	HandToPtr	Copies a range of memory from a block specified with a handle to a given address.
$2A02	HandToHand	Copies a range of memory from a block specified with a handle to a block specified with another handle.

Table 17-4 lists some of the possible errors which may be encountered from Memory Manager routines.

Table 17-4. Memory Manager Errors

$0201	MemoryErr	Unable to allocate block.
$0202	EmptyErr	Illegal operation on empty handle.
$0203	NotEmptyErr	Empty handle expected for that operation.
$0204	LockErr	Illegal operation on a locked or immovable block.
$0205	PurgeErr	Attempt to purge an unpurgeable block.
$0206	HandleErr	Invalid handle given.

Using the Memory Manager

Program 17-1 is a ProDOS 8 application that will load a number of hi-res pictures from disk, store each away in memory using the Memory Manager, and then successively move them back onto the hi-res screen to create a fast-action slide show.

Any regular hi-res pictures will work with this program; the only requirement is that they be named PICTURE.A, PICTURE.B, PICTURE.C, and so forth on the same disk as this sample program. If you don't have any hi-res pictures, Program 17-2 is an Applesoft BASIC program that will create 18 hi-res pictures in something just vaguely like animation. You may want to configure your Apple IIGS RAM disk to 800K to hold all the pictures, or you can use a formatted, but otherwise blank, 3½-inch disk to hold the pictures and the slide show object file.

Without going into great detail, suffice it to say that the Applesoft BASIC program simulates the dropping of a box, which then bounces off to the right of the screen. Unfortunately, because of the size of disk space, the program is limited to about 20 frames. The result is a very spotty animation. Most importantly, the assembly language program demonstrates just how quickly the Memory Manager can move large blocks of memory. If you've got the disk space and the inclination, you can change the 20 in line 105 to a larger number and the value of ACC on line 35 to 3.

This is the longest source listing presented so far in this book. It is true that assembly language programs of any consequence tend to be very long in terms of lines of code. Even a simple program on the Apple IIGS that uses the various tools can easily run from 1000 to 4000 lines of source code. Fortunately, each line is only a few characters for each instruction, and the typing goes quickly. As with previous listings, a checksum is included at the end of the listing to help you be sure the lines have been entered correctly.

You'll notice that the program is similar to, and in fact a derivative of, the P8 File Dump Sample program in Chapter 13. You may find it easier to start with that listing and to use the existing parameter blocks at the end and error message routines within it as a starting point for this program.

Because many of the ProDOS file-handling principles have been discussed in earlier chapters, we'll concentrate the discussion on just those parts of the program that deal with the Memory Manager, or that are otherwise unusual.

Program 17-1. Memory Manager Demo: Slide Show

```
                       *********************************************
                       * MEMORY MANAGER DEMO PROGRAM  *
                       *           PRODOS 8 SYSTEM FILE           *
                       *           MERLIN ASSEMBLER               *
                       *********************************************

                                      ORG    $2000

                      * DSK MM.DEMO.P8
                                      TYP    $FF              ; SYSTEM FILE TYPE

         =BF00         MLI            EQU    $BF00            ; STD. PRODOS 8 ENTRY
         =FDED         COUT           EQU    $FDED
         =FC58         HOME           EQU    $FC58
         =FD0C         RDKEY          EQU    $FD0C            ; MONITOR READ KEY ROUTINE
         =FDDA         PRBYTE         EQU    $FDDA            ; PRINT ACC. AS HEX NUMBER
         =F3D8         HGR2           EQU    $F3D8            ; Applesoft BASIC 'HGR2' ROUTINE
         =F399         SETTXT         EQU    $F399            ; Applesoft BASIC 'TEXT' ROUTINE
         =C000         KYBD           EQU    $C000
         =C010         STROBE         EQU    $C010

         =4000         SCREEN         EQU    $4000            ; HI-RES PAGE TWO MEMORY
         =0006         HNDPTR         EQU    $06              ; $06,07


                       *********************************************
                       * SETUP STARTING CONDITIONS
                       *********************************************

002000: 20 D8 F3       START          JSR    HGR2             ; DO EQUIV. OF HGR2

002003: A9 4C          SETRES         LDA    #$4C             ; JMP INSTRUCTION
002005: 8D F8 03                      STA    $3F8             ; CTRLY VECTOR
002008: A9 91                         LDA    #<RESUME         ; LOW BYTE OF SHUTDOWN ADDR.
00200A: 8D F9 03                      STA    $3F9             ; LOW BYTE OF CTRL-Y VECTOR
00200D: A9 21                         LDA    #>RESUME
00200F: 8D FA 03                      STA    $3FA             ; HIGH BYTE OF CTRL-Y VECTOR

002012: 18             SETUP          CLC
002013: FB                            XCE
```

```
002014: C2 30                       REP   $30            ; SET FULL 16-BIT MODE

                         TLSTART    ToolCall $0201       ; TLStartUp

                         MMSTART    ToolCall $0202       ; MMStartUp

00202C: 68                          PLA                  ; GET OUR ID
00202D: 8D 58 22                    STA   ID             ; KEEP IT ON HAND

002030: 09 00 01         MAKEID     ORA   #$0100         ; SET AUX ID = 1
002033: 8D 5A 22                    STA   ID2            ; SAVE SUB-ID

002036: A9 DC 21         INIT       LDA   #HNDL1         ; ADDRESS OF 1ST PICTURE HANDLE
002039: 85 06                       STA   HNDPTR         ; POINTER TO IT.

                                                         ; FREE 16-BIT OPERATIONS

00203B: 38                          SEC
00203C: FB                          XCE                  ; BACK TO 8 BITS . . .

                          ***********************************************
                         * OPEN THE FILE
                          ***********************************************

00203D: 20 00 BF         OPEN       JSR   MLI
002040: C8                          DFB   $C8            ; OPEN COMMAND
002041: 9F 21                       DA    OPENTBL        ; OPEN CMD TABLE
002043: 90 11   =2056               BCC   OPEN2          ; NO ERROR

002045: C9 46                       CMP   #$46           ; FILE NOT FOUND ERR
002047: D0 0A   =2053               BNE   :1
002049: AE DB 21                    LDX   NAMEEND-1      ; FILE COUNTER BYTE
00204C: E0 C1                       CPX   #"A"           ; 1ST FILE?
00204E: F0 03   =2053               BEQ   :1             ; YEP
002050: 4C DD 20                    JMP   SHOW           ; NOPE, WE GOT AT LEAST ONE!

002053: 4C 66 21         :1         JMP   ERROR          ; PRODOS ERROR

002056: AD A4 21         OPEN2      LDA   REFNUM         ; GET REFERENCE NUMBER
002059: 8D A6 21                    STA   REFNUM1        ; STORE REF NUMBER

                          ***********************************************************
                         * READ $2000 BYTES OF DATA FROM THE FILE
                          ***********************************************************

00205C: A9 04            READ       LDA   #$04           ; # OF PARMS FOR 'READ'
00205E: 8D A5 21                    STA   READTBL        ; MODIFY TABLE ENTRY
002061: 20 00 BF                    JSR   MLI
002064: CA                          DFB   $CA            ; READ COMMAND
002065: A5 21                       DA    READTBL        ; READ CMD TABLE
002067: 90 03   =206C               BCC   CLOSE          ; NO ERRORS . . .
```

```
002069: 4C 66 21                     JMP   ERROR          ; PRODOS ERROR MSSG

                        ************************************************
                        * CLOSE THE FILE
                        ************************************************

00206C: A9 01           CLOSE        LDA   #$01           ; REWRITE READTBL
00206E: 8D A5 21                     STA   READTBL        ; # OF PARMS = 1
002071: 20 00 BF                     JSR   MLI
002074: CC                           DFB   $CC            ; CLOSE COMMAND
002075: A5 21                        DA    READTBL        ; SAME TABLE AS 'READ'
002077: 90 03  =207C                 BCC   :1             ; NO ERROR
002079: 4C 66 21                     JMP   ERROR          ; PRODOS ERROR
                        :1                                ; PROGRAM CONTINUES HERE...

                        ******************************************************************
                        * REQUEST A MEMORY BLOCK TO STORE PICTURE
                        ******************************************************************

00207C: 18                           CLC
00207D: FB                           XCE
00207E: C2 30                        REP   $30            ; FULL 16-BIT MODE

                        GETHNDL      PushLong #$0000      ; PUSH ROOM FOR RESULT
                                     PushLong #$2000      ; SIZE OF BLOCK NEEDED
                                     PushWord ID2         ; GET DATA ID AND PUSH IT
                                     PushWord #$0000      ; ATTRIBUTE BYTE
                                                          ; UNLOCKED, NOT PURGEABLE
                                     PushLong #$0000      ; ADDRESS (NONE NEEDED)

                                     ToolCall $0902       ; NewHandle
                                                          ; GET BLOCK OF MEMORY

0020A4: 68              :1           PLA                  ; GET LOW WORD OF HANDLE
0020A5: 92 06                        STA   (HNDPTR)       ; STORE IN LOW WORD POSN
0020A7: A0 02 00                     LDY   #$02
0020AA: 68                           PLA                  ; GET HIGH WORD OF HANDLE
0020AB: 91 06                        STA   (HNDPTR),Y     ; STORE IN HIGH WORD POSN

                        ****************************************************
                        * MOVE FROM SCREEN TO GS MEMORY
                        ****************************************************

                        STORE        PushLong #SCREEN     ; SCREEN ADDRESS (DATA SOURCE)
0020B3: A0 02 00                     LDY   #$02
0020B6: B1 06                        LDA   (HNDPTR),Y     ; GET HIGH WORD OF HANDLE
0020B8: 48                           PHA                  ; PUSH ON STACK (DESTINATION)
0020B9: B2 06                        LDA   (HNDPTR)       ; GET LOW WORD OF HANDLE
0020BB: 48                           PHA
                                     PushLong #$2000      ; NUMBER OF BYTES TO BE COPIED

                                     ToolCall $2802       ; PtrToHand
```

```
                                                             ; PTRTO-HANDLE MOVE COMMAND

                        ****************************************************************
                        * ADVANCE HANDLE STORAGE TO NEXT GROUP
                        ****************************************************************

0020CD: 18              NXTHNDL     CLC
0020CE: A5  06                      LDA   HNDPTR
0020D0: 69  04  00                  ADC   #$04            ; ADVANCE 4 BYTES
0020D3: 85  06                      STA   HNDPTR

                        ****************************************************************
                        * INCREMENT SUFFIX TO PICTURE NAME . . .
                        ****************************************************************

0020D5: 38              NXTFILE     SEC
0020D6: FB                          XCE                   ; BACK TO 8 BITS . . .

0020D7: EE  DB  21                  INC   NAMEEEND-1      ; INCREMENT FILE COUNTER
0020DA: 4C  3D  20                  JMP   OPEN            ; GET THE NEXT NAME

                        ****************************************************
                        * CYCLE THROUGH "SLIDE SHOW"
                        ****************************************************

0020DD: 18              SHOW        CLC
0020DE: FB                          XCE
0020DF: C2  30                      REP   $30             ; FULL 16-BIT MODE

0020E1: A9  DC  21      FIRST       LDA   #HNDL1          ; ADDRESS OF 1ST PICTURE HANDLE
0020E4: 85  06                      STA   HNDPTR          ; POINTER TO IT.

                        ****************************************************
                        * MOVE PICTURE DATA ONTO SCREEN
                        ****************************************************

0020E6: A0  02  00      XFER        LDY   #$02
0020E9: B1  06                      LDA   (HNDPTR),Y      ; HIGH WORD OF HANDLE
0020EB: 48                          PHA
0020EC: B2  06                      LDA   (HNDPTR)        ; LOW WORD OF HANDLE
0020EE: 48                          PHA
                                    PushLong #SCREEN      ; DESTINATION
                                    PushLong #$2000       ; NUMBER OF BYTES TO COPY

                                    ToolCall $2902        ; HandToPtr
                                                          ; HANDLE-TO-POINTER MOVE
                                                            COMMAND

002106: AD  00  C0      CHKKEY      LDA   KYBD
002109: 29  FF  00                  AND   #$00FF          ; CLEAR HIGH BYTE
00210C: C9  80  00                  CMP   #$0080
00210F: 90  06  =2117               BCC   NEXT            ; NO KEYPRESS
002111: 2C  10  C0                  BIT   STROBE          ; CLEAR KEYBOARD
```

```
002114: 4C 2D 21                 JMP   SHUTDOWN       ; KEYPRESS = TIME TO QUIT

                    **************************************************
                    * INCREMENT HNDPTR TO NEXT HANDLE
                    **************************************************

002117: 18          NEXT         CLC
002118: A5 06                    LDA   HNDPTR
00211A: 69 04 00                 ADC   #$04           ; ADVANCE 4 BYTES
00211D: 85 06                    STA   HNDPTR

00211F: B2 06                    LDA   (HNDPTR)       ; LOW WORD OF NEXT HANDLE
002121: D0 C3 =20E6              BNE   XFER           ; >$00 MEANS REAL DATA
002123: A0 02 00                 LDY   #$02
002126: B1 06                    LDA   (HNDPTR),Y     ; HIGH WORD OF NEXT HANDLE
002128: F0 B7 =20E1              BEQ   FIRST          ; $00 = END OF LIST = ANOTHER
                                                        ROUND
00212A: 4C E6 20                 JMP   XFER

                    *********************************************
                    * SHUTDOWN THINGS AND QUIT
                    *********************************************

                    SHUTDOWN     PushWord ID2         ; GET DATA (PICTURE) ID
                                 ToolCall $1102       ; DisposeAll
                                                      ; RELEASE ALL DATA BLOCKS

                    MMSHUT       PushWord ID          ; MAIN ID (APPLICATION)
                                 ToolCall $0302       ; MMShutDown
                                                      ; TELL MM WE'RE DONE

                    TLSHUT       ToolCall $0301       ; TLShutDown

002156: 38                       SEC
002157: FB                       XCE                  ; BACK TO 8 BITS . . .

002158: 20 99 F3                 JSR   SETTXT         ; BACK TO TEXT MODE
00215B: 20 58 FC                 JSR   HOME

00215E: 20 00 BF    QUIT         JSR   MLI            ; DO QUIT CALL
002161: 65                       DFB   $65            ; QUIT CALL COMMAND VALUE
002162: 98 21                    DA    QUITTBL        ; ADDRESS OF PARM TABLE
002164: 00 00                    BRK   $00            ; SHOULD NEVER GET HERE . . .

002166: 48          ERROR        PHA                  ; SAVE ERROR CODE
002167: 20 99 F3                 JSR   SETTXT         ; SET TEXT MODE
00216A: 20 58 FC                 JSR   HOME           ; CLEAR SCREEN

00216D: A0 00                    LDY   #$00           ; INIT Y-REG
00216F: B9 AD 21    :1           LDA   MSSG1,Y        ; GET CHAR TO PRINT
002172: F0 06 =217A              BEQ   PRCODE
002174: 20 ED FD                 JSR   COUT           ; PRINT IT
```

```
002177: C8                            INY                  ; NEXT CHAR
002178: D0  F5   =216F                BNE   :1             ; WRAPAROUND PROTECT

00217A: 68                 PRCODE     PLA                  ; RETRIEVE ERROR CODE
00217B: 20  DA  FD                    JSR   PRBYTE         ; PRINT IT
00217E: A0  00                        LDY   #$00           ; INIT Y-REG
002180: B9  BD  21         :1         LDA   MSSG1A,Y       ; GET CHAR TO PRINT
002183: F0  06   =218B                BEQ   ERDONE         ; END OF MSSG
002185: 20  ED  FD                    JSR   COUT           ; PRINT IT
002188: C8                            INY                  ; NEXT CHAR
002189: D0  F5   =2180                BNE   :1             ; WRAPAROUND PROTECT

00218B: 20  0C  FD         ERDONE     JSR   RDKEY          ; WAIT FOR KEYPRESS
00218E: 4C  5E  21                    JMP   QUIT           ; QUIT PROGRAM . . .

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

002191: 18                 RESUME     CLC
002192: FB                            XCE
002193: C2  30                        REP   $30            ; 16-BIT MODE . . .
002195: 4C  2D  21                    JMP   SHUTDOWN

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

002198: 04                 QUITTBL    DFB   4              ; NUMBER OF PARMS FOR QUIT
002199: 00                            DFB   $00            ; QUIT TYPE (0 = STD. QUIT)
00219A: 00  00                        DA    $0000          ; NOT NEEDED FOR STD. QUIT
00219C: 00                            DFB   $00            ; NOT USED AT PRESENT
00219D: 00  00                        DA    $0000          ; NOT USED AT PRESENT


00219F: 03                 OPENTBL    DFB   3              ; NUMBER OF PARMS FOR OPEN = 3
0021A0: D2  21             PNAME      DA    NAME           ; POINTER TO PATHNAME
0021A2: 00  23                        DA    DOSBUF         ; POINTER TO PRODOS BUFFER
0021A4: 00                 REFNUM     DFB   $00            ; PRODOS FILE REFERENCE NUMBER


0021A5: 00                 READTBL    DFB   $00            ; NUMBER OF PARMS FOR READ/CLOSE
0021A6: 00                 REFNUM1    DFB   $00            ; REFERENCE NUMBER (= REFNUM)
0021A7: 00  40                        DA    $4000          ; POINTER TO DATA BUFFER (HGR2)
0021A9: 00  20                        DA    $2000          ; READ ENTIRE SCREEN
0021AB: 00  00                        DA    $0000          ; NUMBER OF CHARACTERS READ.

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


0021AD: 8D                 MSSG1      HEX   8D             ; PRINT RETURN FIRST
0021AE: D0  D2  CF  C4                ASC   "PRODOS ERROR $",00
0021BD: 8D                 MSSG1A     HEX   8D             ; ANOTHER CARRIAGE RETURN
```

```
0021BE: D0  D2  C5  D3   301               ASC   "PRESS A KEY TO QUIT",00
                         302
                         303
0021D2: 09  D0  C9  C3   304  NAME         STR   "PICTURE.A"
                         305  NAMEEND                               ; ONE BYTE PAST END OF NAME
                         306
                         307  *********************************************
                         308
0021DC: 00  00  00  00   309  HNDL1        ADRL  $0000              ; 4-BYTE SPACE FOR A HANDLE
0021E0: 00  00  00  00   310               DS    120,0              ; ENOUGH ROOM FOR 29 MORE
                                                                      PICTURES
                         311                                        ; AUTO$0000 AT END OF ACTIVE LIST
                         312
002258: 00  00           313  ID           DA    $0000              ; OUR APPLICATION'S ID
00225A: 00  00           314  ID2          DA    $0000              ; ID'S FOR DATA (PICTURES)
                         315
                         316
                         317
00225C: CA               318  CHKSUM       CHK                      ; CHECKSUM FOR VERIFICATION
                         319
00225D: 00  00  00  00   320               DS    \                  ; SKIP TO NEXT PAGE BOUNDARY
                         321
                         322  DOSBUF                                ; 1024 BYTES FOR PRODOS BUFFER
                         323                                        ; NOT IN PROGRAM SO AS TO NOT
                         324                                        ; TAKE UP DISK SPACE . . .

--End Merlin-16 assembly, 768 bytes, errors: 0
```

Program 17-2. Animation Generator

```
0 REM ANIMATION GENERATOR
5 REM SIMULATES A BOUNCING BOX . . .
10 X = 20:Y = 20: REM STARTING POSITION
20 XV = 0: REM HORIZONTAL VELOCITY
30 YV = 0: REM VERTICAL VELOCITY
35 ACC = 5
40 W = 10: REM WIDTH OF BOX
50 H = 9: REM HEIGHT OF BOX
60 HGR : HCOLOR= 3: HPLOT 0,0
65 CALL 62454
70 POKE - 16302,0: REM FULL MODE
80 PRINT CHR$ (4);"PREFIX /RAM5"
100 REM DROP BOX
105 FOR T = 1 TO 20
110 HCOLOR= 3: HPLOT 0,0
115 CALL 62454: REM CLEAR TO COLOR
120 HCOLOR= 0: HPLOT 0,170 + H TO 279,170 + H
140 HCOLOR= 2: REM BLUE
150 FOR I = X TO X + W
```

```
155 HPLOT I,Y TO I,Y + H
160 NEXT I
170 X = X + XV:Y = Y + YV:YV = YV + ACC: IF INT (X / 2) < > X / 2 THEN X = X + 1:
    REM MAKE EVEN
180 IF Y > 170 THEN Y = 170:XV = ACC * 5:YV = YV - 3 * ACC:YV = YV * - 1
190 IF X + W > 279 THEN 999
200 REM SAVE IMAGE
210 PRINT CHR$ (4);"BSAVE PICTURE."; CHR$ (192 + T);",A$2000,L$1FF8"
215 NEXT T
999 GET A$: TEXT
```

A Closer Look at the Slide Show

The program begins with clearing the hi-res screen using an internal Applesoft routine, HGR = $F3D8, which is equivalent to the HGR command in BASIC. As with the ProDOS 8 file dump program, the program then sets up the Control-Y vector as a "back door" should the program unexpectedly crash at some point. The difference in this program is that, instead of pointing directly to a ProDOS quit routine, the Control-Y vector is now set up to point to a small routine called RESUME at the end of our listing. Because we'll need to shut down the tool sets our program has started up, and to de-allocate any memory that may have been allocated at that point, it will be necessary to make sure we're in the full native 16-bit mode of the 65816 before jumping to the tool shutdown routines in our program, and, ultimately, to the ProDOS quit command.

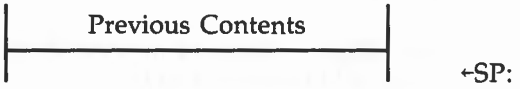
The RESUME routine, lines 268–271, simply sets the processor to the 16-bit native mode before jumping to SHUTDOWN, which we'll talk about shortly.

Lines 47–58 do something you'll be seeing a lot of in future Apple IIGS programs, namely starting up the GS tools needed for a particular application. In this case, they're the Tool Locator and the Memory Manager. When the Memory Manager is started up, it gives us the ID for our application; this is modified to create a sub-ID for our data blocks that will hold the loaded pictures. Since we're not creating a separate application, there is no need to startup the Miscellaneous Tools, nor to get a new ID from that tool set.

The call diagram for MMStartUp looks like this:

MMStartUp ($0202)

Stack Before Call:



Stack After Call:

Previous Contents	
UserID	Word: ID Memory Mgr. returns for application.
	←SP:

You should also notice that the parameter block for the READ command (lines 288–292) is different from the file dump command in that this time it reads the entire $2000 bytes directly into the hi-res page, without using any other buffer area. This makes for a very fast and efficient file load.

As each picture is loaded (lines 69–108), a 16K block of memory will be allocated, and a handle to that memory block will be returned by the Memory Manager (lines 119–133). These handles, which are the only true identifiers of each memory block, will be stored in a data table at the end of the program, starting at HNDL1 (line 309). To make the program flexible and able to accomodate a variable number of pictures, the data block within the program at HNDL1 is 124 bytes long—enough room for 30 pictures plus 4 zeros at the end to flag the end of the list. If fewer pictures are read in, a zero will still be found at the end of the list because we've used the *Merlin* DS 120,0 instruction, which fills the data block entirely with zeros. You can increase the 120 to a larger value if you wish to load more pictures.

To allocate each memory block, the program shifts to the 16-bit mode and uses the NewHandle call to request a memory block. Figure 17-1 is the call diagram for NewHandle.

Figure 17-1. NewHandle ($0902)

Stack Before Call:

Previous Contents	
Longspace	Long: Space for result.
Blocksize	Long: Size of block to create.
UserID	Word: ID of program using block.
MemAttributes	Word: Attribute mask byte.
MemLocation	Long: Bank and/or address of memory block if required by attribute byte.
	←SP: Stack pointer after setup.

Stack After Call:

Previous Contents	
The Handle	Long: Address of handle to new block.
	←SP: Stack pointer after return from routine.

When the handle is returned, its address is stored in the HNDL1 data table using the pointer HNDPTR, which was set up at the beginning of the program on lines 57,58. As each picture is loaded and a handle is assigned, HNDPTR will be incremented to the next storage position in the section NXTHNDL, lines 154–157.

Once the memory block to store the picture has been obtained, the picture data is moved to the allocated memory block by the PtrToHand tool call. This call uses a pointer to a memory location and transfers the specified number of bytes to a memory block specified by a handle. It's important to note that no particular check is done to make sure that the receiving block is large enough for the number of bytes you're writing to it, so you must make sure you've allocated a large enough block for the data. The call diagram for PtrToHand is shown in Figure 17-2.

Figure 17-2. PtrToHand ($2802)

Stack Before Call:

Previous Contents	
SourcePointer	Long: Pointer to beginning address of block.
DestHandle	Long: Address of handle to destination block.
Count	Long: Number of bytes to copy.
	←SP: Stack pointer after setup.

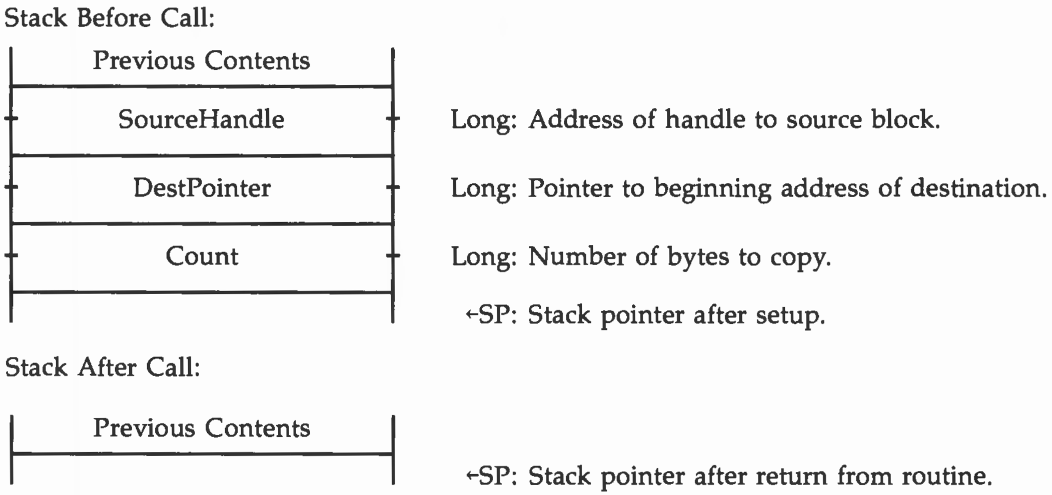
Stack After Call:

Previous Contents	
	←SP: Stack pointer after return from routine.

After incrementing the pointer to the handle storage list, NXTFILE (line 163) increments the suffix letter on the filename A to B, B to C, and so on, and loops back until a File Not Found error ($46) indicates there are no more pictures to be loaded.

Once all the pictures are loaded, the SHOW routine cycles through the handle list, transferring the data back from the memory block, indicated by each handle, to the screen. The tool call HandToPtr is used for that. The call diagram is similar to PtrToHand (Figure 17-3).

Figure 17-3. HandToPtr ($2902)



Stack Before Call:

Long: Address of handle to source block.

Long: Pointer to beginning address of destination.

Long: Number of bytes to copy.

←SP: Stack pointer after setup.

Stack After Call:

←SP: Stack pointer after return from routine.

Each time through the transfer loop, the list of handles is scanned until a handle address of $00/0000 is encountered (lines 206–216), at which point the cycle is repeated. When a keypress is detected, the program jumps to the SHUTDOWN routines.

Whenever a routine using the Apple IIGS tools quits, it should first de-allocate any additional memory it has obtained. Lines 222, 223 take care of this by passing the sub-ID to the command DisposeAll, which de-allocates all memory blocks associated with the sub-ID. You must be very sure not to do this call with your application's ID; otherwise you will have de-allocated yourself at that point, so will be vulnerable immediately to another application somewhere in the computer using your memory while you're trying to execute the last few instructions of your program.

Once the memory has been de-allocated, the Memory Manager and Tool Locators are also shut down, and the ProDOS quit command will return us to whatever program selector was used to launch our application.

Obviously, the Tool Locator and Memory Manager tools are used by the system itself, so cannot really be shut off. The real purpose of the startup and shutdown calls is to just tell these tools that you would like their assistance at the beginning of your program, and to then tell them that you're finished at the end. At the present, these calls for some tools may not do anything at all, but you should build them into all of your programs to provide for the possibility that at some point in the future the startup and shutdown calls for even apparently permanent tools like the Tool Locator may be required for proper system operation.

The Miscellaneous Tool Set

The Miscellaneous tool set is a collection of routines that do not fall into a major group the way the Memory Manager and other tools do. They also include some of the more fundamental tool functions that are called by the internal routines of the other tool sets to create the more complex functions.

For example, the Miscellaneous tool set includes the GetNewID function. Although your program will probably never need to use this, the function is used by the System Loader in assigning new UserIDs to applications as they are loaded. Other Miscellaneous tool set commands include reading the mouse. Again, these are rarely used by themself in an application, but a more sophisticated tool set, the Event Manager, uses the mouse routines to create the more generalized command, GetNextEvent, which includes not only mouse clicks, but keyboard activity as well.

Although we've listed most of the tool calls in the Tool Locator and Memory Manager tools, these lists can get quite large. For example, there are over 200 calls in the QuickDraw tool set alone. For this reason, the list below just describes some of the highlights of each tool set discussed.

It should also be mentioned again that it is impossible for this book to really give a thorough discussion of all the Apple IIGS tools. The intent now is to introduce you to the major concepts so that you have a foundation for the information presented in other books. For specific information on the the Apple IIGS tools, I recommend *Exploring the Apple IIGS* by Gary Little and *COMPUTE!'s Mastering the Apple IIGS Toolbox* by Morgan Davis and Dan Gookin.

Miscellaneous Tool Set Calls

Command Value	Command Name	Description
$0102	MTStartUp	Starts up Miscellaneous tool set.
$0302	MTShutDown	Tells Miscellaneous tool set you're finished.
$0D03	ReadTimeHex	Returns date and time in number value format, including the day of the week (0–6).
$0F03	ReadTimeASCII	Returns data and time as a string of characters.
$1703	ReadMouse	Returns position and status of mouse.
$1803	InitMouse	Initializes mouse.
$1C03	ClampMouse	Sets clamp values for mouse.

$2003	GetNewID	Create new UserID.
$2103	DeleteID	Delete specified ID from ID list. Doesn't deallocate any memory.
$2503	GetTick	Returns number of ticks (1/60 of a second) since computer was started up.
$2603	PackBytes	Compresses a block of data into a smaller space by encoding it.
$2703	UnPackBytes	Unpacks encoded data back into its original form.

The most likely Miscellaneous tool error is in connection with GetNewID. It is $030B for IDNotAvailable, which is returned when there are already 255 UserIDs assigned to a given Type, and an additional ID tag is not available.

Program 17-3 shows how the Miscellaneous tool set clock-reading routines might be used from an Applesoft BASIC program to return both the time and the day of the week.

This program uses the string-variable passing techniques presented in Chapter 12. The new additions, of course, are the routines to read the built-in Apple IIGS clock. Two calls are needed because ReadTimeHex returns the day of the week, but not the time as a string. ReadTimeASCII, on the other hand, returns the time as a string, but does not include the day of the week. Figure 17-4 and 17-5 show call diagrams for these two commands.

This routine can be tested with Program 17-4.

Figure 17-4. ReadTimeHex ($0D03)

Stack Before Call:

Previous Contents	
Space for Result	Word: Allow space for result.
Space for Result	Word: Allow space for result.
Space for Result	Word: Allow space for result.
Space for Result	Word: Allow space for result.
	←SP: Stack pointer after setup.

Stack After Call:

Previous Contents			
WeekDay	Null	Byte: 1–7	Byte: Null
Month	Day	Byte: 0–11	Byte: 0–30
Year	Hour	Byte: 0–99	Byte: 0–23
Minute	Second	Byte: 9–59	Byte: 0–59
		SP: Stack pointer after return from routine.	

Figure 17-5. ReadTimeASCII ($0F03)

Stack Before Call:

Previous Contents	
BufferAddress	Long: Address of where to write time string.
	←SP: Stack pointer after setup.

Stack After Call:

Previous Contents	
	←SP: Stack pointer after return from routine.

Program 17-3. Clock Reading

```
                ************************************************
                *                                              *
                * IIGS TIME ROUTINE                            *
                * SYNTAX: CALL 768,A$ [,D]                     *
                * WHERE A$ IS RETURNED WITH                    *
                * TIME STRING, AND OPTIONAL D                  *
                * RETURNS DAY OF WEEK (0-6),                   *
                * WHERE 0 = SUNDAY.                            *
                *                                              *
                *          MERLIN 16 ASSEMBLER                 *
                *                                              *
                ************************************************

=0083           VARPNT    EQU   $83          ; $83,84
=0085           FORPNT    EQU   $85          ; $85,86
=0200           BUFF      EQU   $200         ; INPUT BUFFER

=00B7           CHRGOT    EQU   $B7
=DA9A           SAVD      EQU   $DA9A
```

```
           =DD6C       CHKSTR   EQU  $DD6C
           =DEBE       CHKCOM   EQU  $DEBE
           =DFE3       PTRGET   EQU  $DFE3
           =E3E9       MAKSTR   EQU  $E3E9

           =DD6A       CHKNUM   EQU  $DD6A
           =EB9D       GIVAYF2  EQU  $EB9D
           =EBF2       QINT     EQU  $EBF2
           =0011       VARTYPE  EQU  $11        ; STR$=$FF, NUM=$00
           =0012       NUMTYPE  EQU  $12        ; INT =$80, REAL = $00
           =DA63       LET2     EQU  $DA63
           =DA6B       LET3     EQU  $DA6B
           =009D       FAC      EQU  $9D
           =0006       DAY      EQU  $06        ; $3C,3D


008000: 20 B7 00       BEGIN    JSR  CHRGOT     ; CHECK CHAR AT TXTPTR
008003: C9 2C                   CMP  #','       ; COMMA?
008005: D0 03 =800A             BNE  :1         ; NOPE
008007: 20 BE DE                JSR  CHKCOM     ; GOBBLE COMMA IF NEEDED

00800A: 20 E3 DF       :1       JSR  PTRGET     ; LOCATE VARIABLE
00800D: 20 6C DD                JSR  CHKSTR     ; MAKE SURE IT'S A STRING
008010: 85 85                   STA  FORPNT     ; SAVE LOC. OF DATA
008012: 84 86                   STY  FORPNT+1

008014: 18                      CLC
008015: FB                      XCE
008016: C2 30                   REP  $30        ; FULL 16-BIT MODE

008018: A2 02 03       MTSTART  LDX  #$0203     ; MISC. TOOLS STARTUP
00801B: 22 00 00 E1             JSL  $E10000    ; NO ERROR LIKELY

00801F: F4 00 00       WEEK     PEA  $0000
008022: F4 00 00                PEA  $0000
008025: F4 00 00                PEA  $0000
008028: F4 00 00                PEA  $0000      ; MAKE ROOM FOR 8 BYTES TO RETURN

00802B: A2 03 0D                LDX  #$0D03     ; ReadTimeHex
00802E: 22 00 00 E1             JSL  $E10000    ; READ NUMBER VALUES FOR TIME
008032: 68                      PLA             ; GET MIN, SEC & DISCARD
008033: 68                      PLA             ; GET YR, HRS, AND SO ON
008034: 68                      PLA             ; GET MONTH, DAY
008035: 68                      PLA             ; GET DAY OF WEEK (HI BYTE)
008036: 85 06                   STA  DAY        ; 2 BYTES FOR LATER USE.

008038: F4 00 00       TIME     PEA  ^BUFF      ; POINTER TO BUFFER
00803B: F4 00 02                PEA  BUFF
00803E: A2 03 0F                LDX  #$F03      ; ReadTimeASCII
008041: 22 00 00 E1             JSL  $E10000    ; WRITE STRING TO MEMORY

008045: A2 02 03       MTSHUT   LDX  #$0303     ; MISC. TOOLS SHUTDOWN
```

```
008048: 22 00 00 E1                  JSL   $E10000    ; NO ERROR LIKELY

00804C: 38                           SEC
00804D: FB                           XCE              ; BACK TO 8 BITS

00804E: A2 13                        LDX   #19        ; LEN OF TIME STRING
008050: BD 00 02         TLOOP       LDA   BUFF,X     ; GET A CHARACTER
008053: 29 7F                        AND   #$7F       ; FIX HI BIT
008055: 9D 00 02                     STA   BUFF,X     ; PUT IT BACK
008058: CA                           DEX
008059: 10 F5    =8050               BPL   TLOOP      ; TILL WE'RE DONE

00805B: A9 00                        LDA   #<BUFF     ; LOCATION OF STRING DATA
00805D: A0 02                        LDY   #>BUFF
00805F: A2 FF                        LDX   #$FF       ; TERMINATOR CHARACTER
008061: 8E 14 02                     STX   BUFF+20    ; PUT AT END OF STRING

008064: 20 E9 E3                     JSR   MAKSTR
008067: 20 9A DA                     JSR   SAVD       ; STRING CREATED AND SENT

                         *===============================
00806A: 20 B7 00         CHECK       JSR   CHRGOT     ; CHECK NEXT CHARACTER
00806D: D0 01    =8070               BNE   DAYWEEK    ; END OF-LINE OR COLON
00806F: 60                           RTS

008070: 20 BE DE         DAYWEEK     JSR   CHKCOM     ; GOBBLE NEXT COMMA
008073: 20 E3 DF                     JSR   PTRGET     ; LOCATE VARIABLE
008076: 20 6A DD                     JSR   CHKNUM     ; VAR = NUM?
008079: 85 85                        STA   FORPNT     ; FOR USE BY LET2/LET3
00807B: 84 86                        STY   FORPNT+1   ; AS ADDR OF VARIABLE DATA

00807D: A4 07                        LDY   DAY+1      ; LO BYTE OF RETURN VALUE (DAY IS HI)
00807F: A9 00                        LDA   #$00       ; HI BYTE ALWAYS ZERO
008081: 85 9E                        STA   FAC+1
008083: 84 9F                        STY   FAC+2
008085: A2 90                        LDX   #$90
008087: 25 12                        AND   NUMTYPE
008089: 20 9D EB                     JSR   GIVAYF2
00808C: A5 12                        LDA   NUMTYPE
00808E: 30 03    =8093               BMI   P1
008090: 4C 63 DA                     JMP   LET2       ; MAKE A REAL VAR AND GO HOME.

008093: 20 F2 EB         P1          JSR   QINT       ; XVERT TO INTEGER
008096: 4C 6B DA                     JMP   LET3       ; THAT'S ALL!

008099: 51               CHKSUM      CHK              ; CHECKSUM FOR LISTING

--End Merlin-16 assembly, 154 bytes, errors: 0
```

Program 17-4. Applesoft Clock Test

```
5 D$ = CHR$ (4)
10 PRINT D$“BLOAD TIME.TB,A$300”
15 FOR I = 1 TO 7: READ D$(I): NEXT I
20 TEXT : HOME
30 CALL 768,A$,D
40 VTAB 1: PRINT D$(D);“ ”;A$
50 IF PEEK (−16384) < 128 THEN 30
55 POKE −16368,0: END
99 DATA SUNDAY, MONDAY, TUESDAY, WEDNESDAY, THURSDAY, FRIDAY, SATURDAY
```

Chapter 18

QuickDraw and the Event Manager

Chapter 18

QuickDraw and the Event Manager

The *G* in Apple IIGS stands for *graphics*. In Applesoft BASIC, the normal hi-res graphics screen has 280 horizontal and 192 vertical pixel positions (*pixel* is an abbreviation for *picture element* and is a measure of the visual graphics points on the screen). There are a choice of eight colors, although effectively there are only six, since black and white are each counted twice in the list of possible colors. The hi-res screen doesn't have a resolution of 280 dots in eight colors. That's because you can't plot any color you want at every dot position. If you don't care about the color (perhaps you're using a monochrome monitor), the screen does have 280 pixels. However, in a given color, the resolution is only 140 pixels, since half the dots are no longer usable.

Double Hi-Res

Double hi-res adds more physical positions across the screen, so that the monochrome resolution is 560 pixels, but again, there is a limitation introduced by adding colors (16 possible) that returns the effective resolution to 140 pixels in color. Some people insist that because a double hi-res color can be plotted anywhere, the resolution is really 560 pixels, but all you have to do is to set the Control Panel Display option to *Color* while you're in the DeskTop program (a double hi-res display) to see how adding color decidedly reduces the resolution (clarity) of the screen.

The Apple IIGS introduces a new graphics mode, called *super hi-res graphics*, which has a greater resolution with true color choice at every pixel. In the first mode, the screen is 320 pixels wide by 200 high, and there are 16 colors available for each pixel at every position. There is a second mode, 640 pixels wide by 200 high, in which only 4 colors are available for a given position. However, through some clever planning in hardware, it's possible to put more colors on the entire line by mixing colors in a process called *dithering*. This works by putting, for example, a red pixel next to a yellow pixel to create the color orange.

Storing Information

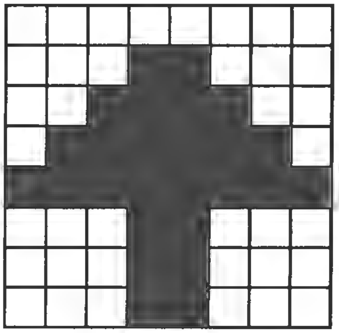
You may have already noticed that there seems to be a relationship between resolution and the number of colors possible. This is easy to understand once you grasp the concept of information storage. Information as a concept, in relation to computers, has to do with the mathematical idea of uniquely describing some entity. This can be a letter of the alphabet, a word in a sentence, a formula for a calculation, or a visual element in a picture. There is a finite limit to how much information you can put in a single byte, or more precisely, in a single bit of any given byte.

For current hardware, a bit can only have two states, 0 or 1. This means that the information contained in that bit is limited to two states. We create meaningful information by combining bits to represent larger numbers, for example %01001011 = $47 = 71 can represent the seventy-first ASCII character, or the letter *G*. The challenge in computing is to devise schemes to pack as much unique information into the smallest memory space possible.

For a graphics screen, let's start with the idea of a screen eight pixels wide by eight pixels high. For the time being, we'll ignore color, and will just display a graphics image in black and white. A direct solution is to use the bits in eight bytes to represent each of the possible pixel positions. If a bit is 0, we'll say that dot is off, or black. If the bit is 1, it will represent an illuminated spot. By adjusting the values of the eight bytes, we can create an image like this:

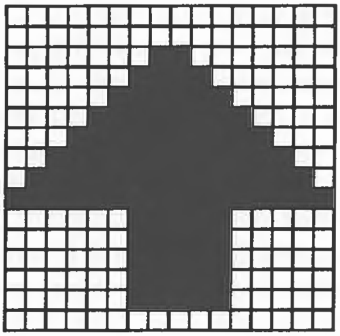
Byte 0: 00000000 = $00
Byte 1: 00011000 = $18
Byte 2: 00111100 = $3C
Byte 3: 01111110 = $7E
Byte 4: 11111111 = $FF
Byte 5: 00011000 = $18
Byte 6: 00011000 = $18
Byte 7: 00011000 = $18

This is how it might look on a screen:



With a little squinting, this looks a little like an arrow. Now suppose you wanted to increase the clarity of the image. This is another way of saying you want to increase the resolution of the image. *Clarity* is a way of saying you want more information communicated to your brain. By doubling the resolution to 16 × 16, we'll get a better image, but it will require *four times* as much memory:

```
Word 0: 0000000000000000 = $0000
Word 1: 0000000000000000 = $0000
Word 2: 0000000110000000 = $0180
Word 3: 0000001111000000 = $03C0
Word 4: 0000011111100000 = $07E0
Word 5: 0000111111110000 = $0FF0
Word 6: 0001111111111000 = $1FF8
Word 7: 0011111111111100 = $3FFC
Word 8: 0111111111111110 = $7FFE
Word 9: 1111111111111111 = $FFFF
Word A: 0000001111100000 = $03D0
Word B: 0000001111100000 = $03D0
Word C: 0000001111100000 = $03D0
Word D: 0000001111100000 = $03D0
Word E: 0000001111100000 = $03D0
Word F: 0000000000000000 = $0000
```



Even without the more graphic drawing, you can probably see the arrow much more clearly using zeros and ones, but remember it took much more memory to increase the resolution. Now suppose you wanted to have four colors, or even just four shades of gray. (It really doesn't matter which because we can design the computer video output hardware to translate any value from 0 to 3 into whatever color or shade of gray we wish.)

However, adding the color or shading will take still more memory. For four possible states, we'll have to use two bits in a byte somewhere (two bits = four possible values: %00 = 0, %01 = 1, %10 = 2, %11 = 3).

As you can see, adding graphics to any computer system puts great demands on the available memory. A normal hi-res graphics screen in Applesoft BASIC uses 8K of memory for the display. The super hi-res display uses 32K. The memory's fixed size creates the trade-off situation of either 320 pixels in 16 colors or 640 pixels in four colors.

QuickDraw and the Drawing Environment

In Applesoft BASIC, there are half a dozen or so commands for drawing on the hi-res screen. The Apple IIGS has a built-in tool set called *QuickDraw* that contains over 200 commands for super hi-res graphics operations. These include not just the mundane clearing of the screen and line-drawing routines, but also operations for defining rectangles, ovals, complex regions, as well as filling these with both colors and patterns. In addition, you have control over the entire drawing area as things are being drawn, and you can create *clipping regions* to automatically omit lines from any part of the final image. In fact, there are more commands in QuickDraw than there are in all the commands in either Applesoft BASIC or 65816 machine language.

But don't let this large number of available commands discourage you. Fortunately, the important one, QDStartUp (QuickDraw StartUp) sets all of the defaults for you, and it only takes a few lines of actual code to draw lines and rectangles, to set colors, or to do the other things you're likely to want to use. The hundreds of other commands are provided to create an immense flexibility for more exotic applications. For example, suppose you want to create a graphics image in memory that is larger than the screen—like a blueprint for a building—and you have QuickDraw create the entire image within the computer. Using some of those more advanced commands, it is possible to draw anywhere in memory—not just the super hi-res display itself—and to have a drawing area limited only by the available memory in your computer.

When QuickDraw is started, the default drawing area is the super hi-res screen. This corresponds to the part of memory in bank $E1 from $2000 to $9FFF (32K). The drawing area itself is the first 32000 bytes (200 lines × 160 bytes per line = 32000), from $2000 to $9CFF.

Remember that 32K is really 32,768. This leaves another 768 bytes to account for. The next 200 bytes are called *scan line control* bytes, or SCBs. There is one SCB for each line on the screen, and these can be used to individually assign the set of 16 colors that will be used on that line, whether that line is in 320 or 640 mode (yes, it's possible to mix them on the same screen), and more. These are assigned the area from $9D00 to $9DFF. This amounts to 256 bytes, which leaves 56 bytes unused. Apple, however, calls these reserved for future use.

The next two pages of memory, $9E00 to $9FFF are used to store the color tables, or *palettes*, for the picture. Each color entry in a palette requires two bytes, so a complete palette of 16 colors requires 32 bytes. Two pages of memory provide room for up to 16 separate palettes. Each line of the screen display can use its SCB to select one of 16 possible palettes for that line's choice of colors.

When a super hi-res picture is saved to disk, the SCBs and color tables are saved along with the picture, for a total file size of 32K (32,768 bytes).

For the most part, this information is more for background than for actual use. When QuickDraw is started up, each line is set to use the default (#0) color table, and you won't have to explicitly set up either the SCBs or a color table.

The call diagram for QDStartUp is shown in Figure 18-1.

Figure 18-1. QDStartUp ($0204)

Stack Before Call:

Previous Contents	
DirectPageLoc	Word: Address of Direct Page for QuickDraw.
MasterSCB	Word: SCB to use for every screen line (0=320; $80=640).
MaxWidth	Word: Image width ($0=full screen).
UserID	Word: ID of application
	←SP:

Stack After Call:

Previous Contents	
	←SP:

To start up QuickDraw, you first need to get three pages of memory in bank 0 to use as its QuickDraw's direct page. This is done using NewHandle in the Memory Manager, which will be detailed in the example program coming up.

The Master SCB entry is the value that QuickDraw will use for each of the 200 lines on the screen display when it starts. This is your opportunity to tell QuickDraw whether you want the 320 or 640 mode for the entire screen. Use an SCB value of $0000 for the 320 mode, $0080 for the 640 mode.

It's possible to create drawing areas both larger and smaller than the super hi-res screen. The MaxWidth parameter is the width, in bytes of the image area. For most applications, just use zero here, for the full screen width.

The last parameter is the UserID you got from MMStartUp; it tells QuickDraw who is starting it up.

Drawing Data Structures: Pens, Lines and Rectangles

QuickDraw supports a very advanced drawing environment: You can control virtually every aspect of the image being created. To support this environment, there are a number of specific data structures that have been created, which will be referenced while using QuickDraw.

The first is the idea of a drawing pen. The pen is a pixel image, much like the arrow image just discussed, that can be moved around on the screen, leaving a trail as it is moved.

It's possible to redefine the pen to be any image you wish, as you have probably seen in the many Apple IIGS painting programs available.

The pen pattern, as it's called, can also be made to draw in a variety of modes, such as reversing the background it draws on or painting a color or a pattern there. These different effects are done internally by QuickDraw using the Boolean AND, EOR, or ORA functions described in earlier chapters.

The pen pattern can be set to a specific color with the command **SetSolidPenPat** ($3704), in which a color value in the range $0 to $F (0 to 15) is passed to the routine.

When QuickDraw is initialized, the pen is a single pixel, and the color is black. Moving the pen as such does not draw a line. Instead, specific drawing commands like **LineTo**, discussed shortly, create the image.

To draw an image, another data structure is used, called a *point*, which is defined by an X and Y position. The Y coordinate comes first, and each is a two-byte value. Thus, the data structure for a point looks like this:

```
POINT  DA   $0000      ; Y COORDINATE
       DA   $0000      ; X COORDINATE
```

This will take four bytes in memory to store. For some operations, the values for a point will be pushed directly on the stack. For others, a pointer to the POINT data structure may be put on the stack so the routine will know where to find the coordinates to use.

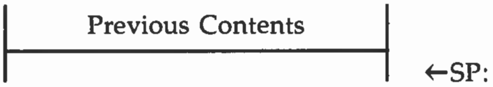
Examples of these types of routines are **MoveTo** ($3A04) and **LineTo** ($3C04). MoveTo repositions the current pen location to the specified coordinate. To use it, you simply push the values for the coordinates on the stack before doing the call. Figure 18-2 is the call diagram for MoveTo.

Figure 18-2. MoveTo ($3A04)

Stack Before Call:

Previous Contents	
H	Word: Horizontal coordinate of point.
V	Word: Vertical coordinate of point.
	←SP:

Stack After Call:



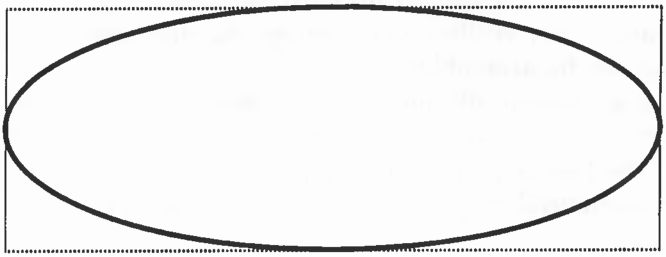
LineTo is similar, but it draws a line using the current pen from the current position to the point specified. The call diagram for LineTo is the same as that for MoveTo.

A rectangle is defined by two points, one for the upper left corner, the second for the lower right corner. The data structure for a rectangle looks like this:

```
RECT                    ; RECTANGLE DEFINITION
V1      DA  $0000       ; VERT. POSN OF UPPER LEFT
H1      DA  $0000       ; HORIZ. POSN OF UPPER LEFT
V2      DA  $0000       ; VERT. POSN OF LOWER RIGHT
H2      DA  $0000       ; HORIZ. POSN OF LOWER RIGHT
```

This takes a total of eight bytes. Rectangle-related objects are usually drawn by passing a pointer to the rectangle, rather than the values for the rectangle itself. We say *rectangle-related,* because the definition of a rectangle can be used as the basis for a variety of shapes. For example, an oval can be defined as the ellipse that fits inside the defined rectangle. A square rectangle defines a circle (see Figure 18-3).

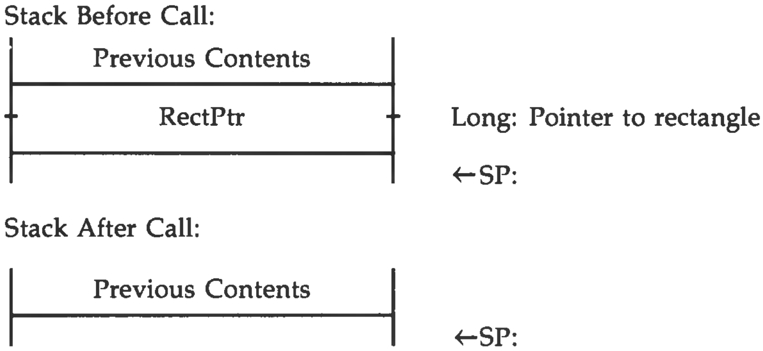
Figure 18-3. Oval Defined by a Rectangle



In addition, a rectangle-related object can either be framed (the outline drawn), painted (filled in with a color or pattern), or inverted (the interior pixels are inverted).

Figure 18-4 is the call diagram for **FrameRect**, which draws the outline of the rectangle using the current pen and color.

Figure 18-4. FrameRect ($5304)



Starting QuickDraw

Program 18-1 starts up QuickDraw, draws a line and a variety of shapes on the screen, and even includes some printed text.

When you run Program 18-1, the screen should clear to black, and a diagonal red line will be drawn across the screen. You should also see four shapes drawn, including rectangles, an oval, and a rounded rectangle. Pressing any key will quit the program and return to whatever program selector started up the program.

Let's look at the listing to see how everything works. Of course, as with the others, it begins with setting the data bank equal to our program bank, and there is also the emergency recovery code set up with the Control-Y vector. That way, if any error should occur while you're testing the program, you can press Control-Y to get back to the assembler.

There is one thing that will be different here: If the program crashes while the super hi-res display is on, you won't be able to see the BRK message, since that is presented on the text screen. The only indication will be the beep heard when the BRK is encountered. If your program does stop, type

```
E1/C029: 21
```

and press Return. This will clear the super hi-res display bit (bit 7) in $C029 and will return the display to the text mode. You should be able to see the register dump from the BRK instruction at that point. Make a note of the address printed for the BRK and of the contents of the Accumulator. The address will tell you which tool call was not executed properly, and the Accumulator will hold the error code. Although certain error codes are provided in this book, you should get the official *Apple Toolbox Reference* by Addison-Wesley, or

COMPUTE!'s Mastering the Apple IIGS Toolbox by Gookin and Davis, for complete information on the tool calls and associated error messages.

After noting the necessary information, press Control-Y to go back to your program selector.

After starting up the Tool Locator and Memory Manager, a sub-ID is produced by setting the Aux field (found in the ID the Memory Manager gives us) to 1 (lines 37–39). This will be used when obtaining the direct-page memory block that QuickDraw requires.

The **GETDP** (Get Direct Page) section uses NewHandle to obtain a $300-byte block in bank 0. The attribute byte $C001 marks this as immovable and locked, and in a fixed bank (bank 0), which is necessary for a direct-page block.

NewHandle will return the handle to this block, but will not return its address. Remember that a handle is a pointer to a pointer, and that the actual address of the block is now part of the handle itself. Normally, you would not use an absolute address for a memory block, but since we know this block has been designated as immovable, its address will be constant until it's de-allocated.

The process of examining a handle is called *dereferencing*. It is done by putting the address of the handle in our own direct-page pointer, and then using indirect addressing to look at the first four bytes of the handle. The first four bytes are always the actual address of the memory owned by that handle.

Line 50 pulls the handle off the stack for the direct page gotten from NewHandle, and stores that handle's address in byte $00 of our own direct page. Line 51 then uses indirect addressing long to look into the first four bytes of the handle. The two-byte value loaded into the Accumulator at that point will be the address in bank 0 of the new direct page. Because we know this is in bank 0, there's no need to look at the third and fourth bytes for the high word of the address, although if you were dereferencing just any old handle, this would be required.

In the full, nonmacro version, here are the instructions to dereference a handle:

```
DEREF  LDA  HNDL      ; GET LOW WORD OF HANDLE
       STA  PTR       ; STORE IN OUR OWN DP POINTER
       LDA  HNDL+2    ; GET HIGH WORD OF HANDLE
       STA  PTR+2     ; STORE IN DP HIGH WORD.
       LDA  [PTR]     ; GET LOW WORD OF ADDRESS.
       STA  ADDR      ; SOME STORAGE LOCATION
       LDY  #$02      ; PREPARE FOR NEXT INSTR.
       LDA  [PTR],Y   ; GET HIGH WORD OF ADDRESS
       STA  ADDR+2    ; SAVE THAT TOO.
```

Program 18-1 looks much simpler because a macro, *PullLong*, sets up our own direct-page pointer, and we only need the LDA [PTR] to retrieve the low word of the address.

Once a direct-page block for QuickDraw has been obtained, we can start things going. The label *QD* (line 54) begins the section that starts up QuickDraw. Referring back to the call diagram for QuickDraw, you can see we're starting up in the 320-pixel mode. Since the direct-page address is still in the Accumulator from the LDA [$00] instruction on line 47, this can be pushed on the stack as the first line of QD.

When QuickDraw starts, the pen pattern color is black. **SETCOLOR** (lines 60–61 sets the pen pattern to the solid color red (color #7). You can use other values here for other colors. The standard color values for the 320 mode are as follows:

Color Entry	Color	Master Value
0	Black	$0000
1	Dark Gray	$0777
2	Brown	$0841
3	Purple	$072C
4	Blue	$000F
5	Dark Green	$0080
6	Orange	$0F70
7	Red	$0D00
8	Beige	$0FA9
9	Yellow	$0FF0
10	Green	$00E0
11	Light Blue	$04DF
12	Lilac	$0DAF
13	Periwinkle Blue	$078F
14	Light Gray	$0CCC
15	White	$0FFF

The column titled *Color Value* shows the two-byte value actually stored in color table (palette) #0 when QuickDraw starts up. If you look at just a select few of the colors, you'll see how the final color is determined from the number value:

4	Blue	$000F
7	Red	$0D00
10	Green	$00E0

Starting with the color values for Blue, Red and Green, you can see that each of these color values has a single hexidecimal digit in just one field. In fact, that is the meaning of each field in the color value. The pattern is:

$0RGB

The color video monitor for the Apple IIGS is called an RGB Monitor for a reason: It refers to the fact that, like your color TV, the image is formed by illuminating red, green and blue dots on the screen. Other colors are created by mixing these three colors. The value in the range of $0 to $F for each position in the color value tells the video hardware how brightly to illuminate the particular color dot.

For each color value, the first nibble (4 bits) is unused, and so is equal to $0. Black is designated by setting all three color elements to $0; white is made by turning all three up to the maximum value.

0	Black	$0000
15	White	$0FFF

Shades of gray (14 in all, plus black and white) are made by varying the matching strengths of each color.

1	Dark Gray	$0777
14	Light Gray	$0CCC

A particular color can be created by adjusting the strength of one color element:

5	Dark Green	$0080

by mixing two together:

9	Yellow	$0FF0

or by mixing all three together in varying proportions:

13	Periwinkle Blue	$078F

Although this program doesn't create new colors, you can add the tool call **SetColorEntry** ($1004) to the program to create new colors if you wish. The call diagram for SetColorEntry is shown is Figure 18-5.

Figure 18-5. SetColorEntry ($1004)

Stack Before Call:

Previous Contents	
TableNumber	Word: Table # ($0 to $F) default = #0.
EntryNumber	Word: Entry you want to change ($0 to $F).
NewColorValue	Word: New Color Value.
	←SP:

Stack After Call:

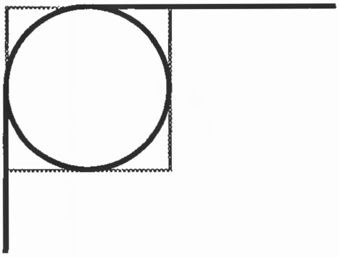
Previous Contents

←SP:

Once the color has been set, the MoveTo and LineTo commands are used to draw a line from one corner of the screen to another (lines 63–70).

Lines 71–75 then change the pen color to blue (#4), and draw a rectangle form using FrameRect ($5304). Notice that the address to RECT, defined on lines 179-183, is pushed on the stack as the input for FrameRect.

The process is then repeated for a filled-in rectangle (PaintRect = $5404), and oval (PaintOval = $5904), and a rounded rectangle (PaintRRect = $5E04). For the rounded rectangle, the width and height of another imaginary rectangle are passed. The final rounded rectangle is produced by replacing square corners of the rectangle with the corner of an oval specified by the height and width parameters.



As each new geometric figure is drawn, the subroutine SHIFT (lines 127–140) changes the horizontal and vertical starting coordinates of where the drawing begins. This is rewritten directly into the definition of the rectangle used for each of the figures.

Printing Text in Super Hi Res

There are also a number of routines in QuickDraw specifically for drawing text in different styles, called *fonts*, on the super hi-res screen. Although additional fonts can be loaded from disk, QuickDraw starts up with a default font, whose definition is stored in ROM, as the standard font. When text is drawn, the routines use both a color for the text itself, and for the background behind the text. At startup, this defaults to a black foreground for the text and a white background.

Since our screen is black, the first thing to do is to set the foreground and background colors for the text printing routines. Lines 103–108 do this with **SetBackColor** ($A204) and **SetForeColor** ($A004). Printing the text is as simple as passing a pointer to the string, which is presumed to end in a zero, to the routine **DrawCString** ($A604). The MoveTo command is used to position the pen at the appropriate spot before drawing the text.

In Program 18-1, the string is defined on line 172. Notice that the high bit is clear for the string (*Merlin* uses single quotation marks to designate high bit clear; *APW* uses the directive MSB OFF). The high bit must be clear for the QuickDraw text printing routines to work properly.

If you want to print a ProDOS-type string with a leading length byte, an alternate routine, **DrawString** ($A504), can be used; the only difference is that DrawString expects a leading length byte in the string to be printed.

RDKEY then just waits for a keypress before doing the ProDOS quit command. As you can see, QuickDraw really is quite simple to use.

You'll hear a lot about clipping windows, something called the *BoundsRect*, and other things, but these are for the most part managed automatically by the system, and are of only minor concern if you're actually doing windows that can be scrolled and dragged around the screen, as we'll see in the next chapter. However, even in the windowed environment, it's still very easy to create just about any image you want.

Although there are over 200 different tool calls in QuickDraw, Table 18-1 lists a few to give you an idea of what's available.

Program 18-1. Simple Quickdraw Demo

```
                          1    ********************************************
                          2    *       SIMPLE QUICKDRAW DEMO              *
                          3    *          MERLIN ASSEMBLER                *
                          4    ********************************************
                          5              MX    %00        ; TELL MERLIN WE'RE IN 16 BITS
                          6              REL
                          7              DSK   QD.DEMO.L
                          8
                          9              LST   OFF        ; DON'T PRINT MACRO LISTING
                         10              USE   UTIL.MACS  ; USE MACRO LIBRARY
                         11              LST   ON         ; LISTING BACK "ON"
                         12              EXP   OFF        ; DON'T EXPAND MACROS
                         13
          =E100A8        14   PRODOS     EQU   $E100A8    ; STD. PRODOS 16 ENTRY
                         15
          =C000          16   KYBD       EQU   $00C000
          =C010          17   STROBE     EQU   $00C010
                         18
                         19    ********************************************
                         20
008000: 4B               21   STARTUP    PHK
008001: AB               22              PLB              ; DATA BANK = PROG. BANK
                         23
```

```
008002: E2 30           SETRES    SEP   $30           ; 8-BIT MODE
008004: A9 5C                     LDA   #$5C          ; JML (JMP LONG)
008006: 8F F8 03 00               STAL  $3F8          ; CTRLY VECTOR
00800A: C2 30                     REP   $30           ; 16-BIT MODE
00800C: A9 ED 81                  LDA   #RESUME
00800F: 8F F9 03 00               STAL  $3F9          ; $3F9,3FA
008013: A9 00 00                  LDA   #^RESUME
008016: 8F FB 03 00               STAL  $3FB          ; $3FB,3FC

                        TL        ToolCall $0201      ; TLStartUp

                        MM        PushWord #$0000     ; SPACE FOR RESULT
                                  ToolCall $0202      ; MMStartUp
                                  PullWord ID         ; PULL ID OFF STACK & SAVE
008037: 09 00 01                  ORA   #$0100        ; OUR SUB-ID
00803A: 8D 10 82                  STA   ID2

                        GETDP     PushLong #$0000     ; SPACE FOR RESULT
                                  PushLong #$300      ; AMT OF MEMORY NEEDED
                                                      ; 3 PAGES FOR QUICKDRAW
                                  PushWord ID2        ; ID FOR OUR APPLICATION
                                  PushWord #$C001     ; TYPE: LOCKED, FIXED
                                  PushLong #$0000     ; BANK = $00, NO SPECIFIC ADDR.
                                  ToolCall $0902      ; NewHandle
                                                      ; OBTAIN A MEMORY BLOCK IN BANK 0

                                  PullLong $00        ; GET HANDLE & STORE IN OUR DP
008067: A7 00                     LDA   [$00]         ; LONG INDIRECT LOAD
                                                      ; GETS NEW DP ADDRESS FOR TOOLS

008069: 48              QD        PHA                 ; PUSH DP ADDRESS ON STACK
                                  PushWord #$0000     ; MASTER SCB = DEFAULT (320)
                                  PushWord #$0000     ; MAX SCREEN SIZE
                                  PushWord ID         ; OUR APPLICATION'S ID
                                  ToolCall $0204      ; QDStartUp

                        SETCOLOR  PushWord #$7        ; COLOR = 'RED'
                                  ToolCall $3704      ; SetSolidPenPat

                        BEGINLN   PushWord #$0000     ; HORIZ (X) = $00
                                  PushWord #$0000     ; VERT (Y) = $00
                                  ToolCall $3A04      ; MoveTo

                        DRAWLN    PushWord #319       ; X = 320TH PIXEL
                                  PushWord #199       ; Y = 200TH PIXEL
                                  ToolCall $3C04      ; LineTo

                        COLOR1    PushWord #$4        ; COLOR = 'BLUE'
                                  ToolCall $3704      ; SetSolidPenPat

                        DRAWRCT   PushLong #RECT      ; ADDR. OF RECTANGLE DEFINITION
                                  ToolCall $5304      ; FrameRect

```

```
0080CE: 20 8B 81         NEXT1     JSR    SHIFT

                         COLOR2    PushWord #$A      ; COLOR = 10 = ‘GREEN’
                                   ToolCall $3704    ; SetSolidPenPat

                         PAINTRCT  PushLong #RECT    ; ADDR. OF RECTANGLE DEFINITION
                                   ToolCall $5404    ; PaintRect

0080F0: 20 8B 81         NEXT2     JSR    SHIFT

                         COLOR3    PushWord #$6      ; COLOR = ‘ORANGE’
                                   ToolCall $3704    ; SetSolidPenPat

                         PAINTOV   PushLong #RECT    ; ADDR. OF RECTANGLE DEFINITION
                                   ToolCall $5904    ; PaintOval

008112: 20 8B 81         NEXT3     JSR    SHIFT

                         COLOR4    PushWord #$3      ; COLOR = ‘PURPLE’
                                   ToolCall $3704    ; SetSolidPenPat

                         ROUNDRCT  PushLong #RECT    ; ADDR. OF RECTANGLE DEFINITION
                                   PushWord #15      ; WIDTH OF ROUNDING OVAL
                                   PushWord #15      ; HEIGTH OF ROUNDING OVAL
                                   ToolCall $5E04    ; PaintRRect

                         TITLE     PushWord #$0000   ; COLOR = BLACK (0)
                                   ToolCall $A204    ; SetBackColor
                                                     ; BACKGROUND FOR TEXT DRAWING

                         T2        PushWord #$000F   ; COLOR = WHITE (15)
                                   ToolCall $A004    ; SetForeColor
                                                     ; SET TEXT COLOR = WHITE

                         T3        PushWord #20      ; X = 20
                                   PushWord #199     ; Y = 199
                                   ToolCall $3A04    ; MoveTo

                         T4        PushLong #MSSG    ; HIGH WORD OF TITLE DATA
                                   ToolCall $A604    ; DrawCString

008178: AF 00 C0 00      RDKEY     LDAL   KYBD       ; CHECK KEYBOARD
00817C: 29 FF 00                   AND    #$00FF     ; CLEAR HIGH WORD
00817F: C9 80 00                   CMP    #$0080     ; KEYPRESS?
008182: 90 F4  =8178               BCC    RDKEY      ; NOPE
008184: 8F 10 C0 00                STAL   STROBE     ; CLEAR KEYBOARD
008188: 4C B1 81                   JMP    SHUTDOWN



00818B: 18               SHIFT     CLC               ; SHIFT RECTANGLE
00818C: AD 12 82                   LDA    V1         ; V1 = V1 + 30, ETC.
```

```
00818F: 69 1E 00                ADC  #30
008192: 8D 12 82                STA  V1
008195: AD 14 82                LDA  H1          ; CARRY NEVER SET, SO
008198: 69 1E 00                ADC  #30         ; NO NEED TO RE-CLR
00819B: 8D 14 82                STA  H1
00819E: AD 16 82                LDA  V2
0081A1: 69 1E 00                ADC  #30
0081A4: 8D 16 82                STA  V2
0081A7: AD 18 82                LDA  H2
0081AA: 69 1E 00                ADC  #30
0081AD: 8D 18 82                STA  H2          ; ENTIRE BOX SHIFTED
0081B0: 60                      RTS



                      SHUTDOWN  ToolCall $0304   ; QDShutDown

                                PushWord ID2     ; GET THE SUB-ID
                                ToolCall $1102   ; DisposeAll

                                ToolCall $0302   ; MMShutDown

                                ToolCall $0301   ; TLShutDown

0081E1: 22 A8 00 E1   QUIT      JSL  PRODOS      ; DO QUIT CALL
0081E5: 29 00                   DA   $29         ; QUIT CALL COMMAND VALUE
0081E7: F6 81 00 00             ADRL QUITBLK     ; ADDRESS OF PARM TABLE
0081EB: 00 00                   BRK  $00         ; SHOULD NEVER GET HERE . . .

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

0081ED: 4B            RESUME    PHK
0081EE: AB                      PLB              ; SET OUR DATA BANK
0081EF: 18                      CLC
0081F0: FB                      XCE              ; SET NATIVE MODE
0081F1: C2 30                   REP  $30         ; 16-BIT MODE
0081F3: 4C B1 81                JMP  SHUTDOWN ; TRY TO SHUTDOWN

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

0081F6: 00 00 00 00   QUITBLK   ADRL $0000       ; NO PATHNMAME
0081FA: 00 00                   DA   $0000       ; STD. QUIT

0081FC: 51 75 69 63   MSSG      ASC  ‘QuickDraw Demo #1’,00
008200: 6B 44 72 61
008204: 77 20 44 65
008208: 6D 6F 20 23
00820C: 31 00

                      * IMPORTANT! TEXT FOR QUICKDRAW MUST HAVE HIGH BIT CLEAR!

```

```
00820E: 00 00        ID        DA    $0000     ; OUR APPLICATION'S ID #
008210: 00 00        ID2       DA    $0000     ; OUR SUB-ID

                     RECT                      ; RECTANGLE DATA STRUCTURE
008212: 1E 00        V1        DA    30        ; UPPER LEFT VERTICAL POSN
008214: 14 00        H1        DA    20        ; UPPER LEFT HORIZ. POSN
008216: 32 00        V2        DA    50        ; LOWER RIGHT VERTICAL POSN
008218: 46 00        H2        DA    70        ; LOWER RIGHT HORIZ. POSN

00821A: 81           CHKSUM    CHK             ; CHECKSUM FOR VERIFICATION

--End Merlin-16 assembly, 539 bytes, errors: 0
```

Table 18-1. QuickDraw Toolset Calls

Command Value	Command Name	Description
$0204	QDStartUp	Starts up QuickDraw, clears screen, initializes GrafPort to defaults.
$0304	QDShutDown	Frees any memory used by QuickDraw, returns screen to text mode.
$0E04	SetColorTable	Rewrites a given color table with contents of another.
$1004	SetColorEntry	Sets value of a color in a specified table.
$1104	GetColorEntry	Returns color value for a given color in a given table.
$1504	ClearScreen	Clears entire screen to a given color.
$1804	OpenPort	Initializes a new part of memory as a GrafPort.
$1A04	ClosePort	De-allocates a GrafPort.
$1B04	SetPort	Make specified GrafPort the current port.
$1C04	GetPort	Returns pointer to current GrafPort.
$1D04	SetPortLoc	Set current GrafPort's information structure to a specified table.
$1E04	GetPortLoc	Write current GrafPort information structure into a given table.
$1F04	SetPortRect	Set current port rectangle to specified rectangle.
$2004	GetPortRect	Writes current port's rectangle values into a specified table.
$2304	SetOrigin	Adjusts PortRect and BoundsRect so that the origin of the current PortRect is equal to a given value (usually 0,0).
$2704	HidePen	Sets pen to no-draw. Does *not* refer to whether cursor is visible or not.
$2804	ShowPen	Sets pen to drawing mode.
$2904	GetPen	Returns pointer to location where current pen coordinates are stored.
$2C04	SetPenSize	Sets pen to given size.
$2E04	SetPenMode	Set drawing mode of pen (ORA, EOR, AND).
$3004	SetPenPat	Set pen to a given pattern.
$3704	SetSolidPenPat	Set pen to solid color.

Command Value	Command Name	Description
$3404	SetBackPat	Set background pattern.
$3804	SetSolidBackPat	Set background to a color.
$3A04	MoveTo	Move pen to given position.
$3B04	Move	Move pen a distance relative to current position.
$3C04	LineTo	Draw a line from current pen position to specified point.
$3D04	Line	Draw line from current pen position to a new relative position.
$5304	FrameRect	Draw boundary of a rectangle.
$5404	PaintRect	Paint interior of rectangle with current pen color or pattern.
$5504	EraseRect	Paint interior of a rectangle with background color or pattern.
$5604	InvertRect	Inverts pixels in a given rectangle.
$5704	FillRect	Fills interior of rectangle with specified pattern.
$5804	FrameOval	Draw boundary of oval.
$5904	PaintOval	Paint interior of oval.
$5D04	FrameRRect	Draw boundary of rounded rectangle.
$5E04	PaintRRect	Paint interior of rounded rectangle.
$BC04	FramePoly	Draw boundary of polygon.
$BD04	PaintPoly	Paint interior of polygon.
$C604	SetClipHandle	Set ClipRgn in GrafPort to region identified by a handle.
$C704	GetClipHandle	Get handle that identifies ClipRgn for a GrafPort.
$7904	FrameRgn	Draws boundary of a region.
$7A04	PaintRgn	Paints interior of a region with current pen color or pattern.
$7E04	ScrollRect	Shift pixels in a rectangle in any direction.
$7F04	PaintPixels	Transfers pixels from one region to another, all specified with a parameter block.
$D604	PPToPort	Transfer pixels from source image to current port, clipping as necessary.
$9404	SetFont	Set current font.
$9C04	SetTextMode	Set text drawing mode (ORA, EOR, AND).
$A004	SetForeColor	Set color of text drawing.
$A204	SetBackColor	Set color of text background.
$9E04	SetSpaceExtra	Set size of space character in pixels. Used to fill-justify text.
$D404	SetCharExtra	Set size of space between all characters.
$A404	DrawChar	Draw a character.
$A504	DrawString	Draw a string whose first byte is a length-byte.
$A604	DrawCString	Draw a string that terminates in a zero.
$A804	CharWidth	Return width in pixels of a character in the current font.
$A904	StringWidth	Return width in pixels of a string in the current font.
$AA04	CStringWidth	Return width in pixels of a string ending with a zero, in the current font.

Command Value	Command Name	Description
$4D04	SectRect	Calculates intersection of two rectangles and places result in specified rectangle data structure. (And you thought you'd never have to remember difference between union and intersection.)
$4E04	UnionRect	Calculates union of two rectangles and places result in specified rectangle data structure. (Union is sum of two rectangles, the intersection is only the common area shared, which may be zero.)
$4F04	PtInRect	Detects whether a point is in rectangle. Saves you all those greater-than and less-than tests.
$8404	LocalToGlobal	Converts a point from the local coordinates based on the BoundsRect to the global coordinates in which 0,0 is the upper left corner of the pixel image.
$8504	GlobalToLocal	Converts a point from global coordinates to local.
$8E04	SetCursor	Set cursor image to a specified pixel image.
$9004	HideCursor	Make cursor invisible.
$9104	ShowCursor	Make cursor visible.
$9204	ObscureCursor	Hide cursor until next mouse movement.
$CA04	InitCursor	Reinitializes cursor to visible arrow.
$8604	Random	Returns random number so you can write those demos with lines shooting everywhere.
$8804	GetPixel	Returns value of pixel at specified point. (For all you who still miss the SCRN function from lo-res graphics that was never included in Applesoft BASIC hi-res.)

Table 18-2. Possible QuickDraw Errors

$0401	AlreadyInitialized	QuickDraw has already been started up. QD can't be started if it's already active.
$0410	ScreenReserved	Memory Mgr. says screen area ($E1/2000–9FFF) is already in use.
$0411	BadRect	Invalid rectangle definition.
$0450	BadTable	You got that table by the kitchen again. No, not really. This means you specified a color table number not in the range of $0–$F.
$0451	BadColorNum	You must use a color number in the range $0–$F.
$0420	NotEqualChunkiness	Returned when transferring pixels from regions with different display modes (320 vs. 640).

The Event Manager

So far, our programs have just looked at $C000 whenever they needed a keypress, but this really isn't very appropriate for an application program. What we need is a way to monitor all the possible input from the user, and to easily respond to keypresses, mouse clicks, special option key modifiers, and other input.

In the Apple IIGS, this is handled by the Event Manager, who's job is to provide the application program with an orderly presentation of events as they occur. An event is most easily defined as a transition from one state to another. In practice, an event is usually user-initiated and consists of a key or mouse button changing from up to down, or some other user input. In addition, the Event Manager gives you an automatic buffering of events, so that if your program happens to be busy doing something when a key is pressed, or a mouse clicked, the event won't be lost. It maintains this list of stored events in what is called the *Event Queue*.

Events are delivered by the Event Manager into a data structure called the *Event Record*, which you define in your program. By looking at the event record, you can determine which of a number of possible events have occurred. The event record itself looks like this:

```
EVENTREC                        ; EVENT RECORD DATA STRUCTURE
EVENT      DA     $0000         ; EVENT CODE
TYPE       ADRL   $0000         ; TYPE OF EVENT (4 BYTES)
TIME       ADRL   $0000         ; TIME (4 BYTES)
YPOS       DA     $0000         ; Y POSN OF MOUSE
XPOS       DA     $0000         ; X POSN OF MOUSE
MOD        DA     $0000         ; EVENT MODIFIER
```

When an event occurs, a number code for the event is stored in EVENT, along with the position of the mouse at that instant, a time in *tics* (a tic is 1/60 second since the computer was started up), and additional information in the form of the TYPE and MOD bytes. Table 18-3 lists the possible event code.

When an event is detected, the application can then look at the TYPE field to obtain additional information. For example, if it is a key-down or auto-key event, the TYPE field will contain the ASCII value for the key pressed in the first byte of the TYPE field. In the case of an activate or update event, TYPE (also called *MSSG*) contains a handle for the for the window that needs to be updated or activated.

The modifier field contains additional information about the event. For keypress events, this is whether additional keys such as the shift, control, or option keys were also pressed. You can also determine whether the Caps Lock key is up or down and whether a number key is coming from the keypad or the main keyboard.

Table 18-3. Possible Event codes

Event	Description
0	Null event
1	Mouse-down event
2	Mouse-up event
3	Key-down event
4	Undefined
5	Auto-key event
6	Update event (for windows)
7	Undefined
8	Activate event (for windows)
9	Switch event
10	Desk accessory event
11	Device driver event
12	Application-defined event
13	Application-defined event
14	Application-defined event
15	Application-defined event

Each modifier is indicated by setting a bit in the modifier word (2 bytes) as shown in Table 18-4.

Table 18-4. Event Code Bit Modifiers

Bit	Description
0	Active Flag (for windows)
1	Change Flag (for windows)
2–5	Unused
6	Button1 up
7	Button0 up
8	Apple (command) key
9	Shift key
10	Caps Lock key
11	Option key
12	Control key
13	KeyPad
14–15	Unused

Events are usually detected in the application by calling GetNextEvent ($0A06). When calling this, you can (and in fact must) include a mask, with appropriate bits set for what types of events you want to accept at that moment. The bits in the mask are set as shown in Table 18-5.

Table 18-5. Event Mask

Bit	Description
0	Unused
1	Mouse down
2	Mouse up
3	Key down
4	Unused
5	Auto-key
6	Update (for windows)
7	Unused
8	Activate (for windows)
9	Switch
10	Desk accessory
11	Device driver
12–15	Application defined

For example, if you only want to deal with key-down events, you can set a mask of $0008 (%0000000000001000). If you want to include mouse events and keys being held down continuously (auto-key events), you can use a mask of $002E (%0000000000101110).

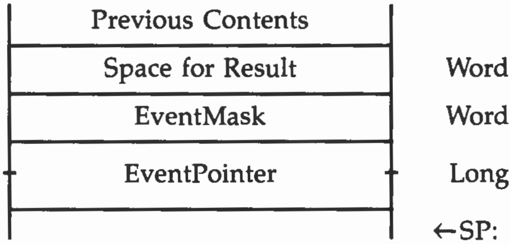
The other nice thing about the event mask is that you can retrieve certain events even though they may have occurred after others. For example, suppose there were a key-down and a mouse-down event waiting in the Event Manager for you. If your mask requested only mouse-down events, you would get the mouse-down event, and the key-down event would remain in the queue until you requested it.

In practice, because you can also just ignore events once the code has been passed to you, an event mask of $FFFF works just fine. The event queue (event buffer) holds a finite number of events, and if you don't pull them off, sooner or later the queue could fill up with the events you haven't dealt with.

The call diagram for GetNext Event is shown in Figure 18-6.

Figure 18-6. GetNext Event ($0A06)

Stack Before Call:



Word: Allow space for result.

Word: Which types of events are of interest.

Long: Pointer to the event record data structure.

Stack after Call:

Previous Contents	
EventFlag	Word: True (>0) if event occurs. Zero if not.
	←SP:

Event-Driven Programs

Part of the underlying idea of the Event Manager and other Apple IIGS tools is the idea of an event-driven program. What this means is that the program is designed around a central loop that continually looks for an event, namely a user input. It then executes a routine related to that event, and returns as soon as possible back to the main loop. This is in contrast to a modal program where the user's command puts the program into a certain mode. In that mode, the commands may be completely different than at the main level, and commands available at the main level may no longer be available.

In an event-driven program, the goal is to create an environment where there are no modes, and the user is free to execute any logical command at any time.

As an example of a modeless, event-driven program, albeit a small one, here is a program that continually checks for an event and prints a message, depending on the event.

Program 18-2 begins very much like the QuickDraw demo program, and in fact, you may wish to use a copy of that source listing as a starting point for this program to cut down on the number of lines you'll have to type in. As usual, a checksum is provided at the end of the listing to assist you in verifying that your entered listing is identical to the printed source.

The first difference in this program is that the **GETDP** routine now obtains four pages ($400) of direct-page space. This is because the Event Manager, like QuickDraw, requires a block of direct-page memory for itself. The easiest way to handle this is to just tack its space onto the end of that assigned to QuickDraw.

In this particular program, the Event Manager is started up before QuickDraw, but it really doesn't matter which one is started first. The Event Manager is started up with the call **EMStartUp**, whose input parameters include the address of the direct page it is to use, the size of the event queue—how many events it will buffer—and the minimum and maximum clamping values for the mouse. In addition, the Event Manager requires a UserID for the application starting it up. Figure 18-7 is the call diagram for EMStartUp.

Figure 18-7. EMStartUp ($0206)

Stack Before Call:

Previous Contents	
DirectPageAddr	Word: Starting address in bank 0 for work area.
QueueSize	Word: Maximum number of events in queue. (0=default 20).
XMinClamp	Word: Minimum mouse X value.
XMaxClamp	Word: Maximum mouse X value.
YMinClamp	Word: Minimum mouse Y value.
YMaxClamp	Word: Maximum mouse Y value.
UserID	Word: ID Event Mgr. will use to get memory.
	←SP:

Stack After Call:

Previous Contents	
	←SP:

A Closer Look

Lines 64–71 start up the Event Manager with the default values, and clamping set to 0–320 for X, and 0–200 for Y, corresponding to the size of the super hi-res display screen. As before, the sub-ID for the program is used so that the memory may be disposed of during the tool shutdown phase of the program.

QuickDraw is started up in the same way as in the QuickDraw demo program, but this time the messages on the screen will be printed a little differently. Because there are six different messages printed on the screen in various places, this program includes a generalized PRINT and CR (for Carriage Return) routine for printing text. Text is printed by doing a JSR PRINT, and following the JSR PRINT with the string you want printed, which should include a length byte at the beginning (use the STR pseudo-op).

The PRINT routine itself is a variation on Program 11-1, the Stack Indirect Indexed sample program in Chapter 11. The routine uses the stack indirect indexed addressing mode in the instruction LDA 1,S to load the return address from the JSR to the print routine. This value will be one byte less than the beginning of the string data, whose first byte is the length of the string to print.

The PRINT routine then saves this address in a pointer (MSSGPTR) that will be used to set up the DrawString command.

Before doing that, however, it adjusts the return address on the stack to resume program execution immediately after the string data following the JSR PRINT that called it.

After printing a string, it then uses the QuickDraw routine **StringWidth**, which returns the width, in pixels of the string. This is used to advance CH to the right so that any successive PRINT calls will continue on the same line.

The PRINT routine is first called on lines 97–104, where the message at the bottom of the screen is printed. The routine CR simple moves the print position down 10 pixels, and returns CH to zero, which is equivalent to printing a carriage return in a text-based program.

That was just the setup. The working part of the program is the main loop on lines 112 to 128. Starting at MAIN, a call is done to **GetNextEvent**, with the mask of $FFFF to allow all events. Each time through the loop, the subroutine MOUSE is called to continually print the coordinates of the cursor as the mouse is moved around.

MOUSE (lines 179–207) uses an interesting Toolbox routine, namely **Int2Dec** from the Integer Math tool set, which converts a number value into a string. Int2Dec converts a two-byte value into an ASCII string in decimal. Later, we'll use another Integer Math tool, Int2Hex, which creates an ASCII string in hexadecimal notation. The Integer Math tool set does not need to be specifically started up or shut down, so these calls are omitted from the program.

Int2Dec requires that the address of the buffer into which the string characters will be written be provided. In this case, the buffer area is part of the messages about to be printed on lines 199–205.

For error-trapping purposes, Int2Dec also requires that the length of the output string, and whether the number is a signed number (>$7FFF is a negative number), be input as well.

When entering the listing, be sure to include the extra two spaces after the 0000 characters. These are included to automatically erase text left on the screen from previous print messages as the number goes from a large value to a smaller one with fewer digits. If you're not sure what this does, try the program without the spaces at the end to see what I mean.

When MOUSE was called in the main loop, the stack held the event flag from **GetNextEvent**. TEST pulls this off the stack and checks to see if an event has occurred. This value will be zero if no event has occurred, and the program will loop back to MAIN with the BEQ MAIN instruction.

If the Accumulator is nonzero, an event has occurred, and the event code is loaded into the Accumulator from within the Event Record (**EVRECORD**). If it's equal to 3, it was a keydown event, and control is passes to the routine **KEYDN** (for KeyDown). If any other event occurs, a JSR is done to the to the routine that prints out the identity of the event, **EVMSSG.**

KEYDN loads the first word of TYPE from the Event Record to see specifically if the Q key was pressed, for a quit. If not, it too passes control to EVMSSG.

EVMSSG is a subroutine that prints out a description of the event that occurred, the value of TYPE, and the ASCII character associated with TYPE. After first setting, the next PRINT coordinates to 0, 50, EVMSSG prints the phrase Event: . For each possible event code from 0 to 15, a message has been set up in a table of text labeled EVENTMSSG (lines 323-340). Each descriptor (including the length byte) is 16 bytes long.

By multiplying the event code by 16, the offset into the message table can be determined. The **Multiply** routine from the Integer Math tool set is used. This routine takes as its input two words (2 bytes each) for each value to be multiplied, and returns a long (4-byte) result on the stack. For our values, the lower two bytes of the result will be sufficient to contain the offset value.

After printing the event message, the TYP portion of the program converts the value of the TYPE field of the event record into a hex value, and also embeds the corresponding character into the string to be printed. Lines 249–253 show a technique of splitting up a string to make labeling pieces of it more convenient. However, this could have been done just as easily with lines 239 and 245 using an offset into a string defined with a simple STR, as was done in the MOUSE routine.

Be sure to look at how the main loop portion of the program continually processes events. In a larger program, an indirect jump table can be created to handle each type of event. However, virtually every Apple IIGS program should be designed to have a central continuous loop, as opposed to modal subsections.

When you run this demonstration program, try pressing Open Apple–Escape to go to the Classic Desk Accessory Menu on the Apple IIGS. You'll notice that, when you return, the program picks up the desk accessory event.

As an additional challenge, you might want to try expanding the program to also print out the appropriate message for the Modifier byte. As a hint in that direction, try constructing the modifier message table the same way as the event message table, but use a loop the does 16 LSRs on the Modifier byte. On each pass through the loop, check to see whether the carry was set or clear, and print the appropriate message. A starting pointer, like MSSGPTR should be set up to point to the beginning of the table, and 16 should be added each time through the loop.

Program 18-2. Event Manager Demo

```
                      ***********************************************
                      *        EVENT MANAGER DEMO                   *
                      *         MERLIN ASSEMBLER                    *
                      ***********************************************

                               MX      %00             ; TELL MERLIN WE’RE IN 16 BITS
                               REL
                               DSK     EM.DEMO.L

                               LST     OFF             ; DON’T PRINT MACRO LISTING
                               USE     UTIL.MACS       ; USE MACRO LIBRARY
                               LST     ON              ; LISTING BACK “ON”
                               EXP     OFF             ; DON’T EXPAND MACROS
                               TR      ON              ; DON’T PRINT ALL BYTES

          =E100A8     PRODOS   EQU     $E100A8         ; STD. PRODOS 16 ENTRY

          =0000       PTR      EQU     $00             ; OUR OWN DIRECT-PAGE PTR
                                                       ; $00,01,02,03

          =0004       MSSGPTR  EQU     $04             ; POINTER TO ANY MESSAGE

                      ***********************************************
                      * STARTUP THE ENVIRONMENT
                      ***********************************************

008000: 4B            STARTUP  PHK
008001: AB                     PLB

                                                       ; DON’T NEED TO START MATH TOOLS

008002: A9 00 00               LDA     #^STARTUP       ; GET OUR DATA BANK
008005: 85 06                  STA     MSSGPTR+2       ; HIGH WORD IS OUR DATA BANK

008007: E2 30         SETRES   SEP     $30             ; 8-BIT MODE
008009: A9 5C                  LDA     #$5C            ; JML (JMP LONG)
00800B: 8F F8 03 00            STAL    $3F8            ; CTRLY VECTOR
00800F: C2 30                  REP     $30             ; 16-BIT MODE
008011: A9 AE 81               LDA     #RESUME
008014: 8F F9 03 00            STAL    $3F9            ; $3F9,3FA
008018: A9 00 00               LDA     #^RESUME
00801B: 8F FB 03 00            STAL    $3FB            ; $3FB,3FC

                      TL       ToolCall $0201          ; TLStartUp

                      MM       PushWord #$0000         ; SPACE FOR RESULT
                               ToolCall $0202          ; MMStartUp
                               PullWord ID             ; PULL ID AND SAVE
00803C: 09 00 01               ORA     #$0100          ; SET SUB-ID
```

```
00803F: 8D 17 83              STA   ID2

                     GETDP    PushLong #$0000      ; SPACE FOR RESULT
                              PushLong #$400       ; AMT OF MEMORY NEEDED
                                                   ; 3 PAGES FOR QUICKDRAW
                                                   ; 1 PAGE FOR EVENT MGR.
                              PushWord ID2         ; ID FOR OUR APPLICATION
                              PushWord #$C001      ; TYPE: LOCKED, FIXED
                              PushLong #$0000      ; BANK = $00
                              ToolCall $0902       ; NewHandle
                              PullLong PTR         ; GET HANDLE & DEREFERNCE
00806C: A7 00                 LDA   [PTR]          ; LONG INDIRECT LOAD
00806E: 8D 19 83              STA   DP             ; SAVE THE DP ADDRESS

008071: 48           EM       PHA                  ; PUSH DP ADDRESS (IN ACC.)
                              PushWord #$0000      ; QUEUE SIZE = DEFAULT = 20
                              PushWord #$0000      ; MIN X CLAMP FOR MOUSE = 0
                              PushWord #320        ; MAX X CLAMP = 320
                              PushWord #$0000      ; MIN Y CLAMP = 0
                              PushWord #200        ; MAX Y CLAMP = 200
                              PushWord ID2         ; PUSH OUR SUB-ID
                              ToolCall $0206       ; EMStartUp

008090: AD 19 83     QD       LDA   DP             ; GET STARTING DP MEMORY ADDR.
008093: 18                    CLC                  ; ADD $100 FOR WHAT EM JUST USED
008094: 69 00 01              ADC   #$100
008097: 8D 19 83              STA   DP             ; PUT THINGS BACK

00809A: 48                    PHA                  ; PUSH DP ADDRESS ON STACK
                              PushWord #$0000      ; MASTER SCB = DEFAULT (320)
                              PushWord #$0000      ; MAX SCREEN SIZE FOR BOUNDSRECT
                              PushWord ID2         ; OUR SUB-ID
                              ToolCall $0204       ; QDStartUp

                     TEXT     PushWord #$0000      ; COLOR = BLACK (0)
                              ToolCall $A204       ; SetBackColor (FOR TEXT)
                                                   ; (DEFAULT WAS WHITE)

                              PushWord #$000F      ; COLOR = WHITE (15)
                              ToolCall $A004       ; SetForeColor (FOR TEXT)
                                                   ; (DEFAULT WAS BLACK)

0080CC: A9 14 00     TITLE    LDA   #20            ; X = 20
0080CF: 8D 1B 83              STA   CH
0080D2: A9 BD 00              LDA   #189           ; Y = 189
0080D5: 8D 1D 83              STA   CV

0080D8: 20 B1 82              JSR   PRINT
0080DB: 15 45 76 65  MSSG1    STR   'Event Manager Demo #1'
0080F1: 20 04 83              JSR   CR             ; SIMULATE A RETURN

0080F4: A9 14 00              LDA   #20            ; X = 20
```

```
0080F7: 8D 1B 83                     STA   CH
0080FA: 20 B1 82                     JSR   PRINT
0080FD: 1B 50 72 65       MSSG2      STR   ‘Press keys          ; use “Q” to Quit’

                          SHOWCURS ToolCall $9104              ; SHOW CURSOR COMMAND

                           *********************************************
                          * MAIN EVENT LOOP
                           *********************************************

                          MAIN       PushWord #$0000          ; SPACE FOR RESULT
                                     PushWord #$FFFF          ; MASK = USE ALL EVENTS
                                     PushLong #EVRECORD       ; RECORD ADDRESS
                                     ToolCall $0A06           ; GetNextEvent
                                                              ; EVENT ON STACK HERE . . .

00813B: 20 BD 81                     JSR   MOUSE              ; CONTINUALLY SHOW MOUSE POSN

00813E: 68                TEST       PLA                      ; GET EVENT TO LOOK AT
00813F: F0 E3   =8124                BEQ   MAIN               ; NOTHING HERE . . .

008141: AD 1F 83          :1         LDA   EVENT              ; GET EVENT CODE
008144: C9 03 00                     CMP   #$3                ; KEYDOWN?
008147: F0 06   =814F                BEQ   KEYDN

008149: 20 22 82          :2         JSR   EVMSSG             ; PRINT EVENT MESSAGE
00814C: 4C 24 81                     JMP   MAIN               ; BACK TO THE LOOP

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

00814F: AD 21 83          KEYDN      LDA   TYPE               ; KEYCODE IF ANY
008152: 29 DF 00                     AND   #$DF               ; CONVERT TO UC IF NEEDED
008155: C9 51 00                     CMP   #’Q’               ; ESCAPE KEY (HI BIT CLR)?
008158: D0 03   =815D                BNE   :1                 ; NOPE
00815A: 4C 63 81                     JMP   SHUTDOWN

00815D: 20 22 82          :1         JSR   EVMSSG             ; PRINT THE EVENT MESSAGE

008160: 4C 24 81          :2         JMP   MAIN               ; BACK FOR MORE

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

                          SHUTDOWN ToolCall $0304             ; QDShutDown

                                     ToolCall $0306           ; EMShutDown

                                     PushWord ID2             ; SUBID
                                     ToolCall $1102           ; DisposeAll

                                     PushWord ID              ; OUR APPLICATION’S ID
                                     ToolCall $0302           ; MMShutDown

```

```
                                  ToolCall $0301         ; TLShutDown

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

0081A2: 22  A8  00  E1   QUIT     JSL   PRODOS           ; DO QUIT CALL
0081A6: 29  00                    DA    $29              ; QUIT CALL COMMAND VALUE
0081A8: B7  81  00  00            ADRL  QUITBLK          ; ADDRESS OF PARM TABLE
0081AC: 00  00                    BRK   $00              ; SHOULD NEVER GET HERE...

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

0081AE: 4B               RESUME   PHK
0081AF: AB                        PLB                    ; SET OUR DATA BANK
0081B0: 18                        CLC
0001B1: FB                        XCE                    ; SET NATIVE MODE
0081B2: C2  30                    REP   $30              ; 16-BIT MODE
0081B4: 4C  63  81                JMP   SHUTDOWN         ; TRY TO SHUTDOWN

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

0081B7: 00  00  00  00   QUITBLK  ADRL  $0000            ; NO PATHNMAME
0081BB: 00  00                    DA    $0000            ; STD. QUIT



                         MOUSE                           ; PRINT MOUSE POSITION

                         XPOSN    PushWord XPOS          ; GET X POSITION
                                  PushLong #XMSG+5       ; ADDR. OF BUFFER
                                  PushWord #4            ; 4 CHAR OUTPUT
                                  PushWord #$0001        ; SIGNED NUMBER FLAG
                                  ToolCall $260B         ; Int2Dec
                                                         ; CONVERT TO ASCII DECIMAL STR$

                         YPOSN    PushWord YPOS          ; GET Y POSITION
                                  PushLong #YMSG+5       ; ADDR. OF BUFFER
                                  PushWord #4            ; 4 CHAR OUTPUT
                                  PushWord #$0001        ; SIGNED NUMBER FLAG
                                  ToolCall $260B         ; Int2Dec

0081F3: A9  00  00                LDA   #0               ; X = 0
0081F6: 8D  1B  83                STA   CH
0081F9: A9  0A  00                LDA   #10              ; Y = 10
0081FC: 8D  1D  83                STA   CV

0081FF: 20  B1  82                JSR   PRINT
008202: 0A  58  20  3D   XMSG     STR   ‘X = 0000 ‘
00820D: 20  04  83                JSR   CR

008210: 20  B1  82                JSR   PRINT
008213: 0A  59  20  3D   YMSG     STR   ‘Y = 0000 ’
```

```
00821E: 20 04 83              JSR   CR

008221: 60                    RTS

                     *********************************************
                     * PRINT THE EVENT MESSAGE
                     *********************************************

008222: A9 00 00     EVMSSG   LDA   #0               ; X = 0
008225: 8D 1B 83              STA   CH
008228: A9 32 00              LDA   #50              ; Y = 50
00822B: 8D 1D 83              STA   CV

00822E: 20 B1 82              JSR   PRINT
008231: 0A 45 76 65  EMSSG    STR   ‘Event: ’

                              PushLong #$0000        ; SPACE FOR RESULT
                              PushWord EVENT         ; EVENT CODE
                              PushWord #16           ; MULTIPLY BY 16
                              ToolCall $090B         ; Multiply

008254: 18                    CLC                    ; ALREADY CLEAR, BUT IT LOOKS
                                                       BETTER
008255: 68                    PLA                    ; PULL RESULT LOW WORD
008256: 69 2F 83              ADC   #EVENTMSSG       ; ADDR. OF MSSG DATA
008259: 85 04                 STA   MSSGPTR          ; STORE IT IN OUR TEMPORARY LOC.
00825B: 68                    PLA                    ; PULL HIGH WORD OF RESULT &
                                                     ; THROW AWAY . . .

                              PushLong MSSGPTR       ; MSSG ADDRESS
                              ToolCall $A604         ; DrawCString

00826D: 20 04 83              JSR   CR

                     TYP      PushWord TYPE          ; GET EVENT TYPE
                              PushLong #HEXSTR+1     ; ADDR. OF BUFFER
                              PushWord #4            ; 4 CHAR OUTPUT
                              ToolCall $220B         ; Int2Hex

008288: E2 30                 SEP   $30              ; 8-BIT ACC.
00828A: AD 21 83              LDA   TYPE
00828D: 8D AA 82              STA   CHAR
008290: C2 30                 REP   $30              ; BACK TO 16 BITS

008292: 20 B1 82              JSR   PRINT
008295: 17           TMSSG    DFB   TMSGEND-TMSSG-1
008296: 54 79 70 65           ASC   ‘Type:      ’
0082A1: 24 30 30 30  HEXSTR   ASC   ‘$0000 = “ ’     ; BUFFER FOR Int2Hex
0082AA: 58 22 20     CHAR     ASC   ‘X” ’
                     TMSGEND
```

```
0082AD: 20 04 83                JSR   CR

0082B0: 60                      RTS                      ; GO BACK FOR MORE . . .

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

                   PRINT        PushWord CH              ; HORIZ. CURSOR POSN
                                PushWord CV              ; VERT. CURSOR POSN
                                ToolCall $3A04           ; MoveTo

                                                         ; ADDR. OF MSSG-1 ON STACK
                                                         ; FROM 'JSR' INSTR.
0082C4: A3 01                   LDA   1,S                ; GET ADDR. OF MSSG-1
0082C6: 1A                      INC                      ; +1 = MSSG ADDRESS
0082C7: 85 04                   STA   MSSGPTR            ; (MSSGPTR) = MSSG ADDRESS
0082C9: A0 00 00                LDY   #$00               ; 1ST CHAR OF MSSG DATA (LEN)
0082CC: B1 04                   LDA   (MSSGPTR),Y        ; GET LEN OF STRING TO PRINT
0082CE: 29 FF 00                AND   #$00FF             ; CLEAR HIGH BYTE OF ACC.
0082D1: 38                      SEC                      ; TRICK TO ADD +1 TO RESULT
0082D2: 63 01                   ADC   1,S                ; ADD TO LOW WORD OF RTS ADDRESS
0082D4: 83 01                   STA   1,S                ; REWRITE RTS TO AFTER MSSG TEXT

                                PushLong MSSGPTR         ; ADDR. OF MSSG TEXT
                                ToolCall $A504           ; DrawString

                                PushWord #$0000          ; SPACE FOR RESULT
                                PushLong MSSGPTR         ; ADDR. OF MSSG
                                ToolCall $A904           ; StringWidth

0082FB: 18                      CLC
0082FC: 68                      PLA                      ; GET WIDTH OF STRING
0082FD: 6D 1B 83                ADC   CH                 ; MOVE CURSOR TO RIGHT
008300: 8D 1B 83                STA   CH

008303: 60                      RTS                      ; RETURN TO CODE 'AFTER' MSSG
                                                          TEXT



008304: 18         CR           CLC
008305: AD 1D 83                LDA   CV
008308: 69 0A 00                ADC   #10                ; SIMULATE A CARRIAGE RETURN
00830B: 8D 1D 83                STA   CV                 ; Y = Y + 10
00830E: A9 00 00                LDA   #$00
008311: 8D 1B 83                STA   CH                 ; X = 0
008314: 60                      RTS



008315: 00 00      ID           DA    $0000              ; OUR APPLICATION'S ID #
008317: 00 00      ID2          DA    $0000              ; SUBID FOR DP

```

```
008319: 00 00          DP        DA    $0000              ; TEMP STORAGE FOR THE DP VALUE

00831B: 00 00          CH        DA    $0000              ; HORIZ. CURSOR POSITION
00831D: 00 00          CV        DA    $0000              ; VERT. CURSOR POSITION



                       EVRECORD                           ; DATA BLOCK WRITTEN BY EV MGR.

00831F: 00 00          EVENT     DA    $0000              ; EVENT CODE
008321: 00 00 00 00    TYPE      ADRL  $0000              ; TYPE OF EVENT
008325: 00 00 00 00    TIME      ADRL  $0000              ; TIME SINCE STARTUP
008329: 00 00          YPOS      DA    $0000              ; Y POSITION OF MOUSE
00832B: 00 00          XPOS      DA    $0000              ; X POSITION OF MOUSE
00832D: 00 00          MOD       DA    $0000              ; EVENT MODIFIER



                       EVENTMSS                           ; TABLE OF EVENT DESCRIPTORS

00832F: 4E 75 6C 6C    E0        ASC   ‘Null Event ‘,00   ; EACH ENTRY = 16 CHARS!
00833F: 4D 6F 75 73    E1        ASC   ‘Mouse Down ‘,00
00834F: 4D 6F 75 73    E2        ASC   ‘Mouse Up ‘,00
00835F: 4B 65 79 20    E3        ASC   ‘Key Down ‘,00
00836F: 55 6E 64 65    E4        ASC   ‘Undefined ‘,00
00837F: 41 75 74 6F    E5        ASC   ‘Auto-Key ‘,00
00838F: 55 70 64 61    E6        ASC   ‘Update ‘,00
00839F: 55 6E 64 65    E7        ASC   ‘Undefined ‘,00
0083AF: 41 63 74 69    E8        ASC   ‘Activate ‘,00
0083BF: 53 77 69 74    E9        ASC   ‘Switch ‘,00
0083CF: 44 65 73 6B    E10       ASC   ‘Desk Acc. ‘,00
0083DF: 44 65 76 69    E11       ASC   ‘Device Driver ‘,00
0083EF: 55 73 65 72    E12       ASC   ‘User1 ‘,00
0083FF: 55 73 65 72    E13       ASC   ‘User2 ‘,00
00840F: 55 73 65 72    E14       ASC   ‘User3 ‘,00
00841F: 55 73 65 72    E15       ASC   ‘User4 ‘,00

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

00842F: 78             CHKSUM    CHK                      ; CHECKSUM FOR VERIFICATION

--End Merlin-16 assembly, 1072 bytes, errors: 0
```

Chapter 19

The Window and Menu Managers

Chapter 19

The Window and Menu Managers

In past chapters, you've seen how to use QuickDraw and the Event Manager and how to use other Apple IIGS tools to make your programming easier. Of course, what you really want to do is to put all those neat-looking windows and menus on the screen. This chapter will show you how to do it.

QuickDraw and Windows

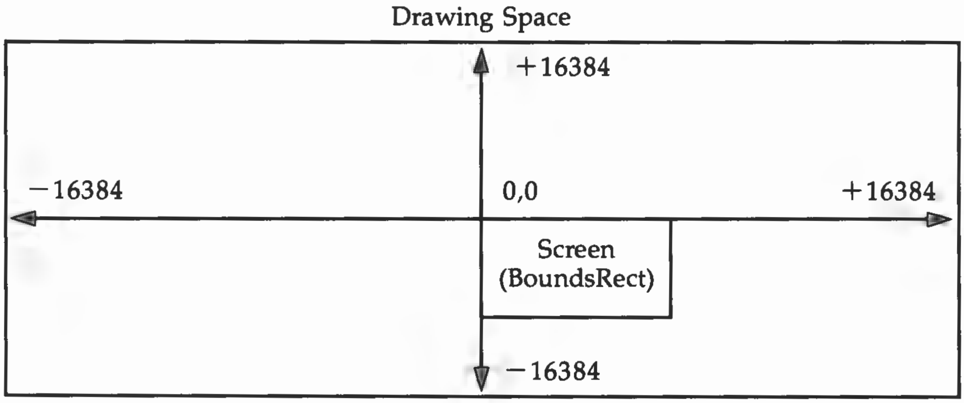
When you started up QuickDraw, it was already operating in a window environment. A window just means that the entire drawing region will be subdivided into a smaller portion for the drawing or viewing actions at that moment. If you imagine these subregions as rectangles, it's easy to explain that QuickDraw starts up with both the drawing space and the active area both set to the entire screen. How could it be otherwise? Just imagine that your drawing space was either bigger than the screen or than just one corner of it. At startup, the upper left corner of the screen has the coordinates 0,0; and the lower right corner (at least in the 320 mode) has 199, 319.

QuickDraw doesn't have to use these coordinates, however. It can make the upper left or lower right corner almost any values you wish, as long as the entire screen remains in the range of −16384 to +16384 both horizontally and vertically. This imaginary drawing space can be represented as a field on which the screen is moved around (see Figure 19-1).

The area representing the total document, a picture, for example, is called the *BoundsRect,* for *Boundaries Rectangle,* and defines the absolute maximum area for drawing. It's possible to set the BoundsRect to a larger or smaller space, and to even point it off into some other part of memory for drawing offscreen, but this is fairly unusual and need not concern you for the moment.

The one thing that is constant for all of the regions discussed here is that the units of measurement, or scaling units, are the same, and are defined in pixel units. That is to say, you cannot arbitrarily take the screen area of 320

Figure 19-1. QuickDraw's Drawing Screen

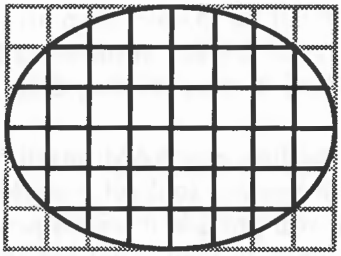


pixels wide and rescale it to a new width of 100 units in the same area. All measurements within QuickDraw and the Window Manager are done in the same pixel units.

There is another rectangle that defines what part of the image (in this case, the screen) will be drawn to at a particular moment. It's easy to see that if you wanted to create a smaller window than the entire screen, you could either have a smaller BoundsRect, or create new rectangle that represented a subdivision of the BoundsRect.

This subdivision is called the *PortRect,* and it represents that actual part to be drawn to. This rectangle exists to provide for the possibility that the entire document might be larger than the screen, and that a smaller rectangle would be required to clip the display to just that part available to the screen. When QuickDraw starts up, the PortRect and BoundsRect are both set to the full screen. When you want to use a window, the Window Manager will automatically set the PortRect to the interior of the window you're using (called the content region), and automatically adjust it as the window is sized smaller or larger.

While drawing in the PortRect, it's also possible to further clip the drawing within regions. Regions are different from rectangles in that they can be any shape at all. These regions are called the *ClipRgn* (for Clipping Region) and *VisRgn* (for Visible Region). The ClipRgn is a mask set up by the application to describe how to clip the image about to be drawn. For example, suppose you wanted to draw a circle with grid lines across it, like this:



Rather than having to start and end each vertical line on the circumference of the circle within some routine, it is much easier to define a circular ClipRgn, and then draw a rectangular grid over it. The ClipRgn will make it so that only the lines within the circle are drawn.

The VisRgn is used most often by the Window Manager to further clip what it has to draw when one window is laid on top of another, and only a certain part is visible. It's similar to the program's use of the ClipRgn, but generally not something you have to be aware of.

All of the parameters for drawing including the BoundsRect, PortRect, Clipping Regions, the pen color, the pen state, and more are grouped together into a total definition of the drawing state called the *GrafPort* (for Graphics Port). The GrafPort data structure (which is a considerable entity) defines all the variables for drawing at that instant. Still more impressive is the fact that the Apple IIGS can maintain a flexible number of individual GrafPorts all at the same time, and quickly switch between them as necessary. This is what makes the multiwindow, multiapplication environment possible on the Apple IIGS.

Generally speaking, though, you won't have to worry about any of these regions other than the PortRect when you use the Window Manager, because all the necessary clipping will take place automatically. All of these rectangles and regions so far mentioned are part of QuickDraw. The purpose of the Window Manager is to insulate you from having to deal with regions and coordinate systems, and to automate the creation and maintenence of windows in which your program will display its data and messages.

The Window Manager: ROM vs. RAM Tool Sets

There is one very outstanding difference between the Window Manager and the QuickDraw tool sets: The Window Manager must be loaded into memory from disk for your program to use it. QuickDraw at least starts out as a ROM-based tool, and—even though patches are made to the basic routines during the boot process for ProDOS 16—it's available to any assembly language routine that wants to call it, including ProDOS 8 system files and routines added to Applesoft BASIC.

The Window Manager, on the other hand, must be loaded from an application running under ProDOS 16, and the System Loader automatically deactivates all RAM tools when switching to ProDOS 8, thus making their use from that environment very difficult.

However, in the ProDOS 16 environment, loading any RAM-based tools your program may require is very simple. The Tool Locator tool set includes a command called *LoadTools,* which only requires that you provide it with a pointer to a list of the code numbers for the tool sets you wish to load. That list also includes the minimum version number for each tool that is acceptable to you. For most applications, specifying zero for the version number will work fine, as this tells the LoadTool command to load whatever version is on the disk.

Tools are stored on the disk with the names TOOL014, TOOL015, and so forth, where the number corresponds to the tool set number given in Chapter 16. The Window Manager is tool number 14, and can be loaded using LoadTools with a code segment like this:

```
TOOLS  PushLong    #TOOLTABL     ; PUSH ADDR. OF TABLE
       ToolCall    $0E01         ; LoadTools
```

and somewhere in your program . . .

```
TOOLTABL  DA  1         ; NUMBER OF TOOLS TO LOAD
          DA  14        ; WINDOW MGR. = #14
          DA  0         ; 0 = ANY VERSION WILL DO
```

All you do is call LoadTools and tell it where the list of the RAM tools you want to load are. RAM tools are always loaded from the SYSTEM/TOOLS directory of the startup disk. Of course, this is one spot in your program where an error is even more likely to be returned if the desired tool is not on the system disk, and so it's generally a good idea to include some code for handling such an error.

You can load more tools by changing the 1 at the beginning of TOOLTABL to equal however many tools will be in the list. For each tool, you must include the tool number and the version number. Zero is the usual default for the version number.

Window Definitions

Like the Event Manager with its Event Record, the Window Manager makes heavy use of something, coincidentally enough, called the *Window Record.* The Window Record includes not only the Grafport for each window, but also information such as the various regions currently displayed in that window, whether there is a title bar at the top, whether there are scroll bars, where to go in memory to execute a window update routine when needed, and more.

When a window is created using the Window Manager tool **NewWindow**, the application receives a handle to the Window Record, which is used from then on as a unique identifier for that window.

There are many different types of windows. How you set up your Window Record will determine how windows produced will appear and operate.

A Window Record is created using NewWindow and a defined parameter list. The contents of that parameter list are shown here and include sample settings for a window with scroll bars, and an UPDATE routine, and can be used as a model for your own Window Records.

Window Parameter List

The window parameter is listed below as it would appear in an assembly listing. Notice that lowercase labels are acceptable in a source listing, and help make the longer labels more readable.

```
WPTR         ADRL   $0000              ; STORAGE FOR HANDLE IDENTIFIER

WTITLE       STR    'Window Mgr. Demo #1'

WINDOW                                 ; DATA STRUCTURE FOR WINDOW

paramlength  DA     windend-WINDOW     ; LENGTH OF DATA BLOCK
wFrame       DA     %1101111111100101  ; WINDOW FRAME DEFINITION
                                       ; BIT 15 = TITLE
                                       ; BIT 14 = CLOSE BOX
                                       ; BIT 13 = (NOT) AN ALERT BOX
                                       ; BIT 12 = VERTICAL SCROLL BAR
                                       ; BIT 11 = HORIZ. SCROLL BAR
                                       ; BIT 10 = GROW BOX
                                       ; BIT 9 = FIXED ORIGIN ON GROW OR ZOOM
                                       ; BIT 8 = ZOOMABLE
                                       ; BIT 7 = DRAGGABLE
                                       ; BIT 6 = ACTIVATE ON CONTENT
                                       ; BIT 5 = WINDOW IS VISIBLE
                                       ; BIT 4 = (NO) INFORMATION BAR
                                       ; BIT 3 = (NO) INDEPENDENT CTRLS
                                       ; BIT 2 = ALLOCATED BY NEWWINDOW
                                       ; BIT 1 = (NOT) CURRENTLY ZOOMED
                                       ; BIT 0 = HIGHLIGHTED
wTitle       ADRL   WTITLE             ; POINTER TO TITLE
wRefCon      ADRL   $0000              ; REFERENCE CONSTANT
wZoom        DA     0,0,0,0            ; ZOOM RECTANGLE
wColor       ADRL   $0000              ; COLOR TABLE
wOrigin      DA     0,0                ; ORIGIN OFFSET
wDataSiz     DA     200,320            ; HEIGHT, WIDTH DATA AREA
wMaxSiz      DA     150,290            ; HEIGHT, WIDTH MAX WINDOW
wScroll      DA     4,16               ; VERT., HORIZ. SCROLL INCREMENT
```

```
wPage          DA     40,160          ; VERT., HORIZ. PAGE INCREMENT
wInfoRefCon    ADRL   $0000           ; INFO BAR REFERENCE CONSTANT
wInfoHeight    DA     0               ; INFO BAR HEIGHT (NONE)
wFrameDefProc  ADRL   $0000           ; FRAME PROCEDURE ADDR. (NONE)
wInfoDefProc   ADRL   $0000           ; INFO BAR PROCEDURE ADDR (NONE)
wContDefProc   ADRL   UPDATE          ; CONTENT PROCEDURE ADDR.
wPosition                             ; CONTENT REGION OF WINDOW
WV1            DA     30              ; UPPER LEFT VERT. POSITION
WH1            DA     20              ; UPPER LEFT HORIZ. POSN
WV2            DA     100             ; LOWER RIGHT VERT. POSN
WH2            DA     200             ; LOWER RIGHT HORIZ. POSN
wPlane         ADRL   -1              ; PUT WINDOW AT FRONT ($FFF.. = -1)
wStorage       ADRL   $0000           ; STORAGE
windend                               ; END OF DATA STRUCTURE
```

The first two lines, WPTR and WTITLE, are not actually part of the window record, but they are kept close by for aesthetic reasons. Each window is uniquely identified by a handle to its Window Record, and WPTR is a storage location to keep the handle to a window. WTITLE is the string of text that you would like to be used as the title to the window.

The window parameter list actually begins at WINDOW, which marks the beginning of the data structure. Paramlength, the first entry in the table, is an error-checking device. A properly set up parameter list should use $1E bytes, and the Window Manager will check this number to make sure your table is properly constructed.

wFrame is a two-byte value that defines which of the many possible window elements will be used in the frame of your window. Each bit in wFrame determines whether a particular element is active. The wFrame value used in this example produces a draggable, resizable window that is typical of the windows used in many Apple IIGS applications.

Each bit is assigned as follows:

Bit 0: HiLited. This is set to 1 when your window is highlighted. This is automatically set when the window is first started up with the Window Manager call *NewWindow*, so the value in the assembled table doesn't matter. The main use is to provide the option of checking to see whether a window has been highlighted while you weren't looking.

Bit 1: Zoomed. This indicates whether the window is in a zoomed or unzoomed state. Setting this in your definition tells the window manager which state to start off with. The zoom box is a control, present at the upper right corner of a window, if so specified in the Window Record. The user clicks in the zoom box to automatically resize the window, most often to the full size of the screen. If the Zoom bit (bit 8) in the wFrame word is not set, this bit is ignored.

Bit 2: Allocated. This is set to indicate that the memory used for the Window Record was not allocated automatically using the NewWindow command. This must be zero if wStorage is zero (the most common situation).

Bit 3: Control Tie. This is usually set to 0 to specify that when the window is not active, its controls, such as scroll bars, will be deactivated. Otherwise the controls are independent of the window's active status.

Bit 4: Information Bar. Some windows may include a bar below the title bar called the *information bar*. In a word processor this might be an ongoing display of the number of words in the document, the line and page you were on, or whatever else the designer wished to display. Leave this set to 0 for now. Set bit 4 to 1 if you want an information bar below the title bar.

Bit 5: Visible. This bit can be set to zero if you want to allocate a window without making it visible. ShowWindow can then be called later, when you want the window to appear. For most applications, however, set this bit to 1 (visible).

Bit 6: QContent. Although it hasn't been discussed yet, there is a part of the Window Manager called *TaskMaster* that will handle certain operations automatically for you. Setting this bit tells TaskMaster that you want it to automatically activate a window that the user has clicked the mouse in, and then to pass the mouse-down event to your application. If this is set to 0, TaskMaster will still activate the window, but it will not pass the mouse-down event to your application. This means the user will have to double-click in the window to actually make something happen, once to activate the window, a second time for your application to see the click at all.

How you set bit 6 is a combination of personal choice in program design, and a consideration of the impact of automatically passing the event through. Try it both ways in the demonstration programs that follow, and see which you prefer.

Bit 7: Move. This determines whether the window can be moved by dragging the title bar. This setting is entirely up to you. Generally speaking, a setting of 1 for this bit is most common (window is draggable).

Bit 8: Zoom. If set to 1, the Window Manager will automatically put a zoom box in the upper right corner of the window frame. The window must have a title bar specified (bit 15 = 1) if this is to be used. Zooms can also be automatically handled by TaskMaster, so this is a nice touch.

Bit 9: Flex. This bit tells the Window Manager what to do when the window grows larger than the data you have to fill it with. If set to 1, the origin (the upper left corner) of the window area stays fixed and white space appears in the lower right corner as the window in enlarged. If the bit is clear, the white space will be padded in the upper left of the window, and the origin will move down and to the right (that is, what you're drawing will move with the lower right corner).

Bit 10: Grow. Setting this tells the Window Manager to put a grow box in the lower right corner of the window. This can only be specified if there is also a horizontal scroll bar (bit 11 = 1), a vertical scroll bar (bit 12 = 1), or both. The grow box allows the user to resize the window dynamically on the screen. This bit is set in the demonstration program.

Bit 11: Bottom (horizontal) Scroll. This tells the Window Manager to include the scroll bar for horizontally adjusting the content region of the window. If the window grows or is set to the maximum size, the scroll control will be deactivated automatically. Set to 1 for a horizontal scroll bar.

Bit 12: Right (vertical) Scroll. This tells the Window Manager to include the scroll bar for vertically adjusting the content region of the window. If the window grows or is set to the maximum size, the scroll control will be deactivated automatically. Set to 1 for a vertical scroll bar.

Bit 13: Alert. Used by the Window Manager for creating dialog boxes and so forth that have a double-line frame, called an *alert box*. For windows you define in your application, this bit should be 0.

Bit 14: Close. If this bit is set to 1, the Window Manager will automatically provide a close box in the upper left corner of the window. If the user clicks in the close box, this event will be passed to your application, at which point you have to handle it by closing the window, erasing the contents, or whatever other action you desire.

Bit 15: Title. Set this bit to display a title at the top of your window. If you do set this bit, you should include a pointer to the string to use in the wTitle part of the Window Record.

That finishes the bit definitions in wFrame. Here are the other parameters in the list:

wTitle is a pointer to the location of the title of the window, presuming that the Title bit (bit 15) in wFrame has been set. The string should begin with a length byte.

wRefCon (for window Reference Constant) defines a storage area that your application can store a 4-byte value in. What you store there, if anything, is entirely up to you. Some programs use these four bytes to store the handle to the Window Record (this example uses WPTR for this, instead).

wZoom defines the maximum rectangle size to be used when the user clicks in the zoom box. This presumes that bit 8 has been set in the wFrame mask. Specifying a rectangle of 0,0,0,0 defaults a zoom to the entire size of the screen, minus the menu bar, if it's there. If you start with the zoomed flag (bit 1 in wFrame) set to 1, the Window Manager uses this value to determine the opening size of the window. If bit 0 in wFrame is clear (not zoomed), the Window Manager uses the wPosition rectangle as the starting size for the window. Once things are rolling along, clicking in the zoom box alternates between the wZoom rectangle and the previous size of the window, even if that has changed from wPosition because the user has resized the window.

For wZoom, and most other QuickDraw point and rectangle definitions, remember that the Y coordinate is given first, then the X coordinate. Thus wZoom is defined as V1,H1,V2,H2 where V1,H1 are the vertical and horizontal coordinates of the upper left corner of the window, and V2,H2 are the vertical and horizontal coordinates of the lower right corner of the window.

Although most windows look fairly standard, and use black, gray and white to draw the window, it is possible—and easy—to redefine the different parts of the window frame. wColor in the window parameter list specifies which color table you would like used in drawing the window frame. The default entry for this is $0000, which defaults to color table #0, but you can put the address of one of the other color tables or a table you've put somewhere else in memory here.

wOrigin determines where in the underlying coordinate system the window will be opened. Ordinarily, you would start with this offset value being 0,0, but you can make it anything you want.

Let's suppose that you have a drawing that is 200 pixels in height and width. For sake of illustration, further suppose that the window you are going to open to display this image is only 100 pixels in height and width. This necessitates a choice on your part: You can either open the window on the upper left corner of your picture (origin = 0,0), or choose to more-or-less center the window on the document (origin = 25,25), or perhaps even the last place the person made a change to the picture (origin = variables).

wDataSiz represents that maximum size of the data the window will be scrolling over, which is necessary for the scroll bar thumbs (the movable box) to be properly scaled and positioned.

wMaxSiz lets you specify what the maximum size of the content (interior) portion of the window will be. With any kind of controls, such as the title bar or other control, the window itself will be larger than this, so remember to take this into account when calculating your largest size. You can set this to zero if growing to the maximum size of the DeskTop is acceptable to you.

wScroll sets the number of pixels you want the window to change when the arrow controls are pressed (when using a scroll bar).

wPage permits the user to click in the open space on either side of the scroll thumb to move a screen (or page) at a time.

wInfoRefCon is a storage location in which you can put a 4-byte value that will be passed to the routine that draws the contents of the information bar (see wInfoDefProc parameter description). This could be the pointer to a string, or to any other value your routines might require. (Set this to zero for most cases.)

wInfoHeight defines how tall, in pixels, the information bar will be. Set this to zero if you're not using an information bar.

wFrameDefProc (for window Frame Definition Procedure) defines the address of a routine which will draw the entire window frame. Use a zero here unless you're very creative. Although most windows you see all seem to be about the same, it's possible to have your own routine create the window, instead of the Window Manager, if you wish.

wInfoDefProc (for window Information Bar Definition Procedure) specifies the address of the routine that will be used to fill in the information bar. If you're not using an information bar, set this to zero.

Whenever a window is moved, opened, or made visible by another window on top of it being moved or closed, it is necessary to update (redraw) the contents of that window. Many times, this update will be required because of something completely unrelated to that window, such as the opening or moving of a desk accessory, or the activity of other windows on the DeskTop.

wContDefProc (for window Content Definition Procedure) defines the address in memory where the routine to draw the contents of your window is located. In the sample listing discussed earlier, this is shown as UPDATE, the label to a routine elsewhere in the program. This may be set to zero if you want to manage all the updating yourself, but it is much easier to have the Window Manager call your routine for you as needed.

wPosition is used to determine its initial size and position on the DeskTop when your window is first opened, . This is usually specified assuming that 0,0 is the upper left of the DeskTop. This will be the same as the upper left of the screen if there is no menu bar. If a menu bar is used, 0,0 corresponds to the upper left corner of the active DeskTop area just below the menu bar.

wPlane allows the positioning of windows in other front to back positons. When a window is opened, you normally want it in front of any other windows on the DeskTop at that point. However, you may want to be able to position the window in other front to back positions. If you set wPlane = $FFFFFFFF (−1), the window will be opened in front of any other windows. If wPlane = 0, the window will be opened behind any other windows on the DeskTop. For any other position, you must specify the handle of the window behind which the new window should be placed. At that point, it is up to your application to determine and manage the handles to other windows on the DeskTop as needed.

wStorage is an optional address to where the Window Record will be created. Normally, this is zero, and the Window Manager, through NewWindow, sets aside about 300 bytes somewhere in memory to keep its own Window Record. However, this parameter is provided to allow for the possibility that you might want to allocate your own Window Record somewhere in memory other than that normally set up by NewWindow. This is flagged by bit 2 in wFrame being set, and by specifying the address of a Window Record area you have provided for in the wStorage field.

Local and Global Coordinates

You have seen how the screen is given a set of coordinates, usually in the range of 0–199 and 0–319. If you think about it, though, what you really want are your own set of coordinates within the window as it is moved around on the DeskTop. Ideally, moving the window should have no effect on your application's attempts to draw data within the window. The difference in coordinate systems leads to the concepts of the global and local coordinate systems. When specifying where to open a window on the DeskTop, you are dealing with global coordinates, in which 0,0 (the origin) is usually in the upper left corner.

When drawing in a window whose scroll bars are in their home position (not scrolled), you want the upper left corner to be 0,0, regardless of where the window is at on the DeskTop. Within the window, your location is defined in local coordinates, local to that window. As the scroll bars are used, the Window Manager will automatically adjust the local coordinate system so that the coordinates of the upper left corner of the screen is appropriate for the current scroll position.

Obviously, 0,0 can't be simultaneously the upper left corner of both the screen and the window. The next best thing though is to have the Window Manager switch coordinate values as needed, depending on whether you are drawing in a window or dealing with the DeskTop. When the window has 0,0 within it, the global coordinates of the upper left of the screen will temporarily become negative. However, this won't matter to you because at that moment your window will be your frame of reference (an appropriate choice of words).

TaskMaster

With the tools you're familiar with so far, managing windows would still be pretty involved. Imagine your program in the main loop calling the Event Manager. A mouse-down event comes back, and now you have to determine whether it was in a window, which window it was, and whether it was on a scroll bar, on the close box, and so on. Once you've determined where the event took place, you then have to be able to move the window if necessary, or resize it, or otherwise handle the possible changes to the window.

As it happens, there are specific routines, like FindWindow ($170E), that will help you determine where a mouse-down took place, and other tool calls, like SizeWindow ($1C0E), that you can use, but there is an even easier way. Part of the Window Manager includes a routine called *Taskmaster*.

TaskMaster is an automated function built into the Window Manager that handles things like scrolling, zooming, dragging a window, and more—all without the slightest bother to your application. When the user clicks in a window, or drags the grow box or the title bar, the appropriate action is automatically handled by TaskMaster. The window is resized, or repositioned on the DeskTop, or has done whatever else needs to be done without you having to put any equivalent routines in your own program. What this really means is that you can write a very professional-looking program in far fewer lines of code than would otherwise be required.

TaskMaster itself involves more than just the Event Manager, QuickDraw, and the Window Manager. The scroll bars in a window are called *controls*, and require the services of another Apple IIGS tool, the Control Manager. A control is any user-input display item including scroll bars, push buttons, check boxes, dials, and other elements in any window or dialog box. In addition, TaskMaster will also help with user input with menus, and will return to your application a number code for the menu item chosen. This, however, requires interaction with another Apple IIGS tool, the **Menu Manager**.

Not too surprisingly, the Menu Manager is the set of routines related to creating, displaying and manipulating pull-down menus on the Apple IIGS.

If you want to write a program that only uses simple windows without scroll bars or grow boxes, and that uses **GetNextEvent** for all the input, it is possible to use the Window Manager, QuickDraw, and the Event Manager by themselves. However, for any program using TaskMaster, the Control Manager must be loaded and started up if the windows will use scroll bars or other controls, and the Menu Manager must also be loaded and started up if you intend to use menus in your application.

Like the Window Manager, the Control Manager and the Menu Manager are RAM-based tools that must be loaded using the LoadTool command in the Tool Locator. All three tools can be easily loaded with a code segment something like this:

```
TOOLS  PushLong   #TOOLTABL     ; PUSH ADDR. OF TABLE
       ToolCall   $0E01         ; LoadTools
```

and somewhere in your program . . .

```
TOOLTABL  DA  3          ; NUMBER OF TOOLS TO LOAD
          DA  14         ; WINDOW MGR. = #14
          DA  0          ; 0 = ANY VERSION WILL DO
          DA  15         ; MENU MGR. = #15
          DA  0          ; 0 = ANY VERSION WILL DO
          DA  16         ; CONTROL MGR. = #16
          DA  0          ; 0 = ANY VERSION WILL DO
```

The Menu Manager

To put menus in a program without the Apple IIGS tools, you first have to allocate an area at the top of the screen and print the available menu headers there, and then you have to wait for a mouse-down event in a menu header, indicating the user wants to view a menu. You also have to create a data structure somewhere in memory that contains a list of all of the choices for each menu item, along with any additional indicator bytes, such as whether a particular menu item has a check mark by it or is disabled (printed in dimmed text). You might also want to allow the user to press a keyboard equivalent of the menu choice. Of course, that means every time a key is pressed, you'll have to scan your complete list of menu entries to see if there is a match.

The Menu Manager is a tool set of routines that makes this process easier than having to write everything yourself. There are routines like **DrawMenuBar**, which automatically draws the entire menu bar, and **InsertMenu**, which tells the Menu Manager to add a new list of menu choices to the menu bar. There are even functions like **EnableItem** and **DisableItem** to make a menu choice disabled or not. But the best news is yet to come: TaskMaster also helps with the menu selecting process itself, and the net result is that you don't have to look for the mouse-down in a menu, or even a keyboard equivalent. TaskMaster will handle all of this for you, and will return as an event an identifying code number for whatever, if any, menu item selected by the user.

The menu bar in an application is supported by an internal menu list that keeps track of each menu (indicated by the various headings, or menu titles) in the list, and the individual items (menu items) in each menu. The menu list can be added to or altered at any time by adding new menus across the top, or by changing individual menu items in a particular menu.

Table 19-1 lists some of the Menu Manager calls used most often.

Table 19-1. Menu Manager Tool Set Calls

Command Value	Command Name	Description
$010F	MenuStartUp	Starts up Menu Manager.
$030F	MenuShutDown	Shuts down Menu Manager and frees the top of the screen, the memory allocated to menus, and so forth.
$2D0F	NewMenu	Adds a new menu to menu list.
$2E0F	DisposeMenu	Removes a menu from menu list.
$130F	FixMenuBar	Menu Mgr. recalculates width of each menu and entries for proper appearance after changes have been made.
$2A0F	DrawMenuBar	Draws current menu bar, along with menu titles.
$2C0F	HiliteMenu	Highlights, or unhighlights, the title of a specified menu. Call after TaskMaster returns a menu event to unhighlight the title.
$0D0F	InsertMenu	Inserts a new menu in menu list.
$0E0F	DeleteMenu	Deletes menu from menu list.
$0F0F	InsertItem	Inserts item in a menu.
$100F	DeleteItem	Deletes item from menu.
$300F	EnableItem	Displays menu item normally.
$310F	DisableItem	Displays menu item in dimmed text and disallows it from being selected.
$320F	CheckItem	Adds or removes check mark from an item.

Menu Definition

Defining a menu centers around creating a data structure which contains the items in a particular menu. One of the simplest possible menu definitions would look like this:

```
MENU  ASC   '>> Title  \N1',00
      ASC   '--Item1  \N257',00
      ASC   '--Item2  \N258',00
      ASC   '.'
```

A menu definition is made up of successive ASCII strings, each terminated by a zero (or alternatively, a carriage return (decimal 13 = $0D)). The beginning of each string contains two more-or-less arbitrary characters that help define the menu title, each item in the menu, and the end of the items for that menu.

In the example, the characters >> signify the beginning of a menu and designate that string as the title of that menu. The next two lines each begin with the characters -- . These signify the individual items in the menu, and the leading characters must be different from the title characters. The menu is terminated by using a character different than the item characters. Notice that only one termination character is needed, and it is not necessary to terminate that string with a zero or carriage return.

You may use any leading characters you wish as long as the item characters are different from the title and terminator characters. For example, an equally legal menu definition could look like this:

```
MENU  ASC   '## Title  \N1',00
      ASC   '..Item1  \N257',00
      ASC   '..Item2  \N258',00
      ASC   '?'
```

As a matter of appearance, it's generally best to put a space on either side of menu titles, and to end each menu item with a space, but this is not required.

The title and item names themselves are delimited at the end by the reverse slash (\ ), after which follows the identifier number for that menu or menu item. Each menu title must be uniquely numbered in the range of 1 to 249, and each menu item (also unique) must be in the range of 256 to 65535. The missing numbers of 250 to 255 are reserved for special editing items, specifically:

Item #	Description	
250	Undo	Cancels last editing operation.
251	Cut	Cuts selected text and puts it on clipboard.
252	Copy	Copies selected text and puts it on clipboard.
253	Paste	Inserts text on clipboard in document.
254	Clear	Cuts selected text but doesn't put on clipboard.
255	Close	Closes active window.

By using these ID numbers for these functions, any Desk Accessory that uses TaskMaster will automatically have access to these menu choices while its window is active.

Although you can give the menu items almost any number value you want, most program listings you'll see start with 256 for the first menu choice, and number from there. This is so they can use the same indexed indirect addressing mode for the command handler discussed in Chapter 10. For example, suppose you had the menu ID numbers 256, 257 and 258. These could all be handled with a code segment like this:

```
LDA   MITEM          ; GET MENU ITEM #
SEC
SBC   256            ; ADJUST TO 0,1,2 . . .
ASL                  ; TIMES 2 = 0,2,4 . . .
JSR   (MENTBL,X)     ; USE TABLE OF ADDRESSES
JMP   MAIN           ; BACK TO MAIN LOOP
```

```
MENTBL  DA   ITEM1          ; ROUTINE FOR ITEM 1
        DA   ITEM2          ; ROUTINE FOR ITEM 2
        DA   ITEM3          ; ROUTINE FOR ITEM 3
```

If you want to be really tricky and save a line of code, you can also use the AND instruction to mask off the high byte from the value for the menu item. This is equivalent to subtracting 256 as long as you don't have a menu item number greater than 511 ($1FF):

```
        LDA  MITEM          ; GET MENU ITEM #
        AND  #$00FF         ; ADJUST TO 0,1,2 . . .
        ASL                 ; TIMES 2 = 0,2,4 . . .
        JSR  (MENTBL,X)     ; USE TABLE OF ADDRESSES
        JMP  MAIN           ; BACK TO MAIN LOOP
```

Even though it only saves one byte, it's mentioned here since you may come across it in sample listings.

You can also include a few special characters at the beginning of your title or menu item string for certain effects. The first is the use of a dash character as the first character of a menu item string, like this:

```
        ASC  '..- \N258D',00
```

The Menu Manager interprets a dash to signify a horizontal line in the menu at that position. Notice that as a menu item, it must still have its own ID number, in this example, 258. The *D* at the end is used to disable that line, so the user doesn't inadvertently select it. Special menu modifiers like D will be discussed in more detail shortly.

In a complete menu, the use of the dash would look like this:

```
MENU    ASC  '>> Title  \N1',00
        ASC  '. . Item1  \N257',00
        ASC  '. . - \N258D',00
        ASC  '. . Item2  \N259',00
        ASC  '%'
```

The other special menu name is the symbol @ (at sign) for the Apple logo character as a menu bar title. This is only used as the title for the first (left-hand) title in the menu bar, and appears as follows:

```
MENU    ASC  '>>@ \N1X',00
        ASC  '—Item1  \N256',00
        ASC  '.'
```

The @ symbol must not have any spaces or other characters other than the title character and end-of-title delimiter. The Apple menu is also different in that a special form of highlighting must be specified, called color-replace highlighting. Because the title, that is the Apple icon, is in color, the normal inverting would make the Apple colors change as well. In color-replace highlighting, only the white background of a colored object is inverted. If for some reason you had a color title or an item name, you would request this type of highlighting. Color-replace highlighting is signified with the X character at the end of the title definition string.

The Apple menu is used as the heading for any desk accessories that may be available, and any other special functions you wish to include. However, it's not possible to define a menu with zero entries. Because there may not be any desk accessories available when your program runs, you should always include at least one of your own menu items in the Apple menu. Usually this is the *About This Program . . .* item that many programmers use to tell about the application.

Designators

Each string in the list of menu items has encoded into it not only the string and identifying number for the menu title or item, but also optional special designator characters that indicate whether that menu item is disabled, what the keyboard equivalent is, if any, and other such information. You have already seen some of these in the form of the X and D characters mentioned a little earlier. The reverse slash (\ ) is used to terminate a menu title or item name. There is no way to include the character \ in a name itself. The special designator characters are placed at the end of the title or item string following the name terminator (\ ) and may be used in any order you wish.

These designators may be used in either a title or a menu item name and are used as follows:

Character	**Description**
N	Title or item ID # (decimal) follows.
H	Title or item ID # (hex) follows.
D	Disables title or name.
X	Uses color-replace highlighting.

Item numbers may be either included in the string as an ASCII string value or defined as a two-byte word. The character *N* designates an ASCII number, which is stored a character at a time. For example, in the string:

```
ASC    ‘--Item1  \N256’,00
```

The number 256 is stored as $32 $35 $36, the ASCII characters for 256. If for some reason you want to encode the menu item as a number value, you can define the line like this:

```
ASC   ‘--Item1 \H’
DA    $103
ASC   ‘D’,00
```

In this case the special character *H* tells the Menu Manager to expect a two-byte value for the menu item, which is then followed by the special character *D* for a disabled menu item, and the string terminator $00.

There are also a few other special characters which can only be used in the menu item names, not in a title. They are as follows:

Character	Description
B	Displays the item in bold text.
I	Displays the item in italic text.
U	Underlines the item name.
*	Keyboard (Open Apple) equivalent letters follow (two characters, always).
C	(Check)Mark character follows.
V	Puts dividing line under this name.

The *B*, *I*, and *U* characters are self-explanatory. The asterisk is used to specify the characters that you will accept as a keyboard equivalent for that menu item. For example, if we wanted to accept Open Apple–Q to quit our program, this menu item would do it the trick:

```
ASC   ‘--Quit \N258*Qq’,00
```

Generally, the second keyboard character is the lowercase equivalent of the first character, so that the status of the Caps Lock key won’t matter when the user presses the Q key, but in theory the two characters can be anything you want.

The letter *C* is used to designate the check-mark character that will be used at the far left of the menu item. This is usually used to show that a menu item, for example show page breaks, is active. The check character can be anything you wish. For example, this would define an *x* as the mark for a menu item:

```
ASC   ‘--Show Page Breaks \N258Cx’,00
```

As you noticed in the Event Manager demonstration program, ASCII characters 17, 18, 19 and 20 ($12, $13, $14 and $15 = Control-Q, Control-R, Control-S, and Control-T) have been given special definitions. To get a real check mark in your menu, you can embed the proper ASCII value in your menu string like this:

```
ASC   ‘--Show Page Breaks \N258C’,12,00
```

This puts the value $12 (18 decimal) after the C in the menu item definition.

Although the dash is available to create a dividing line between menu items as mentioned earlier, you can also include a *V* character in the special characters at the end of the name to create a solid underline that goes all the way across the menu underneath a given item. This avoids having to define a disabled item to create the line, and it also means you can fit more items in the complete vertical menu.

A menu item with an underline divider below it would look like this:

```
        ASC   '--Item1  \N256V',00
```

You can combine as many of these special characters as you wish in a single menu-item definition. Although crowded, this is legal:

```
        ASC   '--Item1  \N256VXBIUCx*Aa',00
```

A typical menu list could look like this:

```
MENU2   ASC   '>> Title2  \N2',00
        ASC   '--Item1  \N257V*Aa',00
        ASC   '--Item2  \N258D*Bb',12,00
        ASC   '--Item3  \N259V',00
        ASC   '--Item4 \N260*Qq',00
        ASC   '--- \N261D',00
        ASC   '.'
```

A menu is added to the Menu Manager's menu list by calling **NewMenu** ($2D0F) and passing it the address of the new menu data structure, like this:

```
        PushLong MENU2      ; POINTER TO OUR DEFINITION
        ToolCall $2D0F      ; NewMenu
        PullLong MENUHD     ; SAVE MENU MGR. HANDLE
```

Construction of the Menu Bar

Defining a menu doesn't put it in the menu bar, however; this just returns a handle to the menu definition so you can add it when you want later. Constructing the menu bar itself is done by repeatedly calling the tool **InsertMenu** ($0D0F). Although you can pass this tool a position value for where you want the new menu inserted, a simple application can just keep calling the routine and inserting each new menu at the far left. Thus, if you want the menu titles FILE, EDIT, and PENS in the menu bar, you call InsertMenu three times with PENS, EDIT and FILE, in that order.

```
        PushLong MENUHD     ; PUSH HANDLE TO MENU
        PushWord #$0000     ; INSERT AT LEFT
        ToolCall $0D0F      ; InsertMenu
```

Because the Apple icon menu involves desk accessories that the application itself will not know about, there is a call to the Desk Manager tool set, **FixAppleMenu** ($1E05) that is done to automatically add any available desk accessories to the specified menu. Since this is usually menu #1 with the Apple icon, this call looks like:

```
PushLong #$0001      ; MENU NUMBER
ToolCall $1E05       ; FixAppleMenu
```

Once all the menus have been defined and inserted in the menu bar, the Menu Manager needs to be told to calculate some internal constants for the size of the longest menu names, and the height of each name and the menu bar using the current font. This is done with **FixMenuBar** ($130F):

```
PushWord #$0000      ; SPACE FOR RESULT
ToolCall $130F       ; FixMenuBar
PullWord HT          ; RETURNS HEIGHT OF BAR
```

This call returns the height of the menu bar in pixels, but this is unlikely to be needed by your application, so is usually ignored. (You do have to pull it off the stack, but you don't have to keep the result.) You must call FixMenuBar whenever you change any menu item or list.

That pretty much takes care of it, except for one thing: We've got to draw the new menu on the screen. This is done with **DrawMenu**:

```
ToolCall $2A0F       ; DrawMenu
```

Program 19-1 will create just about the simplest menu bar there is, and it will open a single window.

A Simple Menu Bar

Although Program 19-1 looks like the previous ProDOS 16 examples, there are some significant additions. When run, it opens a window on the DeskTop that you can drag by its title bar, resize with the zoom or grow box, or close (along with quit the program) by clicking in the go-away box. There is a very empty menu bar at the top of the screen with the Apple icon. If you have any New Desk Accessories, such as the clock, on your startup disk, these will appear in this menu.

Try opening a desk accessory and moving it around on the DeskTop with the sample window. Notice what happens when one window overlaps another. Click in the content region of each window successively and notice how each is activated while the other becomes inactive. When you're done with the program, click in the go-away (close) box, and the program will return to whatever program selector was used to run it.

Although similar to the Event Manager demo program, this program adds some new techniques needed for a program that supports the Window and Menu Managers. The first change is found in the **STARTUP** section, where the instruction **TDC** (Transfer Direct Page to C Accumulator) is found. This instruction copies the Direct Page Register address (a two-byte value) into the Accumulator. The letter C is used for the Accumulator to remind you that two bytes are always transferred, regardless of whether the Accumulator is currently in the 8- or 16-bit mode at that instant.

Once transferred to the Accumulator, the direct-page value is saved in **MYDP**. This will be needed in the routine that refreshes the contents of our window, called the *update* routine. This routine is called by TaskMaster automatically, and at that time the direct page on entry to our routine will be that used by TaskMaster, not our program. If our routine needs any direct-page space, such as for an indirect pointer, it will have to temporarily save TaskMaster's direct page, switch to ours, do the update, and then restore TaskMaster's direct page. This will require that our direct page value be on hand when **UPDATE** is called. Storing it in MYDP accomplishes this.

The next new item is the generation of a third UserID in the **MM** (Memory Manager startup) routine. Strictly speaking, the ORA $0200 on line 49 does not produce the second ID possible ($1202 for example), but rather produces the third ($1303) because the Accumulator at that point already holds $1102 from the previous instructions ($1102 ORA $0200 = $1302). In our case though, it really doesn't matter as long as the UserID is different from the other two.

In **GETDP**, because we'll need direct page for the Menu Manager and Control Managers in addition to that previously obtained for the Event Manager and QuickDraw, a total of 6 pages ($600) of memory are obtained, and the base address is stored in our variable **DP**. As each block of direct page is assigned, DP will be incremented by the amount just used so that each new assignment will begin at the next available address (see lines 114 to 117 for example).

LOADTOOLS, on line 92, loads the RAM-based tools using the table TOOLTBL on lines 343–350. If you examine TOOLTBL, you'll see that the Menu Manager, Window Manager and Control Manager are loaded from the startup disk.

Once these are loaded, WM, CTRL and MENU start up each tool, followed by DESK, which starts up the Desk Accessory Manager in preparation of setting up the Apple icon.

APPLE begins the portion of the program that actually creates and displays the menu bar. NewHandle is first used to allocate memory in the Menu

Manager for MENU1, which will be the Apple icon menu. Looking at MENU1, you can see there is only one entry with a message you can customize. This menu item has a dividing underline to set it off from any desk accessories that may be listed. At least one menu item must be defined here to protect against the possibility that there are no desk accessories on the disk, which would result in an empty menu.

Once the handle for the menu has been obtained and stored, the menu is added at the left of the menu bar with InsertMenu. DESKACC then calls FixAppleMenu to add any desk accessories to this menu. FIXBAR completes the menu bar definition followed by DRAWMENU, which displays the complete menu bar. If you had further menus you wanted to define and add to the menu bar, those instructions would be inserted before the APPLE routine, and they would be inserted in reverse order. There will be an example of this in an upcoming program.

Now it's time to open a window. Since this is a generalized routine that may be called many times within a program, OPEN is set off as a separate routine on lines 209 to 215. Let's see what OPEN does. As you can see, the routine is very short. All it does is pass a pointer to a window definition, WINDOW (lines 373–416), and call NewWindow ($090E), from which is returned the handle to the Window Manager's window record for this window. This is saved for future reference in WPTR, and the OPEN routine is finished.

If the visible bit is set in the wFrame definition, the act of calling NewWindow automatically opens the defined window at the position and size indicated within the window parameter list. TaskMaster will automatically keep track of the window from then on, until the window is closed, which will be discussed shortly. The parameter list for the defined window is based on the list described earlier in this chapter. You should look it over carefully to make sure you understand each component of the data structure.

The main event loop is on lines 153–184, in the sections MAIN, EVT and DOCMDS. MAIN is similar to the Event Manager demonstration program, except that this time we call TaskMaster ($1D0E) on lines 153–156. Notice that the call structure with the event mask, points to each item in the identical as in GetNextEvent.

The main difference in using TaskMaster over GetNextEvent is that the event record, EVRECORD (lines 314–339) must be extended to add two new variables, TDATA and TMASK. TDATA is where TaskMaster will return information about which menu item (first two bytes, TDATA) and which menu title (third and fourth bytes, TDATA+2) were chosen. TMASK is a mask used to tell TaskMaster which events it should handle automatically. Each bit in

TMASK specifies a certain type of event, as follows:

Bit	Description
0	Menu keys.
1	Update handling.
2	Find window.
3	Menu select.
4	Open New Desk Accessories.
5	Clicks in New Desk Accessory windows.
6	Drag window.
7	Select window if click in content region.
8	Track go-away box.
9	Track zoom box.
10	Track drag box.
11	Handle scrolling.
12	Handle special menu (#s 250–255) events.
13–31	These bits always clear (reserved).

By selectively setting specific bits, you can elect to have TaskMaster automate only certain functions. Functions not handled by TaskMaster will be passed on to your application as an event. When TaskMaster is called, an event code indicating some type of window or DeskTop event is returned on the stack. The event could be related to the user clicking in a window, in a window control like a zoom box, or in a menu event like selecting an item from a menu.

Event Code	Abbreviation	Description
$0000	wNoHit	No event.
$0010	wInDesk	In desktop, but not in a window or menu.
$0011	wInMenuBar	In the menu.
$0013	wInContent	Within the content region of a window.
$0014	wInDrag	Within the window's drag region.
$0015	wInGrow	Within the window's grow box.
$0016	wInGoAway	Within the window's go-away (close) box.
$0017	wInZoom	Within the window's zoom box.
$0018	wInInfo	Within the window's information bar.
$0019	wInSpecial	Special menu item selected.
$001A	wInDeskItem	Desk Accessory was selected.
$001B	wInFrame	Within the frame of a window.
$8xxx	wInSysWindow	Within a desk accessory window.

Not all of these codes will always be returned. They are actually originally generated by the Window Manager tool **FindWindow** ($170E), which TaskMaster uses to see where a click or other mouse-down event occurred. If the TaskMaster TMASK has been set to handle the event, your application may not see an event code at all. For example, if the Track Zoom Box is enabled (bit 9 in TMASK), TaskMaster will handle the zoom action for you. Other events, like selecting a menu item, are returned by TaskMaster as an event, at which your application should check TDATA and TDATA+2 to handle the menu item selected.

The Main Loop

Let's look at the main event loop to see how various events returned by TaskMaster are handled in the sample program.

GETEV starts the processing by pulling the result of the TaskMaster call off the stack. If the value is zero, then either no event has occurred or TaskMaster has handled some particular event for us and nothing remains to be done. The application will spend most of its time looping back to MAIN in this part of the program.

When an event that TaskMaster could not complete occurs, the BEQ test fails, and program execution falls through to EVT. At this point, I've included a JSR to a do-nothing routine called *SPECIAL* that could be used to do any special processing for every event, regardless of what type it is. This routine will be expanded in an upcoming program example. Remember that the Accumulator now holds the TaskMaster event code (any routine at SPECIAL must take care to preserve this), and line 167 checks to see if the event was a menu event ($11). If so, a JSR to the routine DOMENU is called.

DOMENU looks at TDATA for the menu item number that was selected, and tests to see if is was our custom message. In this case, it is ignored by jumping to the exit to the DOMENU routine, but a real application would handle the menu choice any way it wanted at that point. Any additional menu items can be tested and handled in a similar manner.

When a menu item has been selected, TaskMaster leaves the menu title inverted when it returns to your application. After completing whatever action for that menu item you wish, your application should unhighlighting the menu title. NORMAL does this by calling **HiLiteMenu** ($2C0F). This tool is used by passing it either a zero (for unhighlight) or a nonzero value (for highlight), and the menu title number for the menu you wish to highlight. NORMAL sets the highlight to unhighlight and uses TDATA+2 to determine the current menu title that was selected.

The idea behind unhighlighting being the last action in a menu event handler is that the user can see something has happened while waiting for the routine to do its job. This may seem unneccessary for a routine that acts instantly, but for any function that may take more than a few seconds, it lets the user know something has happened. Particularly with a keyboard equivalent, leaving the menu title highlighted may be the user's only indication as to why the keyboard appears to be no longer responding.

If the TaskMaster event doesn't indicate a menu event, we next check for a click in the close box ($16). If there is one, the program jumps to SHUTDOWN. In addition to the usual shutting down of any tools and de-allocating any memory we've used, SHUTDOWN now closes the window with the routine CLOSE (lines 235–249). Closing a window can mean two different things, and it's important to understand the difference.

When the user closes a window, it may mean just hiding the window from view, or it may mean actually disposing of the window and any associated documents or memory blocks in use related to that window. Our CLOSE routine does the latter, completely removing our window from the control of the Window Manager and TaskMaster, and de-allocating any memory associated with that window. CLOSE in this form should be called only when you're absolutely done with a window and its data.

If there are several windows open on the screen when your application receives the close event, you will need to first determine which window was active and needs to be closed. The Window Manger routine **FrontWindow** ($150E) returns the handle identifier for the currently active (and therefore in front) window. In Program 19-1 there is only one window active (TaskMaster will handle closing any desk accessory windows automatically), so the handle returned by FrontWindow is pulled off the stack and put in PTR as an easy way to ignore it.

Any memory associated with that window should then be disposed of, and the third UserID, ID3 is passed to DisposeAll to do this. This SHELL program does not have any document or application-generated memory associated with the window, but this step is included to show what would normally be done here.

Finally, the window is closed and Window Manager–associated memory de-allocated with the call CloseWindow. Remember, this is not the same as temporarily hiding a window. That technique will be discussed shortly.

Returning our attention to the main event loop, if a close event was not detected on line 172, then control passes to the handler of Event Manager events, in the routine DOCMDS (DO CoMmanDS). The Event Manager event codes will all be in the range of 0 to 15, as was explained in the Chapter 18 on the Event Manager. Knowing this, we can create a vector table to be used with indirect indexed addressing, as was also described in previous chapters, and also mentioned in this chapter with respect to handling menu commands.

Lines 354–369, titled CMDS, define the entry points for the routine to handle each possible event. This SHELL program is pretty fancy, as you can tell; every possible event is routed to IGNORE (a simple RTS). However, if your program were a word processor, you would look for keydown events and process them accordingly. A drawing program might use the mouse-down event to start drawing. The DOCMDS routine (lines 179–184) shifts the event code (equivalent to multiplying by 2), and then does a JSR to the appropriate routine.

Program 19-1. SHELL Program

```
                       1  ************************************************
                       2  *             SHELL PROGRAM                    *
                       3  *           MERLIN ASSEMBLER                   *
                       4  ************************************************
                       5
                       6               MX   %00             ; TELL MERLIN WE'RE IN 16 BITS
                       7               REL
                       8               DSK  SHELL.L
                       9
                      10               LST  OFF             ; DON'T LIST MACROS
                      11               USE  UTIL.MACS       ; USE MACRO LIBRARY
                      12               LST  ON              ; LISTING BACK "ON"
                      13               EXP  OFF             ; DON'T EXPAND MACROS
                      14               TR   ON              ; DON'T PRINT ALL BYTES
                      15
        =E100A8       16  PRODOS       EQU  $E100A8         ; STD. PRODOS 16 ENTRY
                      17
        =0000         18  PTR          EQU  $00             ; OUR OWN DIRECT-PAGE PTR
                      19                                    ; $00,01,02,03
                      20
                      21
                      22
                      23  ************************************************
                      24  * STARTUP THE ENVIRONMENT
                      25  ************************************************
                      26
008000: 4B            27  STARTUP      PHK
008001: AB            28               PLB
008002: 7B            29               TDC                  ; PUT DIRECT PG IN ACC.
008003: 8D F1 82      30               STA  MYDP
                      31
008006: E2 30         32  SETRES       SEP  $30             ; 8-BIT MODE
008008: A9 5C         33               LDA  #$5C            ; JML (JMP LONG)
00800A: 8F F8 03 00   34               STAL $3F8            ; CTRLY VECTOR
00800E: C2 30         35               REP  $30             ; 16-BIT MODE
008010: A9 E0 82      36               LDA  #RESUME
008013: 8F F9 03 00   37               STAL $3F9            ; $3F9,3FA
008017: A9 00 00      38               LDA  #^RESUME
00801A: 8F FB 03 00   39               STAL $3FB            ; $3FB,3FC
                      40
                      41  TL           ToolCall $0201       ; TOOL LOCATOR STARTUP
                      42
                      43  MM           PushWord #$0000      ; SPACE FOR RESULT
                      44               ToolCall $0202       ; MEMORY MGR. STARTUP
```

```
                                PullWord ID         ; SAVE OUR ID
                                                    ; LIKELY = $1002
00803B: 09 00 01                ORA  #$0100         ; CREATE SUB-ID
00803E: 8D EB 82                STA  ID2            ; LIKELY = $1102
008041: 09 00 02                ORA  #$0200         ; 2ND SUB-ID FOR PICTURE DATA
008044: 8D ED 82                STA  ID3            ; LIKELY = $1302

                     GETDP      PushLong #$0000     ; SPACE FOR RESULT
                                PushLong #$600      ; AMT OF MEMORY NEEDED
                                                    ; 3 PAGES FOR QUICKDRAW
                                                    ; 1 PAGE FOR EVENT MGR.
                                                    ; 1 PAGE FOR MENU MGR.
                                                    ; 1 PAGE FOR CTRL. MGR.
                                PushWord ID2        ; SUBID
                                PushWord #$C001     ; TYPE: LOCKED, FIXED
                                PushLong #$0000     ; BANK = $00
                                ToolCall $0902      ; NewHandle

                                PullLong PTR        ; GET HANDLE FOR NEW DP
008071: A7 00                   LDA  [PTR]          ; LONG INDIRECT LOAD
008073: 8D EF 82                STA  DP             ; SAVE THE DP ADDRESS

008076: 48           EM         PHA                 ; PUSH DP ADDRESS (IN ACC.)
                                PushWord #$0000     ; QUEUE SIZE = DEFAULT = 20
                                PushWord #$0000     ; MIN X CLAMP FOR MOUSE = 0
                                PushWord #320       ; MAX X CLAMP = 320
                                PushWord #$0000     ; MIN Y CLAMP = 0
                                PushWord #200       ; MAX Y CLAMP = 200
                                PushWord ID2        ; SUBID
                                ToolCall $0206      ; EMStartUp

008095: 18                      CLC
008096: AD EF 82                LDA  DP             ; GET STARTING DP MEMORY
                                                     ADDR.
008099: 69 00 01                ADC  #$100          ; JUST USED BY EVENT. MGR.
00809C: 8D EF 82                STA  DP

00809F: 48           QD         PHA                 ; PUSH DP ADDRESS ON STACK
                                PushWord #$0000     ; MASTER SCB = DEFAULT (320)
                                PushWord #$0000     ; MAX SCREEN SIZE FOR
                                                     BOUNDSRECT
                                PushWord ID2        ; SUBID
                                ToolCall $0204      ; QDStartUp

0080B5: 18                      CLC
0080B6: AD EF 82                LDA  DP
0080B9: 69 00 03                ADC  #$300          ; JUST USED BY QD
0080BC: 8D EF 82                STA  DP

                     LOADTOOLS  PushLong #TOOLTBL
                                ToolCall $0E01      ; LoadTools

                     WM        PushWord ID2
                               ToolCall $020E        ; WMStartUp

                               PushLong #$0000       ; 0 = DRAW ENTIRE SCREEN
                               ToolCall $390E        ; Refresh (DRAW DESKTOP)

                     CTRL      PushWord ID2          ; SUBID
                               PushWord DP           ; DP AREA FOR CTRL MGR.
                               ToolCall $0210        ; CtlStartUp

008103: 18                     CLC
008104: AD EF 82               LDA   DP
008107: 69 00 01               ADC   #$100           ; $100 JUST USED BY CTRL MGR.
00810A: 8D EF 82               STA   DP

                     MENU      PushWord ID2          ; SUBID
                               PushWord DP           ; DP AREA FOR MENU MGR.
                               ToolCall $020F        ; MenuStartUp

008120: 18                     CLC
008121: AD EF 82               LDA   DP
008124: 69 00 01               ADC   #$100           ; $100 JUST USED BY MENU MGR.
008127: 8D EF 82               STA   DP

                     DESK      ToolCall $0205        ; DeskStartup

                     APPLE     PushLong #$0000       ; SPACE FOR RESULT
                               PushLong #MENU1       ; ADDR. OF MENU STRUCTURE
                               ToolCall $2D0F        ; NewMenu

                               PullLong MENU1HD      ; HANDLE FOR 1ST MENU

                               PushLong MENU1HD
                               PushWord #$0000       ; INSERT AT THIS POSITION
                                                       (FRONT)
                               ToolCall $0D0F        ; InsertMenu

                     DESKACC   PushWord #$0001       ; APPLE MENU ID
                               ToolCall $1E05        ; FixAppleMenu
                                                     ; ADD DA NAMES TO APPLE
                                                       MENU

                     FIXBAR    PushWord #$0000       ; SPACE FOR RESULT
                               ToolCall $130F        ; FixMenuBar
                                                     ; CALC SIZES FOR EVERY MENU

008186: 68                     PLA                   ; GET MENU HEIGHT & DISCARD

                     DRAWMENU  ToolCall $2A0F        ; DrawMenuBar
                                                     ; DRAW MENU, LOWER WINDOW

```

```
008192: 20  FA  81       WIND       JSR   OPEN            ; OPEN A WINDOW

                         SHOWCURS   ToolCall $9104        ; ShowCursor


                          *********************************************
                         * MAIN EVENT LOOP
                          *********************************************

                         MAIN       PushWord #$0000       ; SPACE FOR RESULT
                                    PushWord #$FFFF       ; ALLOW ALL EVENTS
                                    PushLong #EVRECORD    ; RECORD ADDRESS
                                    ToolCall $1D0E        ; TaskMaster

0081B7: 68               GETEV      PLA                   ; GET EVENT CODE IN ACC.
0081B8: F0  E6  =81A0               BEQ   MAIN            ; NO EVENT

                          *********************************************
                         * HANDLE THE EVENT
                          *********************************************

0081BA: 20  F9  81       EVT        JSR   SPECIAL         ; ANY SPECIAL EVENT HANDLING

0081BD: C9  11  00                  CMP   #$11            ; MENU EVENT?
0081C0: D0  06  =81C8               BNE   :1              ; NOPE
0081C2: 20  DB  81                  JSR   DOMENU          ; HANDLE IT
0081C5: 4C  A0  81                  JMP   MAIN            ; BACK FOR MORE

0081C8: C9  16  00       :1         CMP   #$16            ; CLOSE BOX
0081CB: D0  03  =81D0               BNE   DOCMDS

0081CD: 4C  60  82                  JMP   SHUTDOWN        ; ALL DONE!

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

0081D0: AD  F7  82       DOCMDS     LDA   EVENT
0081D3: 0A                          ASL                   ; EVENT * 2
0081D4: AA                          TAX                   ; PUT IN X REG
0081D5: FC  1D  83                  JSR   (CMDS,X)

0081D8: 4C  A0  81                  JMP   MAIN            ; BACK FOR MORE

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

0081DB: AD  07  83       DOMENU     LDA   TDATA           ; MENU ITEM NUMBER
0081DE: C9  00  01                  CMP   #256            ; APPLE MENU MSSG?
0081E1: D0  03  =81E6               BNE   :1              ; NOPE
0081E3: 4C  E6  81                  JMP   NORMAL          ; IGNORE (BUT UNHILITE)

                         :1                               ; OTHER TESTS HERE . . .

                         NORMAL     PushWord #$0000       ; 0 = UNHIGHLIGHT
```

```
                              PushWord TDATA+2      ; MENU HEADER #
                              ToolCall $2C0F        ; HiLiteMenu

0081F8: 60                    RTS

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

                    SPECIAL                         ; SPECIAL EVENT HANDLING

0081F9: 60                    RTS



                    OPEN      PushLong #$0000       ; SPACE FOR RESULT
                              PushLong #WINDOW      ; ADDR. OF WINDOW DEFINITION
                              ToolCall $090E        ; NewWindow

                              PullLong WPTR         ; GET WIND. MGR. HANDLE FOR
                                                      THIS

008219: 60          RTS

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

00821A: 8B          UPDATE    PHB                   ; SAVE OTHER'S DATA BANK
00821B: 4B                    PHK
00821C: AB                    PLB                   ; DATA BANK = OURS

00821D: 0B                    PHD                   ; SAVE THE DIRECT PAGE
00821E: AD F1  82             LDA   MYDP            ; USE OURS FOR NOW...
008221: 5B                    TCD

                    * DO ANY WINDOW UPDATING HERE...

008222: 2B                    PLD                   ; RESTORE THE DIRECT PAGE
008223: AB                    PLB                   ; RESTORE THE ORIG. DATA
                                                      BANK
008224: 6B                    RTL                   ; BACK TO TASKMASTER!



                    CLOSE     PushLong #$0000       ; SPACE FOR RESULT
                              ToolCall $150E        ; FrontWindow
                                                    ; GETS HANDLE TO ACTIVE
                                                      WINDOW
                                                    ; WE DON'T REALLY NEED THIS
                                                      IN
                                                    ; THIS PROGRAM, BUT IT'S GOOD
                                                      FORM.

                              PullLong PTR          ; STORE HANDLE, PTR IS AVAIL.

```

```
                                  PushWord ID3        ; SUBID FOR PICTURE DATA
                                  ToolCall $1102      ; DisposeAll

                                  PushLong WPTR       ; HANDLE TO WINDOW RECORD
                                  ToolCall $0B0E      ; CloseWindow

00825E: 60                        RTS

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

00825F: 60             IGNORE     RTS

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

008260: 20 25 82       SHUTDOWN   JSR   CLOSE         ; CLOSE THE WINDOW

                                  ToolCall $0305      ; DeskShutdown

                                  ToolCall $030F      ; MenuShutdown

                                  ToolCall $0310      ; CtlShutdown

                                  ToolCall $030E      ; WMShutdown

                                  ToolCall $0304      ; QDShutdown

                                  ToolCall $0306      ; EMShutdown

                                  PushWord ID2
                                  ToolCall $1102      ; DisposeAll

                                  PushWord ID
                                  ToolCall $0302      ; MMShutdown

                                  ToolCall $0301      ; TLShutdown

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

0082CE: 22 A8 00 E1    QUIT       JSL   PRODOS        ; DO QUIT CALL
0082D2: 29 00                     DA    $29           ; QUIT CALL COMMAND VALUE
0082D4: DA 82 00 00               ADRL  QUITBLK       ; ADDRESS OF PARM TABLE
0082D8: 00 00                     BRK   $00           ; SHOULD NEVER GET HERE . . .

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

0082DA: 00 00 00 00    QUITBLK    ADRL  $0000         ; NO PATHNMAME
0082DE: 00 00                     DA    $0000         ; STD. QUIT

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

0082E0: 4B             RESUME     PHK
0082E1: AB                        PLB                 ; SET OUR DATA BANK
```

```
0082E2: 18                             CLC
0082E3: FB                             XCE                     ; SET NATIVE MODE
0082E4: C2 30                          REP   $30               ; 16-BIT MODE
0082E6: 4C 60 82                       JMP   SHUTDOWN          ; TRY TO SHUTDOWN

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

0082E9: 00 00              ID          DA    $0000             ; OUR APPLICATION'S ID #
0082EB: 00 00              ID2         DA    $0000             ; SUB-ID FOR MEMORY BLOCKS
0082ED: 00 00              ID3         DA    $0000             ; 2ND SUB-ID

0082EF: 00 00              DP          DA    $0000             ; TEMP STORAGE FOR THE DP
                                                                 VALUE
0082F1: 00 00              MYDP        DA    $0000             ; TO STORE OUR DP ADDRESS

0082F3: 00 00              YLOC        DA    $0000             ; LOCAL Y POSN
0082F5: 00 00              XLOC        DA    $0000             ; LOCAL X POSN

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

                           EVRECORD                            ; DATA BLOCK WRITTEN BY EV
                                                                 MGR.

0082F7: 00 00              EVENT       DA    $0000             ; EVENT CODE
0082F9: 00 00 00 00        TYPE        ADRL  $0000             ; TYPE OF EVENT
0082FD: 00 00 00 00        TIME        ADRL  $0000             ; TIME SINCE STARTUP
008301: 00 00              YPOS        DA    $0000             ; Y-POSITION OF MOUSE
008303: 00 00              XPOS        DA    $0000             ; X-POSITION OF MOUSE
008305: 00 00              MOD         DA    $0000             ; EVENT MODIFIER

008307: 00 00 00 00        TDATA       ADRL  $0000             ; TASK MASTER MENU & ITEM #
00830B: FF                 TMASK       DFB   %11111111         ; TASK MASTER EVENT MASK
                                                                 (LOW BYTE)
                                                               ; BIT 0 = MENU KEYS
                                                               ; BIT 1 = UPDATE HANDLING
                                                               ; BIT 2 = FIND WINDOW
                                                               ; BIT 3 = MENU SELECT
                                                               ; BIT 4 = OPEN NDAS
                                                               ; BIT 5 = SYSTEM (NDA) CLICKS
                                                               ; BIT 6 = DRAG WINDOW
                                                               ; BIT 7 = SELECT WINDOW IF IN
                                                                 CONTENT
00830C: 1F                             DFB   %00011111         ; (HIGH BYTE)
                                                               ; BIT 8 = TRACK GO-AWAY BOX
                                                               ; BIT 9 = TRACK ZOOM BOX
                                                               ; BIT 10 = TRACK DRAG BOX
                                                               ; BIT 11 = SCROLLING
                                                               ; BIT 12 = SPECIAL MENU
                                                                 EVENTS
00830D: 00 00                          DA    $0000             ; BITS 16-31 ALWAYS CLEAR
                                                                 (HIGH WORD)

```

```
                     ************************************************

00830F: 03  00       TOOLTBL    DA    3                  ; THREE TOOLS TO LOAD

008311: 0E  00                  DA    14                 ; WINDOW MGR
008313: 00  00                  DA    0                  ; ANY VERSION
008315: 0F  00                  DA    15                 ; MENU MGR
008317: 00  00                  DA    0                  ; ANY VERSION
008319: 10  00                  DA    16                 ; CONTROL MGR.
00831B: 00  00                  DA    0                  ; ANY VERSION

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

00831D: 5F  82       CMDS       DA    IGNORE             ; NULL EVENT
00831F: 5F  82       C1         DA    IGNORE             ; MOUSE DOWN
008321: 5F  82       C2         DA    IGNORE             ; MOUSE UP
008323: 5F  82       C3         DA    IGNORE             ; KEY DOWN
008325: 5F  82       C4         DA    IGNORE             ; UNDEFINED
008327: 5F  82       C5         DA    IGNORE             ; AUTOKEY
008329: 5F  82       C6         DA    IGNORE             ; UPDATE WINDOW EVENT
00832B: 5F  82       C7         DA    IGNORE             ; UNDEFINED
00832D: 5F  82       C8         DA    IGNORE             ; ACTIVATE WINDOW EVENT
00832F: 5F  82       C9         DA    IGNORE             ; SWITCH EVENT
008331: 5F  82       C10        DA    IGNORE             ; DESK ACCESSORY EVENT
008333: 5F  82       C11        DA    IGNORE             ; DEVICE DRIVER EVENT
008335: 5F  82       C12        DA    IGNORE             ; APPLICATION DEFINED EVENT
008337: 5F  82       C13        DA    IGNORE             ; APPLICATION DEFINED EVENT
008339: 5F  82       C14        DA    IGNORE             ; APPLICATION DEFINED EVENT
00833B: 5F  82       C15        DA    IGNORE             ; APPLICATION DEFINED EVENT

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

00833D: 00  00  00  00  WPTR    ADRL  $0000              ; POINTER TO WINDOW RECORD

008341: 11  41  70  70  WTITLE  STR   'Apple IIGS Window'

008353: 4E  00       WINDOW     DA    WINDEND-WINDOW     ; LENGTH OF DATA BLOCK
008355: E5  DD                  DA    %1101110111100101  ; WINDOW FRAME DEFINITION
                                                         ; BIT 15 = TITLE
                                                         ; BIT 14 = CLOSE BOX
                                                         ; BIT 13 = (NOT) AN ALERT BOX
                                                         ; BIT 12 = VERTICAL SCROLL
                                                         BAR
                                                         ; BIT 11 = HORIZ. SCROLL BAR
                                                         ; BIT 10 = GROW BOX
                                                         ; BIT 9 = FLEXIBLE ORIGIN ON
                                                         GROW OR ZOOM
                                                         ; BIT 8 = ZOOMABLE
                                                         ; BIT 7 = DRAGGABLE
                                                         ; BIT 6 = ACTIVATE ON
                                                         CONTENT
                                                         ; BIT 5 = WINDOW IS VISIBLE
```

```
                                                     ; BIT 4 = (NO) INFORMATION
                                                       BAR
                                                     ; BIT 3 = (NO) INDEPENDENT
                                                       CTRLS
                                                     ; BIT 2 = ALLOCATED BY
                                                       NEWWINDOW
                                                     ; BIT 1 = (NOT) CURRENTLY
                                                       ZOOMED
                                                     ; BIT 0 = HIGHLIGHTED
008357: 41 83 00 00            ADRL WTITLE           ; POINTER TO TITLE
00835B: 00 00 00 00            ADRL $0000            ; REFERENCE CONSTANT
00835F: 00 00 00 00            DA   0,0,0,0          ; ZOOM RECTANGLE
008367: 00 00 00 00            ADRL $0000            ; COLOR TABLE
00836B: 00 00 00 00            DA   0,0              ; ORIGIN OFFSET
00836F: C8 00 40 01            DA   200,320          ; HEIGHT, WIDTH DATA AREA
008373: 96 00 22 01            DA   150,290          ; HEIGHT, WIDTH MAX WINDOW
008377: 04 00 10 00            DA   4,16             ; VERT., HORIZ. SCROLL
                                                       INCREMENT
00837B: 28 00 A0 00            DA   40,160           ; VERT., HORIZ. PAGE INCREMENT
00837F: 00 00 00 00            ADRL $0000            ; INFO BAR REFERENCE
                                                       CONSTANT
008383: 00 00                  DA   0                ; INFO BAR HEIGHT (NONE)
008385: 00 00 00 00            ADRL $0000            ; FRAME PROCEDURE ADDR.
                                                       (NONE)
008389: 00 00 00 00            ADRL $0000            ; INFO BAR PROCEDURE ADDR
                                                       (NONE)
00838D: 1A 82 00 00            ADRL UPDATE           ; CONTENT PROCEDURE ADDR.
                    WRECT                            ; CONTENT REGION OF WINDOW
008391: 1E 00       WV1        DA   30               ; UPPER LEFT VERT. POSITION
008393: 14 00       WH1        DA   20               ; UPPER LEFT HORIZ. POSN
008395: 64 00       WV2        DA   100              ; LOWER RIGHT VERT. POSN
008397: C8 00       WH2        DA   200              ; LOWER RIGHT HORIZ. POSN
008399: FF FF FF FF            ADRL -1               ; PUT WINDOW AT FRONT ($FFF..
                                                       = -1)
00839D: 00 00 00 00            ADRL $0000            ; STORAGE
                    WINDEND                          ; END OF DATA STRUCTURE

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

0083A1: 3E 3E 40 5C MENU1      ASC  ‘>>@ZN1X’,00     ; APPLE MENU
0083A9: 2D 2D 59 6F            ASC  ‘--Your Message Here... ZN256V’,00
0083C7: 2E                     ASC  ‘.’              ; END OF MENU

0083C8: 00 00 00 00 MENU1HD    ADRL $0000            ; STORAGE FOR HANDLE



0083CC: 4B          CHKSUM     CHK                   ; CHECKSUM FOR VERIFICATION

--End Merlin-16 assembly, 973 bytes, errors: 0
```

Monitoring Events in a Window

Although the demonstration program just presented should work properly for you, it lacks routines to actually update the window with any information. In addition, it would be worthwhile to have a program that could provide a little more information about what is actually going on in the system each time an event occurrs.

EVENT.DISPLAY, our next program, combines the SHELL program just presented with parts of the Event Manager demonstration program from the previous chapter. EVENT.DISPLAY will display a description of each event as it occurs within the window on the DeskTop, and it will print out not only the mouse global mouse coordinates (relative to the BoundsRect—the DeskTop) but also the local coordinates within the window.

By experimenting with activities like moving the mouse around, opening a New Desk Accessory and moving it around, and other actions on the DeskTop, you'll gain a better understanding of the entire DeskTop and window environment, and also how TaskMaster handles certain events and passes others through to the application.

Because the listing for the total program would be fairly large (about 1000 lines), we'll step through how to combine the two existing programs using source listings you've already entered, rather than retyping the entire program.

Start with the SHELL program, and save it under the new name, EVENT.DISPLAY. You may also want to change the title banner at the top of the source listing to this:

```
********************************************
*    WINDOW WITH EVENT DISPLAY             *
*          MERLIN ASSEMBLER                *
********************************************
```

Having saved this new source file, load Program 18-2, EVENT MANAGER DEMO from Chapter 18, and delete lines 310–320, which are the Event Record. It is already present in the SHELL. Next, delete lines 301–305. This removes the duplicate labels ID, ID2, and DP, which are also already in SHELL. Finally, delete lines 1–176, and the checksum instruction at the end. Save the resulting program segment under the name EVENT.SEGMENT. This will be added to the SHELL program in a moment. This program segment could be linked into the SHELL program by defining the necessary **EXT** (external) and **ENT** (entry) labels for the *Merlin* or *APW* assemblers, but, for a relatively short program like this, it's probably just as easy to combine them in one listing.

The easiest way to do this is to first use the text copy command in your assembler to copy the entire source list for EVENT.SEGMENT onto the clipboard of the assembler's editor. In *Merlin*, this is done by positioning the cursor on the first line of the program and then pressing Open Apple–C to start the copy selection. Next, press Open Apple–Q to select from that point to the very end of the listing. Finally, press Open Apple–C again to complete the copy of this text onto *Merlin*'s clipboard.

Now, load the program EVENT.DISPLAY and press Open Apple–N to move to the end of that listing; then move the cursor to line 428, which should correspond to the checksum instruction. Pressing Open Apple–V (for paste) at that point should make the entire EVENT.SEGMENT code appear as it is pasted from the *Merlin* clipboard into the program. Check to make sure everything looks OK, and then resave this new version back to the disk under the current name, EVENT.DISPLAY. If you're using the *APW* assembler, use follow the same procedure using the *APW* editor commands to copy and paste text.

Now, the only remaining changes are to add a few lines here and there to make the UPDATE routine fill in the event message within our window, and to do a few other minor changes.

For each change, we'll reprint the neighboring lines so you can see exactly what the finished portion should look like.

The beginning of the program first needs to be modified to set up MSSGPTR as was done in the Event Manager demonstration program. You'll recall that MSSGPTR will be used as a pointer into the list of event descriptions as each event occurs.

```
PTR       EQU  $00            ; OUR OWN DIRECT PAGE PTR
                              ; $00,01,02,03

MSSGPTR   EQU  $04            ; POINTER TO ANY MESSAGE

STARTUP   PHK
          PLB
          TDC                 ; PUT DIRECT PG IN ACC.
          STA  MYDP

          LDA  #^STARTUP      ; GET OUR DATA BANK
          STA  MSSGPTR+2      ; WRITE HIGH WORD TO OUR DATA BANK

SETRES    SEP  $30            ; 8-BIT MODE
```

The next modification is to the main event loop, which starts at the label MAIN.

```
MAIN    PushWord #$0000       ; SPACE FOR RESULT
        PushWord #$FFFF       ; ALLOW ALL EVENTS
        PushLong #EVRECORD    ; RECORD ADDRESS
        ToolCall $1D0E        ; TaskMaster
        JSR  MPOSN

GETEV   PLA                  ; GET EVENT CODE IN ACC.
        BEQ  MAIN            ; NO EVENT
```

The only change here is to insert a JSR to the routine MPOSN, which will print out the current mouse position for each pass through the event loop, regardless of whether an event has actually occurred or not. MPOSN will be described shortly.

In the SHELL program there was a JSR to a routine called *SPECIAL*, which consisted of nothing more than a JSR. This is where we will print out the description of each and every event that is passed on by TaskMaster. Add the instruction JSR PRINTEV to the SPECIAL routine:

```
SPECIAL                      ; SPECIAL EVENT HANDLING
         JSR   PRINTEV       ; EVENT VERSION

         RTS
```

With the Window Manager, a vector can be set up in the window parameter list to point to the routine which should be called whenever the window needs to be updated by TaskMaster. For example, this would occur when the window was resized, or when another window that partially obscured ours was moved out of the way. The SHELL program already contains the foundation of any update routine, namely the setting of the data bank and program registers to those of our application and then restoring them after the update action takes place. Notice that the UPDATE routine always ends with an **RTL** (*never* an RTS). Simply insert the JSR EVMSSG into the update routine so that it looks like:

```
UPDATE  PHB                  ; SAVE OTHER'S DATA BANK
        PHK
        PLB                  ; DATA BANK = OURS

        PHD                  ; SAVE THE DIRECT PAGE
        LDA   MYDP           ; USE OURS FOR NOW...
        TCD

        JSR   EVMSSG         ; PRINT EVENT MGR. MSSG

        PLD                  ; RESTORE THE DIRECT PAGE
        PLB                  ; RESTORE THE ORIG. DATA BANK
        RTL                  ; BACK TO TASKMASTER!
```

Now for the MPOSN routine. At the beginning of the EVENT.SEGMENT code that you added to the program, insert two new routines, MPOSN and PRINTEV. These routines correspond to the code that would be executed whenever the application updated its own window. The key points are that two

Window Manager routines, StartDrawing and SetOrigin, must be at the beginning and end of any routine which draws in a window during the application.

Although the local coordinates of the upper left corner of the visible window shift as the scroll bars are adjusted, QuickDraw internally always keeps the upper left corner at 0,0. When UPDATE is called, the Window Manager temporarily sets the origin back to the proper value while our UPDATE routine is drawing on the screen, but then it immediately reverts back to 0,0 when our routine exits.

When executing a window update within an application (but separate from the window definition update vector), it is neccessary to manually reset the coordinates of the window to the proper local coordinates with the command StartDrawing. StartDrawing and SetOrigin are used by passing the handle to the specified window record. Once the window update is complete, the tool call SetOrigin is used to return the upper left corner of the window back to 0,0 for the Window Manager.

MPOSN prints the local and global coordinates of the mouse on a continual basis. PRINTEV is only called from within SPECIAL, which is executed whenever an actual event occurs.

```
MPOSN    PushLong WPTR       ; PRINT MOUSE POSITION
         ToolCall $4D0E      ; StartDrawing
                             ; MUST DO THIS FOR A DRAW
                             ; OUTSIDE THE UPDATE ROUTINE
                             ; TO SET ORIGIN CORRECTLY

         JSR   MOUSE

         PushWord #$0000     ; X = 0
         PushWord #$0000     ; Y = 0
         ToolCall $2304      ; SetOrigin
                             ; MUST DO THIS FOR A DRAW
                             ; OUTSIDE THE UPDATE ROUTINE
                             ; TO RETURN ORIGIN TO 0,0

         RTS

*********************************************
*       PRINT EVENT DESCRIPTION             *
*********************************************

PRINTEV  PHA                 ; SAVE EVENT CODE IN ACC.

         PushLong WPTR       ; HANDLE FOR WINDOW TO DRAW IN
         ToolCall $4D0E      ; StartDrawing

         JSR   EVMSSG        ; UPDATE EVENT DESCRIPTION

         PushWord #$0000     ; X = 0
         PushWord #$0000     ; Y = 0
```

```
          ToolCall $2304      ; SetOrigin (BACK TO 0,0)
          PLA                 ; PUT EVENT CODE BACK IN ACC.
          RTS
```

This would pretty much take care of things, except that the MOUSE routine from the Event Manager demonstration program only printed out the global coordinates of the mouse. Rewrite the MOUSE routine as follows:

```
MOUSE     PushLong #YLOC      ; DATA TO REWRITE
          ToolCall $0C06      ; GetMouse (LOCAL)

XPOSN     PushWord XPOS       ; GET X POSITION
          PushLong #XMSG+5    ; ADDR. OF BUFFER
          PushWord #4         ; 4 CHAR OUTPUT
          PushWord #$0001     ; SIGNED NUMBER FLAG
          ToolCall $260B      ; Int2Dec
                              ; CONVERT TO ASCII DECIMAL STR$

YPOSN     PushWord YPOS       ; GET Y POSITION
          PushLong #YMSG+5    ; ADDR. OF BUFFER
          PushWord #4         ; 4 CHAR OUTPUT
          PushWord #$0001     ; SIGNED NUMBER FLAG
          ToolCall $260B      ; Int2Dec

X2        PushWord XLOC       ; GET X LOCAL
          PushLong #XMSG+23   ; ADDR. OF BUFFER
          PushWord #4         ; 4 CHAR OUTPUT
          PushWord #$0001     ; SIGNED NUMBER FLAG
          ToolCall $260B      ; Int2Dec
                              ; CONVERT TO ASCII DECIMAL STR$

Y2        PushWord YLOC       ; GET Y LOCAL
          PushLong #YMSG+23   ; ADDR. OF BUFFER
          PushWord #4         ; 4 CHAR OUTPUT
          PushWord #$0001     ; SIGNED NUMBER FLAG
          ToolCall $260B      ; Int2Dec

          LDA  #0             ; X = 0
          STA  CH
          LDA  #10            ; Y = 10
          STA  CV

          JSR  PRINT
XMSG      STR  'X = 0000      Local X = 0000 '
          JSR  CR

          JSR  PRINT
YMSG      STR  'Y = 0000      Local Y = 0000 '
          JSR  CR

          RTS
```

The main change here is to lengthen the output strings for XMSG and YMSG to include the local coordinates, and to use the tool call GetMouse, which returns the coordinates of the mouse in local (within-the-window = PortRect) coordinates. GetMouse writes the position into a data structure indicated by the pointer pushed on the stack when the routine is called.

In our new program, the local mouse coordinates will be written into **YLOC** and **XLOC**, which were included in the original SHELL program. As usual, the Y point is allocated first in the data structure.

When you've made the changes indicated here, double-check the listing, then assemble and link it as usual. Remember to save the new listing to disk before you assemble and link it.

If the changes are made exactly as described here, the new checksum at the end of the listing should be $28, and the program should assemble to be 1780 bytes long ($6F4).

Running the Event Display Program

When you run the Event Display program, there are some things to try and notice, things that illustrate some very important concepts about how the Window Manager works.

When the program first runs, before you even move the mouse, an event is displayed called *update*. This is the Window Manager telling the application that the window has been opened and may need to be updated. In our application, the update takes place when SPECIAL calls PRINTEV, which then calls the EVMSSG routine. The contents will also be automatically updated via the Window Manager and the UPDATE routine specified in the window parameter list whenever the window is resized or scrolled, or the like, bringing a previously obscured portion of the window into view.

With the cursor in the upper left corner of the screen, notice that the global coordinates of the mouse, as reported by the Event Manager in the event record (EVRECORD), are 0,0. Because the upper left corner of the content region of our application's window is also 0,0 in local coordinates, the DeskTop corner at this moment corresponds to −20,−30 (local).

Move the cursor to the upper left corner of the content region of the window to demonstrate this, and notice that the content region's global coordinates are 20,30 as specified in the wPosition field of the window parameter list. You can move the cursor and explore the coordinates assigned to the entire window and DeskTop areas at this point. The lower right corner of the content region should have global coordinates of 200,100, also as specified in the window parameter list.

Now drag the window by its title bar to a new location on the DeskTop.

Notice that the local coordinates within the window remain fixed, while the global coordinates of the window change as expected.

Click the mouse in the content region of the window, and see the mouse-down and mouse-up events displayed on the screen. Notice that, as you click in the title bar, the mouse-down and mouse-up events are not passed through by TaskMaster, because it has already handled these itself. Click in the zoom box to make the window fill the screen. The event passed through now becomes update. Click a few times in the window, then zoom back to the previous size.

Now press the down-arrow key once on the vertical scroll bar in the window frame. The text printed in the window is automatically clipped as it scrolls out of view. Move the cursor and see that the local coordinates of the upper left corner of the content region are now 0,4. The vertical scroll increment as specified in the window parameter list was four pixels. Experiment with the scroll controls, including paging and sliding the thumb control, and observe how the local coordinates automatically change.

If at some point your application wanted to know what was currently in view in the window, there is a QuickDraw routine called **GetPortRect** ($1E04), that returns the current rectangle in local coordinates; this routine can be used to determine exactly what part of the underlying data area is being viewed. There is also a Window Manager routine, **GetCOrigin** ($3F0E), that returns the current local coordinates of the origin (upper left corner) of the content window at that moment.

Before continuing, return the window scroll bars to their starting position so that 0,0 is the origin of the window once more, and you can see the complete event display. Now click once in the menu bar—in the middle, away from the Apple icon. Notice that no event is passed through. Now select the Apple menu, and select Your Message. . . . The menu will flash when it is selected, and then the NORMAL routine in our DOMENU section of the program will unhighlight the title.

If you have a desk accessory listed (if you don't, try to put one on your system disk to try this out), select it to open a second window on the DeskTop. Click in one window and then the other to see how one is activated and the other is de-activated automatically. If you click in a window, you'll see the event *activate* show up. This tells the application that windows are being changed, and is different from an update event. When an activate or update event occurs, the handle to the related window is passed in the TYPE field of the event record (also called the *message* field).

After you've thoroughly explored the DeskTop and window environment, click in the close box of the application window to quit the program.

Chapter 20

A Drawing Program for the Apple IIGS

Chapter 20

A Drawing Program for the Apple IIGS

QuickDraw and the Window Manager don't care whether the drawing they're doing is on the screen or a real document in memory. This also means that just drawing something in a window does not automatically constitute any permanent record of that image anywhere in the computer.

If all you want to do is to draw something on the screen, and you don't need an associated permanent record, then the techniques presented so far will be adequate.

Unfortunately, this is rarely the case. It's a simple matter to rewrite the SHELL program to draw lines on the screen whenever a mouse-down event is detected. However, as soon as you scrolled whatever you drew out of view, it would be lost forever because there is no underlying document associated with the window. In Event Display program, when you changed the viewing window with the scroll bars or the grow box, any part of the message clipped from being printed just didn't exist. The illusion, of course, is that the missing or clipped letters are just out of sight behind the window frame, but that's all it is—an illusion.

If you want actions taken in your window to be permanently recorded, it's up to you to create a block of memory somewhere else in the computer, and to store data there as is appropriate to your application.

This information may not always be graphics images. If you're writing a database, for example, the document itself would consist of the words and numbers that made up your file. The display would be done by expressing a portion of that data as a graphics printout within an open window. You normally would not, as a matter of course, generate an entire graphics version of the document that the window then scrolled over.

For instance, if the origin of the scrolled window was currently 0,200, and you knew that each line of text in your list of names was 10 pixels high, a quick calculation (200/10 = 20) would tell you that you could start printing in the window with the twentieth name in your list. A look at the **PortRect** would tell you how high the window was, and dividing that height also by 10 would tell you how many names to print. All text to the left and right would be automatically clipped depending on the horizontal scroll position and width of the window. Thus, your program would only print, for example, records 20 through 25. It would not have converted the entire document to a graphics image that the window then scrolled over.

In the case of a paint program, there is an underlying graphics document. That document is a pixel image of the entire picture, and is stored in memory as continuous block of memory allocated by the memory manager.

QuickDraw allows for the definition of a new drawing area by either creating a new **GrafPort** or by redirecting the memory controlled by the current GrafPort to a new location. The memory controlled by the GrafPort is described by a data structure called the **PortLocInfo**, which looks like this:

```
PortLocInfo                       ; DATA STRUCTURE FOR PortLocInfo
PortSCB  DFB   $00                ; MASTER SCB BYTE
         DFB   $00                ; RESERVED BYTE
Loc      ADRL  $0000              ; LONG ADDRESS OF MEMORY BLOCK
Width    DA    $0000              ; WIDTH IN BYTES OF IMAGE
BoundsRect                        ; RECTANGLE COORDINATES IN PIXELS
V1       DA    $0000              ; VERTICAL UPPER LEFT COORD.
H1       DA    $0000              ; HORIZ. UPPER LEFT COORD.
V2       DA    $0000              ; VERTICAL LOWER RIGHT COORD.
H2       DA    $0000              ; HORIZ. LOWER RIGHT COORD.
```

Defining a Block of Memory

To define a block of memory equivalent to the super hi-res screen, the following PortLocInfo structure could be used:

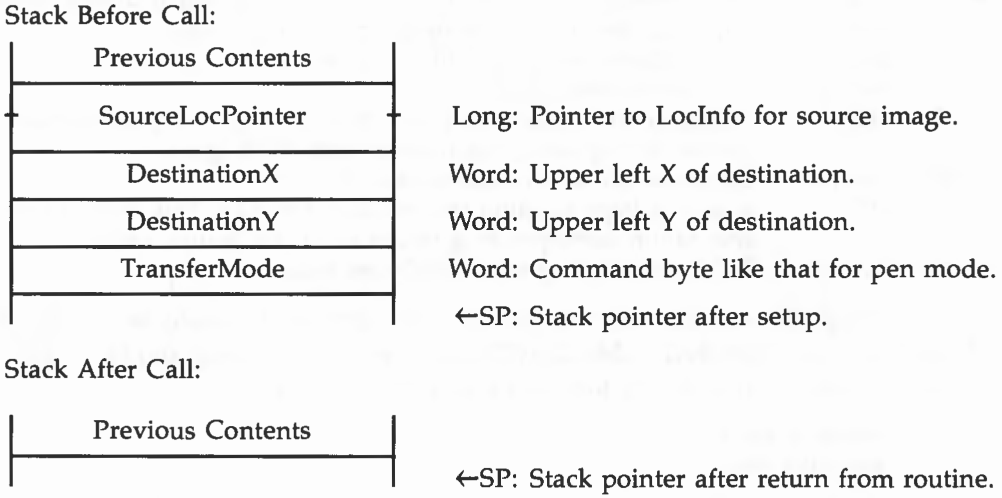
```
PICBLK                            ; PortLocInfo for a new image
         DFB   $00                ; $00 = 320 MODE
         DFB   $00                ; UNUSED
         ADRL  $E10000            ; SUPER HI-RES SCREEN
         DA    160                ; 160 BYTES WIDE
         DA    0,0                ; UPPER LEFT = 0,0
         DA    200,320            ; LOWER RIGHT = 320,200
```

The PortLocInfo data structure can be generalized into a definition of any pixel memory area, called the *LocInfo block*. By changing the address of the pixel image, and passing this to the GrafPort using a QuickDraw call **SetPortInfo**, you can redirect QuickDraw to draw anywhere into memory. We'll see how to do that a little later.

You can use a LocInfo data structure in two other QuickDraw commands, **PPToPort** ($D604) and **PaintPixels** ($7F04).

PPToPort (Paint Pixels To Port) will be used for our update routine. It transfers part of a pixel image somewhere in memory into the current PortRect of the GrafPort, using the current clipping windows. The result is that the entire window is updated using the pixels from a graphic document we'll create in memory. Figure 20-1 is the call diagram for PPToPort.

Figure 20-1. PPToPort ($D604)


Stack Before Call:
Previous Contents
SourceLocPointer
Long: Pointer to LocInfo for source image.
DestinationX
Word: Upper left X of destination.
DestinationY
Word: Upper left Y of destination.
TransferMode
Word: Command byte like that for pen mode.
←SP: Stack pointer after setup.
Stack After Call:
Previous Contents
←SP: Stack pointer after return from routine.

The source parameter block determines where the pixel image is in memory. The address of the image is stored within the Info block for the image must usually be filled in by dereferencing the handle to the memory block you've allocated as the graphics document.

PPToPort allows you to specify a rectangle as just part of the entire document to copy into the current window's PortRect. This can be determined by calling the GetPortRect, but Program 20-1 just takes the brute force approach of copying the entire document image to the window, letting the normal clipping functions filter out the excess.

Destination X and Y specify where in the destination port the image will be transferred. For our update routine, both the source rectangle and the destination point will use 0,0. These are equivalent to the local coordinates when dealing with the window. Again, the fact that the window may be currently scrolled so that its origin is no longer 0,0 is not a concern since we'll be copying the entire image over the window, and the clipping regions of the Window Manager will ensure that only the content region of the active window is changed.

The transfer mode refers to a code value that tells the routine whether to use an AND, ORA, or other function in transferring the pixels from our document to the window. If you wanted to blend two images, for example, you could use a different transfer mode than a straight copy. Table 20-1 is a summary of the possible transfer modes.

Table 20-1. Transfer Mode

Value	Mode	Description
$0000	Copy	Copy pixels to destination, overwriting whatever is already there.
$8000	NotCopy	Copy inverse of pixels to destination, as in Copy.
$0001	OR	Use OR logic to overlay (blend) pixels.
$8001	NotOR	Overlay inverted pixels.
$0002	XOR	Exclusive OR pixels with destination. This allows you to undo the transfer by repeating the transfer with XOR again.
$8002	NotXOR	Exclusive OR of inverted pixels.
$0003	BIC	A special logic function for *Bit Clear* ANDing. This clears bits in the destination corresponding to bits set in the source image.
$8003	NotBIC	BIC function using inverse of pixel image.

One of the easiest ways to experiment with these would be to add the QuickDraw tool call **SetPenMode** ($2E04) to set the drawing mode to the value of your choice. SetPenMode looks like this in a program:

```
PushWord #MODE
ToolCall $2E04
```

In fact, once you get this program running as it is presented here, it would be an excellent exercise for you to add a new menu of pen modes to try out what you've learned.

Updating the Screen

Getting back to the update routine, PPToPort is designed specifically for transferring a portion of the existing document to the current window (port). This is fine for the update routine, but how do we transfer the image of a line just drawn on the screen into the actual document somewhere in memory? To do this we could probably change the current port to be our document, and the source document to be the PortRect of the window, and then call PPToPort, but there is another routine, called *PaintPixels,* which is generalized for transferring pixels from one place to another.

PaintPixels is passed a pointer to another parameter block, which in turn points to several LocInfo data structures to determine which pixels to transfer. The structure of the PaintPixels parameter block is as follows:

Data Type	Name	Description
Pointer	PtrToSourceLocInfo	Pointer to the LocInfo structure for the source pixel.
Pointer	PtrToDestLocInfo	Pointer to the LocInfo for the destination image.
Pointer	PtrToSourceRect	Pointer to rectangle within source image.
Pointer	PtrToDestPoint	Pointer to point at which transfer will begin.
Word	Mode	Transfer mode to use.
Handle	MaskHandle (ClipRgn)	Handle to region to use as mask over destination.

Setting up the clipping region for MaskHandle is the new item here. A region is a special data structure within QuickDraw that can describe all sorts of strange shapes, like the profile of W.C. Fields and his cigar. You can use a region as a clipping mask so that only a portion of an entire pixel image will be transferred to the destination.

For our purposes, a rectangle will do just fine; this can be defined using two calls: **NewRgn** ($6704), which creates a region data structure, including the automatic allocation of some memory from the Memory Manager; and **SetRect** ($6B04), which sets a given region equal to a rectangle passed to that routine. With these two calls, we can create a rectangular region equal to our document in memory that will satisfy the requirement for the PaintPixel command.

You may have already guessed that there are a number of options in using these commands that will all produce the same results. We could just as easily set the source and destination rectangles equal to the entire screen and the entire document respectively, and then set the Clip Region equal to just the part of our document to be updated from the window. But in the end the results are all the same. You can design your application to use whichever approach best suits your programming style.

Constructing the Paint Program

Hopefully, this gives you an idea of where we're headed to put together a simple sketching program using QuickDraw and the Window Manager. To do this, we'll again start with the SHELL program, Program 19-1, and then we'll add some routines to turn it into a drawing program. As before, start off by loading the source file SHELL, and save it under a new name. We'll call the new program SIMPLE.SKTCH.

Now add a block of new code to the end of the program, just before the checksum byte. Use Program 20-1 for the new addition.

Program 20-1. Sketcher
(See instructions above before entering program.)

```
************************************************
*     SKETCHER ADDITIONS TO SHELL      *
************************************************

DOCSETUP  PushLong #$0000        ; SPACE FOR RESULT
          PushLong #$8000        ; HOW MUCH MEM WE NEED
          PushWord ID3           ; SUB-ID
          PushWord #$0000        ; MEM ATTRIBUTE = NO RESTRICTIONS
          PushLong #$0000        ; LOCATION NOT IMPORTANT
          ToolCall $0902         ; NewHandle

          PullLong PICHNDL       ; GET HANDLE TO MEMORY BLOCK

          JSR    ERASE           ; ERASE PICTURE AREA

SETREGN   PushLong #$0000        ; SPACE FOR RESULT
          ToolCall $6704         ; NewRgn (GET AN OFFSCREEN
                                 ; DRAWING AREA.)

          PullLong PREGION       ; GET HANDLE AND SAVE IT

          PushLong PREGION
          PushWord #$0000        ; H1 = 0
          PushWord #$0000        ; V1 = 0
          PushWord #320          ; H2 = 320
          PushWord #200          ; V2 = 200
          ToolCall $6B04         ; SetRect
                                 ; MAKE THE REGION A RECTANGLE

          RTS
******************************************

ERASE     PushLong PICHNDL
          ToolCall $2002         ; HLock
                                 ; MAKE SURE IT DOESN'T MOVE

          LDA    [PICHNDL]       ; LONG INDIRECT LOAD
          STA    PTR             ; GET THE MEM ADDRESS
          LDY    #$02
          LDA    [PICHNDL],Y
          STA    PTR+2           ; (PTR) = ADDR. OF PICTURE

CLR       LDA    #$EEEE          ; CLEAR BLOCK OF MEMORY TO COLOR #14
          LDY    #$0000          ; BEG. OF BLOCK
:1        STA    [PTR],Y
          INY
          CPY    #32000          ; DONE YET?
          BCC    :1              ; NOPE
```

```
UNLOCK     PushLong PICHNDL
           ToolCall $2202          ; HUnlock

           PushLong #WINRECT       ; POINTER TO WINDOW RECTANGLE
           ToolCall $2004          ; GetPortRect
                                   ; MAKE WINRECT = WINDOW

           PushLong #WINRECT       ; THE WINDOW RECTANGLE
           ToolCall $3A0E          ; InvalidRect
                                   ; FORCE TASKMASTER TO UPDATE

           RTS
*****************************************

PAINT      PushLong PICHNDL
           ToolCall $2002          ; HLock

           LDA    [PICHNDL]        ; LONG INDIRECT LOAD
           STA    PICLOC           ; SET THE MEM ADDRESS
           LDY    #$02
           LDA    [PICHNDL],Y
           STA    PICLOC+2

           PushLong #PICBLK        ; POINTER TO PARM BLOCK
           PushLong #PAINTRECT     ; POINTER TO DATA RECT
           PushWord #$0000         ; DESTINATION X = 0
           PushWord #$0000         ; DESTINATION Y = 0
           PushWord #$0000         ; XFER MODE = 'COPY'
           ToolCall $D604          ; PPtoPort
                                   ; COPY THE PICTURE TO THE WINDOW

           PushLong PICHNDL
           ToolCall $2202          ; HUnlock

           RTS
*****************************************

PENS       PushWord #$0000         ; 0 = UNCHECK
           PushWord PEN            ; CHANGE CHECK MARK (MENU ITEM #)
           ToolCall $320F          ; CheckItem (UNCHECK)

           PushWord #$FFFF         ; BOOLEAN TRUE = CHECK ITEM
           PushWord TDATA          ; GET MENU ITEM AND PUSH
           STA    PEN              ; SET NEW CURRENT PEN (= MENU ITEM #)
           ToolCall $320F          ; CheckItem (CHECK)

           RTS
*****************************************

COLORS     PushWord #$0000         ; 0 = UNCHECK
           PushWord COLOR          ; CHANGE CHECK MARK (MENU ITEM #)
           ToolCall $320F          ; CheckItem (UNCHECK)
```

```
          PushWord #$FFFF     ; BOOLEAN TRUE = CHECK ITEM
          PushWord TDATA      ; GET MENU ITEM AND PUSH
          STA    COLOR        ; SET NEW CURRENT PEN (MENU ITEM #)
          ToolCall $320F      ; CheckItem (CHECK)

          RTS

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

MDOWN     PushLong #CURSOR    ; NEW CURSOR ADDRESS
          ToolCall $8E04      ; SetCursor

SETPEN    LDA    PEN          ; (MENU ITEM #)
          SEC
          SBC    #261         ; RESULT = 0, 1, 2
          ASL
          ASL                 ; RESULT * 4 = 0, 4, 8
          INC                 ; RESULT = 1, 5, 9
          PHA                 ; PUSH PEN WIDTH
          PHA                 ; PUSH SAME FOR HEIGHT
          ToolCall $2C04      ; SetPenSize

SETCOL    LDA    COLOR        ; (MENU ITEM #)
          CMP    #265         ; BLACK MENU ITEM
          BEQ    BLACK
          CMP    #266         ; RED MENU ITEM
          BEQ    RED

BLUE      PushWord #$0004     ; 4 = BLUE
          JMP    SETCOLOR

RED       PushWord #$0007     ; 7 = RED
          JMP    SETCOLOR

BLACK     PushWord #$0000     ; 0 = BLACK

SETCOLOR  ToolCall $3704      ; SetSolidPenPat (COLOR)

DRAW      PushLong WPTR       ; IDENTIFY THE WINDOW
          ToolCall $4D0E      ; StartDrawing
                              ; MUST DO THIS FOR A DRAW
                              ; OUTSIDE THE UPDATE ROUTINE
                              ; TO RETURN ORIGIN TO ACTUAL
                              ; LOCAL COORDINATES

          PushLong #YPOS      ; TABLE TO REWRITE
          ToolCall $0C06      ; GetMouse (LOCAL)

          LDA    XPOS         ; GET X POSN OF MOUSE
          STA    OLDX         ; SAVE ORIG. POSN
          LDA    YPOS         ; GET Y POSN OF MOUSE
          STA    OLDY         ; SAVE THAT TOO . . .
```

```
STILL       PushWord #$0000      ; SPACE FOR RESULT
            PushWord #$0000      ; MOUSE BUTTON (#0)
            ToolCall $0E06       ; StillDown
                                 ; SEE IF MOUSE BUTTON STILL DOWN

            PLA                  ; GET BOOLEAN RESULT
            BNE   :1
            JMP   UP             ; DONE DRAWING...

:1          PushWord OLDX        ; X POSN OF MOUSE
            PushWord OLDY        ; Y POSN OF MOUSE
            ToolCall $3A04       ; MoveTo

LOCL        PushLong #YPOS       ; ADDR. OF Y AND X DATA
            ToolCall $0C06       ; GetMouse (LOCAL)

            PushWord XPOS        ; X POSN OF MOUSE
            PushWord YPOS        ; Y POSN OF MOUSE
            ToolCall $3C04       ; LineTo

            LDA   XPOS           ; MAKE OLD X = CURRENT X
            STA   OLDX
            LDA   YPOS           ; OLD Y = CURRENT Y
            STA   OLDY

            JMP   STILL          ; BACK FOR MORE...
*------------------------------

UP          ToolCall $9004       ; HideCursor (DON'T COPY THAT!)

            PushLong #$0000      ; SPACE FOR RESULT
            ToolCall $C704       ; GetClipHandle

            PullLong CLIP        ; SAVE CLIP REGION HANDLE

            PushLong #WINBLK     ; POINTER TO WINDOW LOC INFO BLOCK
            ToolCall $1E04       ; GetPortInfo
                                 ; WRITE IT TO WINBLK

            PushLong #WINRECT    ; POINTER TO WINDOW RECTANGLE
            ToolCall $2004       ; GetPortRect
                                 ; WRITE IT TO WINRECT

            LDA   WINRECT        ; SET PICRECT = WINRECT
            STA   PICRECT        ; SO PaintPixels WILL XFER
            LDA   WINRECT+2      ; WINDOW AREA TO OUR PICTURE
            STA   PICRECT+2

            PushLong #PAINTBLK   ; POINTER TO PARM BLOCK
            ToolCall $7F04       ; PaintPixels
                                 ; COPY NEW IMAGE TO PICTURE IN MEM
            PushWord #$0000     ; X = 0
            PushWord #$0000     ; Y = 0
            ToolCall $2304      ; SetOrigin
                                ; MUST DO THIS FOR A DRAW
                                ; OUTSIDE THE UPDATE ROUTINE
                                ; TO RETURN ORIGIN TO 0,0

            ToolCall $CA04      ; InitCursor

            RTS
******************************************

SHOW        PushLong WPTR
            ToolCall $130E      ; ShowWindow

            PushWord #257       ; ITEM # FOR 'ERASE'
            ToolCall $300F      ; EnableItem

            PushWord #259       ; ITEM # FOR CLOSE
            ToolCall $300F      ; EnableItem

            PushWord #258       ; ITEM # FOR OPEN
            ToolCall $310F      ; DisableItem

            LDA   #MDOWN        ; ADDRESS FOR MDOWN ROUTINE
            STA   C1            ; REWRITE MDOWN VECTOR

            RTS
******************************************

HIDE        PushLong WPTR
            ToolCall $120E      ; HideWindow

            PushWord #257       ; ITEM # FOR ERASE
            ToolCall $310F      ; DisableItem

            PushWord #259       ; ITEM # FOR CLOSE
            ToolCall $310F      ; DisableItem

            PushWord #258       ; ITEM # FOR OPEN
            ToolCall $300F      ; EnableItem

            LDA   #IGNORE       ; ADDRESS FOR IGNORE ROUTINE
            STA   C1            ; REWRITE MDOWN VECTOR

            RTS
******************************************

PEN         DA    #261          ; CURRENT PEN CHOICE (MENU ITEM #)
COLOR       DA    #265          ; CURRENT COLOR CHOICE (MENU ITEM #)

OLDX        DA    $0000         ; OLD MOUSE X
OLDY        DA    $0000         ; OLD MOUSE Y
```

```
PAINTBLK   ADRL WINBLK          ; WINDOW LOCINFO BLOCK
           ADRL PICBLK          ; PICTURE LOCINFO BLOCK
           ADRL WINRECT         ; POINTER TO WINDOW RECTANGLE
           ADRL PICRECT         ; POINTER TO PICTURE POINT
           DA   $0000           ; XFER MODE (COPY)
CLIP       ADRL $0000           ; CLIP REGION HANDLE
******************************************

CURSOR     DA   3               ; CURSOR HEIGHT (3 SLICES)
           DA   2               ; CURSOR WIDTH (2 WORDS)

IMAGE      HEX  0000,0000       ; LAST WORD MUST ALWAYS BE $0000!
           HEX  0f00,0000       ; F + F = BLACK CURSOR
           HEX  0000,0000       ; 0 + 0 = NO IMAGE

MASK       HEX  0F00,0000       ; F + 0 = WHITE BORDER
           HEX  FFF0,0000
           HEX  0F00,0000

HOTSPOT    DA   1               ; Y = 1
           DA   1               ; X = 1
******************************************

PICBLK     DA   $0000           ; 0 = 320 MODE
PICLOC     ADRL $0000           ; POINTER TO PICTURE DATA
           DA   160             ; WIDTH OF IMAGE IN BYTES
           DA   0,0,200,320     ; RECT OF DATA

PICRECT    DA   0,0,200,320     ; RECT OF PIXELS TO XFER

PAINTRECT  DA   0,0,200,320     ; RECT OF PIXELS FOR ‘PAINT’

PREGION    ADRL $0000           ; STORAGE FOR HANDLE

*-----------------------------

WINBLK                          ; WILL BE WRITTEN BY GETPORTLOC
           DA   $0000           ; 0 = 320 MODE
WINLOC     ADRL $E12000         ; ADDR. OF SUPER HI-RES SCREEN
           DA   160
           DA   0,0,0,0         ; MAX SCREEN SIZE

WINRECT    DA   0,0,0,0         ; RECT OF PIXELS TO XFER

WREGION    ADRL $0000           ; STORAGE FOR HANDLE
******************************************

CHKSUM     CHK                  ; CHECKSUM FOR VERIFICATION
```

After you've added this to the end of your source listing, make the following changes to the main body of the program itself. As before, each addition will be presented in the context of its surroundings, and we'll use the introduction of each addition as the opportunity to discuss the related text that you've added at the end of the listing.

The first modification is to add a new direct-page pointer, **PICHNDL**, in the same spot as you added the pointer **MSSGPTR** for the Event Display program. PICHNDL will be used to dereference the address of our memory block that holds the actual document we're painting.

```
PRODOS   EQU  $E100A8      ; STD. PRODOS 16 ENTRY

PTR      EQU  $00          ; OUR OWN DIRECT PAGE PTR
                           ; $00,01,02,03

PICHNDL  EQU  $04          ; HANDLE OF OUR PICTURE
```

This program will make use of two new menus, one called *FILE* that will have the Quit option in it, along with some options for opening and closing the document window, and erasing the document if you want to start over. The second menu is called *PENS*, and offers choices of pen sizes and colors for drawing. You'll recall from earlier discussions that additional menus are added by first telling the Menu Manager about them via the NewMenu command, and then adding these menus with InsertMenu. Menus are inserted in the order in which they appear from right to left, so the Apple icon menu will always be defined last, at least using this method. InsertMenu actually lets you insert a menu anywhere, but remember that menu position zero always does the insert at the far left.

```
DESK     ToolCall $0205      ; DeskStartup

PENMENU  PushLong #$0000     ; SPACE FOR RESULT
         PushLong #MENU3     ; ADDR. OF MENU STRUCTURE
         ToolCall $2D0F      ; NewMenu

         PullLong MENU3HD    ; STORE HANDLE TO 3RD MENU

         PushLong MENU3HD
         PushWord #$0000     ; INSERT AT THIS POSITION (FRONT)
         ToolCall $0D0F      ; InsertMenu (ADD TO MENU BAR)

FILE     PushLong #$0000     ; SPACE FOR RESULT
         PushLong #MENU2     ; ADDR. MENU STRUCTURE
         ToolCall $2D0F      ; NewMenu

         PullLong MENU2HD    ; STORE 2ND MENU HANDLE

         PushLong MENU2HD
         PushWord #$0000     ; INSERT AT THIS POSITION (FRONT)
         ToolCall $0D0F      ; InsertMenu
APPLE    PushLong #$0000     ; SPACE FOR RESULT
```

These lines show the new menus being defined and inserted just previous to the Apple icon menu. The new menu definitions should be added right after the definition for **MENU1** in the shell program, and will look like this:

```
MENU1      ASC  '>>@ \N1X',00  ; APPLE MENU
           ASC  '--Your Message Here...  \N256V',00
           ASC  '.'                    ; END OF MENU

MENU1HD    ADRL $0000                  ; STORAGE FOR HANDLE

MENU2      ASC  '>> File  \N2',00 ; FILE MENU
           ASC  '--Erase Picture  \N257V*Ee',00
           ASC  '--Open Window  \N258D*Oo',00
           ASC  '--Close Window  \N259V*Hh',00
           ASC  '--Quit \N260*Qq',00
           ASC  '.'

MENU2HD    ADRL $0000

MENU3      ASC  '>> Pens  \N3',00 ; PENS MENU
           ASC  '--Small Pen  \N261C',12,00
           ASC  '--Medium Pen  \N262C ',00
           ASC  '--Large Pen  \N263C ',00
           ASC  '--- \N264D',00
           ASC  '--Black  \N265C',12,00
           ASC  '--Red  \N266C ',00
           ASC  '--Blue  \N267C ',00
           ASC  '.'

MENU3HD    ADRL $0000
```

The menu items for Small Pen and Black include a startup default check mark, defined with the value $12 after the C special character. Once the menus have been defined and the menu bar has been drawn, we will want to open up the document window. Just prior to that, though, it wouldn't hurt to create the document itself by allocating some memory and clearing it to whatever background color you want to use. A good place to insert the routine to set up a new document would be at the label **WIND** (for Window) in the SHELL program:

```
DRAWMENU   ToolCall $2A0F        ; DrawMenuBar
                                 ; DRAW MENU, LOWER WINDOW

WIND       JSR   DOCSETUP        ; START A NEW DOCUMENT

           JSR   OPEN            ; OPEN A WINDOW, SET DEFAULTS

SHOWCURS   ToolCall $9104        ; ShowCursor
```

The instructions for **DOCSETUP** (Document Setup) have already been entered at the end of the listing. The beginning of DOCSETUP first uses the

Memory Manager call NewHandle to allocate a 32K block of memory equivalent to the super hi-res display screen. Although the actual pixel area is only 32,000 bytes and leaves some unused memory in the block, it is a convenient memory definition. In a more advanced drawing program, you would use the extra memory to store a copy of the SCBs and color tables used for that particular drawing. Since this program has no provision for loading or saving pictures, we won't have to worry about that.

You're also not limited to a document size equal to that of the screen. It's only arbitrary that the window parameter list and the document itself have specified a data area equal to the screen. By adjusting wDataSize in the window parameter list, obtaining more memory for the document, and adjusting the LocInfo parameter block accordingly, we can create a document limited only by the amount of available memory.

Once memory has been obtained, DOCSETUP does a JSR to the ERASE routine. ERASE works by dereferencing the handle to the memory block to determine exactly where in memory the picture is currently located. Before dereferencing a movable block, the block must be temporarily locked to make sure some other application doesn't force a memory compaction that would move the block while our program was trying to erase it. Locking the block was not a concern in dereferencing the direct page block, because the attributes of the direct page specified the block as unmovable at creation time.

The drawing program could have requested that the document memory be fixed, but this is not a good practice because it unnecessarily jams up memory that other applications may want to use.

Once the block is locked and dereferenced, the CLR (CLeaR) loop puts the value $E in every pixel location. This corresponds to dark gray, but you can use any value you want. Each nibble should have the same value ($5555, $AAAA, $3333, and so on). Once the block is erased, it is unlocked, and we continue with the DOCSETUP routine.

SETREGN is then used to create a rectangular region that will be used by PaintPixels as the Clip Region each time we copy a new line that has been drawn on the screen into the picture in memory. Once the region has been set up, and the handle to it is stored in PREGION (Picture REGION), DOCSETUP is done, and we resume the overall setup portion of our program.

Once everything is set up and the window opened, this brings us to the main event loop of the program. SPECIAL will remain a do-nothing routine, and the JSR SPECIAL could be removed if you were so inclined. In the interest of minimizing changes while you're debugging, though, we'll leave it alone.

More Changes

The main change to the beginning of the event loop will be to replace the JSR SHUTDOWN response to the close box with a JSR HIDE:

```
******************************************
* HANDLE THE EVENT
******************************************

EVT   JSR   SPECIAL      ; ANY SPECIAL EVENT HANDLING

      CMP   #$11         ; MENU EVENT?
      BNE   :I           ; NOPE
      JSR   DOMENU       ; HANDLE IT
      JMP   MAIN         ; BACK FOR MORE

:1    CMP   #$16         ; CLOSE BOX
      BNE   DOCMDS

      JSR   HIDE         ; CLOSE THE WINDOW
      JMP   MAIN

******************************************
```

HIDE is the routine that will actually be called when the user selects Close from the File menu or clicks in the close box. HIDE has already been added to the end of the listing, and is fairly simple. There is a Window Manager command, **HideWindow** ($120E), that makes the specified window invisible. While we're doing this, however, we'll want to change the menu choices to disable Close and Erase (since there's nothing on the screen to close or erase), and enable the choice Open Window. This is done with the Menu Manager commands **EnableItem** ($300F) and **DisableItem** ($310F).

Since we can't draw in a hidden window, the HIDE routine finishes by rewriting the MDOWN (Mouse-DOWN) vector to ignore mouse events. You might think the answer would be to set the TaskMaster mask TMASK, or the event mask used in the actual call to TaskMaster to ignore a mouse-down event. But then mouse-down events would be ignored everywhere—something you probably wouldn't want.

HIDE, along with the other menu functions, is supported in the DOMENU part of the event loop. In the SHELL program, only one menu item is tested for. In this program, we can set up an indexed indirect command processor to jump to the appropriate routine for each menu choice. This is only possible when each menu item is successively numbered (or at least with minimal skipping of items).

```
DOMENU    LDA   TDATA           ; MENU ITEM NUMBER
          CMP   #256            ; APPLE MENU MSSG?
          BNE   :1              ; NOPE
          JMP   NORMAL          ; IGNORE (BUT UNHILITE)

:1        SEC
          SBC   #256            ; ADJUST TO ZERO
          ASL                   ; TIMES 2 FOR OFFSET
          TAX
          JSR   (MENUCMDS,X)

NORMAL    PushWord #$0000       ; 0 = UNHIGHLIGHT
          PushWord TDATA+2      ; MENU HEADER #
          ToolCall $2C0F        ; HiLiteMenu

          RTS

MENUCMDS  DA    IGNORE          ; "YOUR MESSAGE"
          DA    ERASE           ; "ERASE"
          DA    SHOW            ; "OPEN"
          DA    HIDE            ; "CLOSE"
          DA    SHUTDOWN        ; "QUIT"
          DA    PENS            ; "SMALL"
          DA    PENS            ; "MEDIUM"
          DA    PENS            ; "LARGE"
          DA    IGNORE          ; (DIVIDING LINE)
          DA    COLORS          ; "BLACK"
          DA    COLORS          ; "RED"
          DA    COLORS          ; "BLUE"
*******************************************

OPEN      PushLong #$0000       ; SPACE FOR RESULT
```

The routines supported in the DOMENU handler are IGNORE, ERASE, SHOW, HIDE, SHUTDOWN, PENS and COLORS. You've already seen some of these; let's look at the new ones.

SHOW is the opposite of the HIDE routine, and calls the Window Manager tool ShowWindow. Like HIDE, the remainder of SHOW then properly enables and disables related menu choices. Erase and Close are enabled, Open is disabled. The mouse-down vector in the command table is also reactivated to use the MDOWN routine, which will be discussed shortly.

For simplicity's sake, PENS and COLORS both just store the menu item value as the code number for a pen size or color. This makes it easy to change the check mark for each menu item as a new choice is selected. It's in the actual drawing routine, MDOWN, that converts the current code value for the pen and color to a value usable by the QuickDraw SetPenSize and SetSolidPenPat routines.

Revising UPDATE

The next part of the SHELL program to change is the **UPDATE** routine that will bring new portions of the document into view as we scroll or resize the window. This addition will be minor, and will consist of a JSR to the PAINT routine that fills in the window.

```
UPDATE  PHB                     ; SAVE OTHER'S DATA BANK
        PHK
        PLB                     ; DATA BANK = OURS

        PHD                     ; SAVE THE DIRECT PAGE
        LDA   MYDP              ; USE OURS FOR NOW...
        TCD

        JSR   PAINT             ; PAINT THE PICTURE IN THE WINDOW

        PLD                     ; RESTORE THE DIRECT PAGE
        PLB                     ; RESTORE THE ORIG. DATA BANK
        RTL
```

The PAINT Routine

PAINT was included in the text added at the end, and looked like this:

```
PAINT   PushLong PICHNDL
        ToolCall $2002          ; HLock

        LDA   [PICHNDL]         ; LONG INDIRECT LOAD
        STA   PICLOC            ; SET THE MEM ADDRESS
        LDY   #$02
        LDA   [PICHNDL],Y
        STA   PICLOC+2

        PushLong #PICBLK        ; POINTER TO PARM BLOCK
        PushLong #PAINTRECT     ; POINTER TO DATA RECT
        PushWord #$0000         ; DESTINATION X = 0
        PushWord #$0000         ; DESTINATION Y = 0
        PushWord #$0000         ; XFER MODE = 'COPY'
        ToolCall $D604          ; PPToPort
                                ; COPY THE PICTURE TO THE WINDOW

        PushLong PICHNDL
        ToolCall $2202          ; HUnlock

        RTS
```

The idea here is to first dereference the handle to our document (the picture), and to then store this address in the LocInfo structure for our picture, PICBLK. In addition, a rectangle definition, PAINTRECT has been set up to equal the entire size of our document. PPToPort is then called to actually transfer the pixels from memory onto the active window. After unlocking the memory block, PAINT then returns to UPDATE, and we're all done repainting the window.

The last change to make to the original SHELL program is to rewrite the mouse-down vector (previously IGNORE) to point to the heart of our drawing program, MDOWN:

```
CMDS DA   IGNORE      ; NULL EVENT
C1   DA   MDOWN       ; MOUSE DOWN
C2   DA   IGNORE      ; MOUSE UP
C3   DA   IGNORE      ; KEY DOWN
```

The Mouse-Down Drawing Loop

Here's where the real work gets done. MDOWN is called whenever the main event loop determines that the mouse is being held down. If the program were only slightly more refined, it would also check the TaskMaster code on the stack to make sure that the mouse-down was in the content region of the window, but that would preclude a demonstration that will be the grand finale of the book.

Once the mouse-down is detected, the gears start turning and the program gets ready to draw. First, the cursor is changed from an arrow to a very little dot. This is done with **SetCursor** ($8E04). A cursor definition consists of a data structure that includes the height of the cursor in rows (slices), and the width in words. One of the restrictions to a cursor definition is that the last word of each slice by $0000. A cursor definition consists of two patterns. The first is the image itself, wherein any black portion is indicated with a nibble set to $F.

To keep the cursor from disappearing on a black background, there is also a mask as part of the cursor record, which includes a larger pattern of $F's that create the border. Wherever there is an $F in both the image and the mask, the cursor is solid black. Wherever both the image and the mask are $0, there is no cursor, that is, you can just see whatever's under the cursor. Wherever the cursor image is $0 and the mask is $F, a white pixel is shown, which creates the outline to the cursor.

If you want to get really fancy, you can put an $F in the mask but leave the corresponding pixel in the image $0. This will invert whatever is on the screen at that point or pattern, producing a really interesting result. The $0 and $F are also used to specify black and white. If you want a colored cursor, you can use other pixel values as you desire.

Finally, each cursor record also contains a definition of the *hot spot* for that cursor. The hot spot is just the part of the cursor that will be assigned to the current mouse position as the mouse is moved around. It's called the hot spot because this also has the effect of being the part of the cursor that counts when you are checking to see if the user clicked on a certain part of the screen, for example in a window control.

With this information, you may wish to experiment with this program in designing new and more creative cursors.

Once the new cursor has been assigned, the routines SETPEN and SETCOL use the store PEN and COLOR values to determine a value to use for the QuickDraw SetPenSize and SetSolidPenPat routines.

Now, although the pen and cursor have been set up, the coordinate system of the window is still set for the QuickDraw internal routines with the origin (upper left corner of the content region) at 0,0. The command StartDrawing fixes this, which is followed by the GetMouse instruction to figure out where the mouse is in terms of the local coordinates of the window. To enable continuous drawing, and to help with some other techniques to be discussed later, we also start two new position variables called *OLDX* and *OLDY*. This will allow us, as we get each new mouse position, to know where the previous one was to use as a starting point to draw a line.

The section STILL uses an Event Manager routine called *StillDown* that returns a zero or nonzero value that tells us whether or not the mouse is still down after the initial mouse-down. On each pass through the STILL(down) loop, we'll draw a line between the last mouse position on the screen and the current one. Only when StillDown fails, which means the user has released the mouse button, do we complete the drawing operation and copy the line just drawn to the document in memory.

The part of code beginning with the local label **:1** and continuing to the jump back to STILL executes the actual drawing loop, and continually cycles the mouse position just used into the OLDX and OLDY variables for the next pass through the loop.

This is all pretty straightforward. The tricky part comes when the user releases the mouse button, and the program branches to UP, which then has to copy the new lines into the document in memory.

The first thing UP does is to hide the cursor completely. Otherwise, the image of the cursor would be copied into our picture as well. The remaining block of code then determines the current clip handle and PortLocInfo for the window's GrafPort, and saves this in CLIP and the storage block WINBLK. There are two LocInfo structures used in the PaintPixel transfer—one each for the destination and source images. WINBLK is the LocInfo structure for the window; PICBLK is the corresponding LocInfo structure for our picture.

The next information needed is the actual local coordinate description of the content rectangle of the window. That is, where do the users think they're drawing on the document? **GetPortRect** ($2004) will write this into a Rect data structure for us, and, in the interest of efficiency, I've set it up to write directly into the WINBLK LocInfo structure that will be used in just a moment by PaintPixels. When that rectangle is returned, I also copy it into the destination LocInfo structure for PICBLK.

Now the moment of truth. PAINTBLK is the supervisory parameter block for PaintPixels, and it is already set up to point to WINBLK and PICBLK as the source and destination LocInfo data structures. It's actually the PaintPixel call that does all the work in copying the currently visible part of the window onto the corresponding portion of our document in memory.

Once that's completed, SetOrigin is used to return the origin of the window back to 0,0 for QuickDraw, the cursor is restored to the arrow with **InitCursor** ($CA04), and the routine returns to the main event loop.

One last comment. On first reading, it's easy to become disoriented with all the new terms referring to clipping regions, the PortRect, and so on. Try not to be discouraged, though. The learning phase of any new vocabulary is a stressful time while your brain sorts out all the new words and concepts.

One way to make your programming easier to to just concentrate on the terms used in the particular tool call you need to use to accomplish a particular function. Learn to be a tool browser. Get in the habit of skimming through your tool reference books to find the particular tool that sounds relevant at a given moment, and don't worry about all those other cryptic entries flashing by, trying to distract you.

Trying Out the Drawing Program

After you've made all the above changes, you should get a final checksum of $05. However, don't panic if you get a different number on your first assembly. If you don't get this checksum, it's possible you've added an extra space or character to a menu item, and it may not be a fatal error. Try running your program and see if everything works all right.

If you have problems, remember to type E1/C029: 21 when you hear the BRK bell, and look at the place where the program broke and at the contents of the Accumulator for clues as to what went wrong. Then type Control-Y to try to return to your program selector. If you do have problems, be sure to double-check all the uses of PushLong and PushWord in your source file to make sure they agree with the listings in this book. When those fingers get flying along, it's easy to go into autopilot an absent-mindedly type a PushLong when it should have been PushWord, or vice versa.

When the program is running successfully, try drawing with the different pens and colors. Also notice that your drawing isn't destroyed by closing the window. It's right there when you open the window again.

You might also notice that even when you press the mouse button outside of the window, the cursor still changes and the routine tries to draw outside the window. Of course, nothing happens because the Window Manager has already established a clipping window that prevents you from drawing outside of the window. This could have been prevented by just checking the TaskMaster code returned on the stack to make sure we were in the content region of the window when the mouse-down event occurred. However, leaving it this way lets you explore another issue.

As an experiment, try drawing a circle or box that goes outside the window area, and then use the scroll bars or grow box to make the window bigger to see what happened. What you'll see is that the only part of your line that was copied into your document was the portion that was drawn within the content portion of the window and then copied to the document with PaintPixels.

This makes sense, but brings up the question: Suppose you wanted to draw a square or an object bigger than the window under program control, perhaps in an object-oriented drawing program? If you've ever seen MacPaint or MousePaint for the Apple IIe, you may have noticed that when you try to use an eraser or to fill a background with the *paint* function, only the visible part of the screen is changed, leaving a big unaffected area for everything offscreen at the time of the action.

One solution is to continually duplicate any drawing action in the visible window, and to also draw directly into the offscreen document. With this approach, you should be able to uncover and view an entire shape, even if it was drawn with the cursor outside the active window. Of course, a real program wouldn't let the user do this, but the technique used will illustrate how you could do any QuickDraw command into a document that was not entirely visible through an active window.

The Better Sketcher Program

Save the source listing for SIMP.SKTCH once it's all working, and then save a duplicate under the new name BETTER.SKTCH. The only part of the program that needs to be changed is the MDOWN drawing routine.

To do this, rewrite the MDOWN routine starting at LOCL so that it looks like this:

```
LOCL      PushLong #YPOS          ; ADDR. OF Y AND X DATA
          ToolCall $0C06          ; GetMouse (LOCAL)
          PushWord XPOS        ; X POSN OF MOUSE
          PushWord YPOS        ; Y POSN OF MOUSE
          ToolCall $3C04       ; LineTo

OFFSCRN   PushLong #WINBLK     ; POINTER TO WINDOW LOC INFO BLOCK
          ToolCall $1E04       ; GetPortLocInfo
                               ; WRITE IT TO WINBLK

SAVEW     PushLong #WINRECT    ; POINTER TO WINDOW RECTANGLE
          ToolCall $2004       ; GetPortRect
                               ; WRITE IT TO WINRECT

          PushLong #$0000      ; SPACE FOR RESULT
          ToolCall $C904       ; GetVisHandle

          PullLong WREGION     ; SAVE HANDLE TO WINDOW VIS REGION

SETOFF    PushLong PREGION     ; PICTURE VIS REGION
          ToolCall $C804       ; SetVisHandle
                               ; GET VIS REGION FOR ENTIRE PICTURE

          PushLong #PICBLK
          ToolCall $1D04       ; SetPortLoc
                               ; SET PORT LOC TO PICTURE

          PushLong #PICRECT    ; POINTER TO PICTURE RECT DEF.
          ToolCall $1F04       ; SetPortRect
                               ; PORT = ENTIRE PICTURE

DRAWOFF   PushWord OLDX        ; X POSN OF MOUSE
          PushWord OLDY        ; Y POSN OF MOUSE
          ToolCall $3A04       ; MoveTo

          PushWord XPOS        ; X POSN OF MOUSE
          PushWord YPOS        ; Y POSN OF MOUSE
          ToolCall $3C04       ; LineTo

SETWIN    PushLong WREGION     ; GET WINDOW VIS REGION HANDLE
          ToolCall $C804       ; SetVisHandle
                               ; MAKE VIS REGION WINDOW AGAIN

          PushLong #WINBLK
          ToolCall $1D04       ; SetPortLoc
                               ; SET PORT LOC BACK TO WINDOW

          PushLong #WINRECT    ; POINTER TO WINDOW RECT DEF.
          ToolCall $1F04       ; SetPortRect
                               ; PORT = ACTIVE WINDOW

          LDA   XPOS           ; MAKE OLD X = CURRENT X
          STA   OLDX
          LDA   YPOS           ; OLD Y = CURRENT Y
          STA   OLDY
```

```
         JMP   STILL          ; BACK FOR MORE...
*******************************************

UP       PushWord #$0000      ; X = 0
         PushWord #$0000      ; Y = 0
         ToolCall $2304       ; SetOrigin
                              ; MUST DO THIS FOR A DRAW
                              ; OUTSIDE THE UPDATE ROUTINE
                              ; TO RETURN ORIGIN TO 0,0

         ToolCall $CA04       ; InitCursor

         RTS
```

This revised routine changes things by adding another step to the drawing process. As each line segment is drawn from OLDX, OLDY to XPOS, YPOS in the main window, a repeat performance is made after switching the GrafPort LocInfo pointer to our offscreen document. Let's look at the actual program steps to see how this is done.

The offscreen portion begins at the label OFFSCRN, where the current GrafPort LocInfo data is written to our data block WINBLK. This stores the current window's address information (this will make a lot more sense if you review the listing while you read each reference). SAVEW then uses GetPortRect to get the local coordinates of the window into WINRECT and the VisRgn clipping region handle into WREGION. These are saved because these are precisely the GrafPort attributes we are about to change to get the next drawing command to draw directly into our document.

SETOFF initiates this change-over by setting the VisRgn for the GrafPort to the rectangular region created for our document when it was first created. That region definition was stored in the handle PREGION. It then uses SetPortLoc to switch the drawing area to the part of memory designated by the LocInfo structure PICBLK. Finally, the PortRect is set to the entire document size of 200 × 320 pixels. This guarantees there will be no clipping as long as the drawing action is still within our document boundaries.

The actual offscreen drawing takes place starting at DRAWOFF, and only takes a few instructions.

SETWIN then starts the process of restoring the GrafPort back to the window on the display screen. The VisRgn is restored using the stored handle in **WREGION**; the PortLocInfo parameters are restored with the data stored in **WINBLK**, and finally the PortRect is restored to that of the open window using the values stored in **WINRECT**.

Because the drawing takes place in both the window and the offscreen document almost simultaneously, the UP routine no longer needs to do any pixel copying, and so only needs to restore the origin and the cursor before returning to the event loop.

This is not the only approach to drawing offscreen, and probably not even the best one. The QuickDraw call OpenPort is designed specifically for opening many GrafPorts, none of which are required to be visible on the screen. The techniques shown here were chosen to give you a hands-on feel for what actually happens at the lower levels with various regions and data structures when you use commands like OpenPort and other Apple IIGS tools.

Conclusion

Well, here we are at last. Even though there is a lot to learn on the Apple IIGS, I hope you've found that in the end, everything really can be reduced to very simple elements.

The information presented here is only the beginning of the process of discovering the many facets of the Apple IIGS, and assembly language programming in general.

The real challenge begins now. In the end, a teacher only shows students what they were on the verge of discovering for themselves. As a facilitator to your own path of discovery, I hope you'll continue the process you've begun in this book and use each demonstration program as a starting point for many other explorations and experiments. Not every answer has to come out of a book, and now is as good a time as any to begin to discover your own secrets to the Apple IIGS.

It is the very fact that a computer has no defined purpose that makes it the ideal vehicle for the human imagination. You now have the ability and tools to make your Apple IIGS do what *you* want it to do. You're no longer limited to programs "off the shelf," someone else's preconceived notion of what the computer can do.

Remember that the most important person to please in writing programs is yourself, and it is your own quest for challenges and accomplishments that determine the value of the computer in your life. I hope this book has helped influence that process and helped nurture the seeds that will grow into the future reality of computers for everyone.

Appendices

Appendix A

65816 Instructions

This section will provide you with a quick reference for various 65816 instructions.

Although the terms *native* and *emulation* are used for the 16- and 8-bit modes of the 65816, it probably would have been better if the *e* bit had stood for *enable bit*, in regard to enabling the options of the 16-bit modes. The term *emulation* implies that the 65816 is somehow limited when in the emulation mode to a subset of the 65816 that emulates the 6502, and that many of the 65816 instructions are not available when in the emulation mode. This is not true, and you should not forget that even in the emulation mode, you have the full complement of 65816 instructions available to you. The main limitations in the emulation mode are simply in register size and the stack size and location.

Most instructions operate on either a *byte* or *word* (2 bytes) depending on the status of the *e*, *m*, and *x* bits.

For Accumulator and Memory operations:

e = 1 (emulation):	byte operation (*m* and *x* not applicable)
e = 0 (native), m = 0:	word operation
e = 0 (native), m = 1:	byte operation

For Index Register operations:

e = 1 (emulation):	byte operation (*m* and *x* not applicable)
e = 0 (native), x = 0:	word operation
e = 0 (native), x = 1:	byte operation

Because the relevance of the *m* and *x* bits are directly dependent on the status of the *e* bit, individual instructions may be commented with a phrase like "How many bytes are transferred is dependent on the condition of the *m* bit." Obviously the *e* bit is also a factor, but because the *m* bit can only be conditioned if e = 0, the mention of it would be redundant. There are a few instructions, notably the transfer commands like TAX, that involve both the *m* and *x* bits, and where some question may exist about the effect of the *e* bit, so appropriate discussion of all the status bits is included.

Although many of the example code segments use an 8-bit mode in the interest of clarity, it should be easy for you to anticipate the 16-bit version. Most actions with softswitches, hardware registers, and ASCII data are only done in the 8-bit mode, and many of the best illustrations of the uses of instructions like CMP and BIT are in reference to these operations. Remember that the 8-bit mode for a particular instruction doesn't require that the microprocessor be in the emulation mode (e = 1), only that the *m* or *x* bit be set for that particular instruction as appropriate.

For each instruction, the addressing modes are indicated. Note that under Common Syntax, lowercase letters are used within each example, like this:

Absolute Long **ADC $00FFff** **6F ff FF 00**

These are used only to clarify which byte of a word is allocated at a given position in the final assembly. You would not normally use lowercase letters in the operand of an instruction, although nothing specifically prohibits you from doing so.

For some examples, binary numbers are indicated in the form

%01100100

This is supported in the *Merlin* assembler, but may not be in the particular assembler you're using. This form of the operand is not required for any particular instruction and is used only in the interest of clearly showing the binary operation in any particular example.

Summary of Addressing Modes

Although the various addressing modes available on the 65816 are covered in greater detail in the main body of this book, here is an exampled summary of some of the modes available.

Absolute LDA $1234

Loads one or two bytes from locations $1234 (low byte), $1235 (high byte) in the current data bank.

Absolute Long LDA $FF1234

Loads one or two bytes from locations $1234 (low byte), $1235 (high byte) in bank $FF, regardless of the current data bank setting.

Direct Page **LDA $12**

Loads one or two bytes from relative positions $12 (low byte) and $13 (high byte) on the direct page. Remember the base address of the direct page depends on the setting of the direct page register, but this need not be considered within the context of any particular instruction.

Direct Page Indirect **LDA ($12)**

A 16-bit address is determined by examining the contents of bytes $12 and $13 (low byte, high byte) on the direct page. The resulting address in the current data bank is then used as the source of the data to be loaded into the Accumulator. It's only at that point that the condition of the *m* bit is taken into account and will affect how many bytes are loaded into the Accumulator.

Direct Page Indirect Long **LDA [$12]**

A 24-bit address is determined by examining the contents of bytes $12, $13 and $14 (low byte, high byte, bank byte) on the direct page. The resulting address is then used as the source of the data to be loaded into the Accumulator. It's only at that point that the condition of the *m* bit is taken into account and will affect how many bytes are loaded into the Accumulator.

Immediate **LDA #$12**

The value specified, in this example, $12, is loaded into the Accumulator. If m = 0 (16 bits), two bytes will be loaded ($0012).

Absolute Indexed,X **LDA $1234,X**
Absolute Indexed,Y **LDA $1234,Y**

A 16-bit address is determined by adding the contents of the X or Y Register to the base address specified in the current data bank. The resulting address is then used as the source of the data to be loaded into the Accumulator. If the calculated address exceeds the end of the current data bank, data will be accessed in the next bank of memory. This allows data blocks to cross bank boundaries. One or two bytes will then be loaded into the Accumulator depending on the condition of the *m* bit. If the X or Y Registers held the value $05, then the examples above would load the data from $1239, $123A.

Absolute Long Indexed,X LDA $FF1234,X

A 16-bit address is determined by adding the contents of the X Register to the base address specified. The resulting address is then used as the source of the data to be loaded into the Accumulator. If the calculated address exceeds the end of the base address bank, data will be accessed in the next bank of memory. This allows data blocks to cross bank boundaries. One or two bytes will then be loaded into the Accumulator depending on the condition of the *m* bit. If the X Register held the value $05, then the example above would load the data from $FF1239, $FF123A.

Direct Page Indexed,X LDA $12,X

Loads one or two bytes from position $12 plus the contents of the X Register on the direct page. Thus, if the X Register contained $05, the bytes would be loaded from locations $17, $18. Remember the base address of the direct page depends on the setting of the direct page register, but this need not be considered within the context of any particular instruction.

Direct Page Indexed Indirect,X LDA ($12,X)

A 16-bit address in bank zero is determined by adding the contents of the X Register to the specified direct-page address. One or two bytes are then loaded from the resulting relative address (low byte, high byte) on the direct page. Remember that the base address of the direct page depends on the setting of the direct-page register, but this need not be considered within the context of any particular instruction. If the X Register held the value $05, then the example above would first use the contents of locations $17, $18 to determine the target address. If $17, $18 pointed to location $1000, the data would then be loaded from $1000, $1001.

Direct Page Indirect Indexed, Y LDA ($12),Y

A 16-bit address is determined by examining the contents of bytes $12 and $13 (low byte, high byte) on the direct page. The contents of the Y Register are then added to the address in $12, $13, and the resulting address is then used as the source of the data to be loaded into the Accumulator. If the calculated address exceeds the end of the current data bank, data will be accessed in the next bank of memory. This allows data blocks to cross bank boundaries. It is only at that point that the condition of the *m* bit is taken into account and will affect how many bytes are loaded into the Accumulator. If the Y Register contained $05, and locations $12, $13 pointed to location $1000, the bytes would be loaded from locations $1005, $1006.

Direct Page Indirect Long Indexed,Y LDA [$12],Y

A 24-bit address is determined by examining the contents of bytes $12, $13 and $14 (low byte, high byte, bank byte) on the direct page. The resulting address is then added to the contents of the Y Register, and the result is used as the source of the data to be loaded into the Accumulator. If the calculated address exceeds the end of the base address bank, data will be accessed in the next bank of memory. This allows data blocks to cross bank boundaries. It is only at that point that the condition of the *m* bit is taken into account and will affect how many bytes are loaded into the Accumulator. If $12, $13, and $14 pointed to $FF1000, and the Y Register held $05, the data would be loaded from locations $FF1005, $FF1006.

Stack Relative LDA $12,S

This instruction adds the value in the operand ($12) to the current Stack Pointer value and loads the Accumulator with one or two bytes from the resulting address in the current data bank. Because the Stack Pointer always points to the next available position on the stack, which is empty, the first meaningful byte of data is always found at 1,S.

Stack Relative Indirect Indexed,Y LDA ($12,S),Y

This is similar to the Stack Relative addressing mode, but instead uses the contents of ($12,S) as a two-byte pointer to an address in the current data bank. The contents of the Y Register are then added to this address to determine the actual locations from which one or two bytes will be loaded into the Accumulator. If the calculated address exceeds the end of the current data bank, data will be accessed in the next bank of memory. This allows data blocks to cross bank boundaries.

Absolute Indexed Indirect JSR ($1234,X)

This instruction uses the contents of locations $1234, $1235 (low byte, high byte) as a base address to which the contents of the X Register are added. The resulting address in the current program bank is used as the target for the JSR.

ADC: Add with Carry

Description

This instruction adds the contents of a memory location or immediate value to the contents of the Accumulator, plus the carry bit, if it was set. The result is put back in the Accumulator. ADC works for both the binary and BCD modes.

Flags & Registers Affected

N	V	-	B	D	I	Z	C
•	•					•	•

Acc	X	Y	Mem
•			

Addressing Modes Available

Mode	Common Syntax	Hex Coding
Absolute	ADC $FFff	6D ff FF
Absolute Long	ADC $00FFff	6F ff FF 00
Direct Page	ADC $FF	65 FF
Direct Page Indirect	ADC ($FF)	72 FF
Direct Page Indirect Long	ADC [$FF]	67 FF
Immediate	ADC #$FF	69 FF
Absolute Indexed,X	ADC $FFff,X	7D ff FF
Absolute Long Indexed,X	ADC $00FFff,X	7F ff FF 00
Absolute Indexed,Y	ADC $FFff,Y	79 ff FF
Direct Page Indexed,X	ADC $FF,X	75 FF
Direct Page Indexed Indirect,X	ADC ($FF,X)	61 FF
Direct Page Indirect Indexed,Y	ADC ($FF),Y	71 FF
Direct Page Indirect Long Indexed,Y	ADC [$FF],Y	77 FF
Stack Relative	ADC $FF,S	63 FF
Stack Relative Indirect Indexed,Y	ADC ($FF,S),Y	73 FF

Uses

Peculiarly enough, ADC is most often used to add numbers together. Here are some common examples:

Adding a constant to the Accumulator or memory location:

```
CLC                ; GET READY TO ADD
LDA   MEM          ; GET FIRST VALUE (BYTE OR WORD)
ADC   #$80         ; ADD #$80
STA   RSLT         ; STORE RESULT
```

(RSLT = MEM + #$80)

Adding a constant (such as an offset) to a 2-byte (or 2-word) memory value:

```
2-Byte Form        2-Word Form
CLC                CLC                ; GET READY TO ADD
LDA   MEM          LDA   MEM          ; GET LOW BYTE (WORD) OF MEM
ADC   #$80         ADC   #$80         ; ADD LOW BYTE (WORD) OF #$80
STA   MEM          STA   MEM          ; SAVE LOW BYTE (WORD) RESULT
LDA   MEM+1        LDA   MEM+2        ; GET HIGH BYTE (WORD) OF MEM
ADC   #$00         ADC   #$00         ; ADD HIGH BYTE (WORD) OF #$80
STA   MEM+1        STA   MEM+2        ; SAVE HIGH BYTE (WORD) RESULT
```

(MEM,MEM+1(2) = MEM,MEM+1(2) + #$80)

Adding two 2-byte (or word) values together:

```
2-Byte Form       2-Word Form
CLC               CLC               ; Get ready to add
LDA   MEM         LDA   MEM         ; GET LOW BYTE (WORD) OF MEM
ADC   MEM2        ADC   MEM2        ; ADD LOW BYTE (WORD) OF MEM2
STA   MEM         STA   MEM         ; SAVE LOW BYTE (WORD) RESULT
LDA   MEM+1       LDA   MEM+2       ; GET HIGH BYTE (WORD) OF MEM
ADC   MEM2        ADC   MEM2        ; ADD HIGH BYTE (WORD) OF MEM2
STA   MEM+1       STA   MEM+2       ; SAVE HIGH BYTE (WORD) RESULT
```

(MEM,MEM+1(2) = MEM,MEM+1(2) + #$80)

AND: Logical AND

Description

This instruction takes each bit of the Accumulator and performs a logical AND with each corresponding bit of the specified memory location or immediate value. The result is put back in the Accumulator. The memory location specified is unaffected. (See ORA also.)

The truth table used is:

AND:

	0	1
0	0	0
1	0	1

Example:

Accumulator:	0 0 1 1 0 0 1 1
Memory:	0 1 0 1 0 1 0 1
Result	0 0 0 1 0 0 0 1

Flags & Registers Affected

N	V	-	B	D	I	Z	C
•						•	

Acc	X	Y	Mem
•			•

Addressing Modes Available

Mode	Common Syntax	Hex Coding
Absolute	AND $FFff	2D ff FF
Absolute Long	AND $00FFff	2F ff FF 00
Direct Page	AND $FF	25 FF
Direct Page Indirect	AND ($FF)	32 FF
Direct Page Indirect Long	AND [$FF]	27 FF
Immediate	AND #$FF	29 FF
Absolute Indexed,X	AND $FFff,X	3D ff FF
Absolute Long Indexed,X	AND $00FFff,X	3F ff FF 00
Absolute Indexed,Y	AND $FFff,Y	39 ff FF
Direct Page Indexed,X	AND $FF,X	35 FF
Direct Page Indexed Indirect,X	AND ($FF,X)	21 FF
Direct Page Indirect Indexed,Y	AND ($FF),Y	31 FF
Direct Page Indirect Long Indexed	AND [$FF],Y	37 FF
Stack Relative	AND $FF,S	23 FF
Stack Relative Indexed,Y	AND ($FF,S),Y	33 FF

Uses

AND is used primarily as a mask, that is, to let only certain bit patterns through a section of a program. The mask is created by putting 1's in each bit position where data is to be allowed through, and 0's where data is to be suppressed.

For example, it's frequently desirable to mask out the high-order bit of ASCII data, such as would come from the keyboard or another input device (like a disk file). The routine shown assures that no matter what value is gotten from DEVICE, the high-order bit of the value put in MEM will always be clear:

```
 Routine:                          Sample Input:
LDA  DEVICE     Accumulator:  01010111  or  11010111
AND  #7F        #$7F          01111111      01111111
STA  MEM                      ________      ________
                Result:       01010111      01010111
```

As an example, when reading the keyboard directly, without the benefit of the Event Manager (8-bit mode, usually in Applesoft BASIC or ProDOS 8), it is necessary to clear the high-order bit (bit 7). Here is the way this is usually done:

```
WATCH  LDA  KYBD        ; $C000
       BPL  WATCH       ; AGAIN IF < #$80
       BIT  STROBE      ; CLEAR STROBE: $C010
       AND  #$7F        ; CLR HIGH BIT
       STA  MEM
```

Furthermore, because the only difference between upper- and lowercase characters is that lowercase characters have bit 5 set, AND can be used to normalize input to all uppercase:

```
       LDA  CHAR        ; INPUT CHARACTER
       AND  #$DF        ; %1101 1111 (LC -> UC)
       STA  CHAR        ; CONVERTS LOWERCASE TO UPPER.
```

Another way of looking at this same effect is to say that AND can be used to force a zero in any desired position in the bit pattern of a byte or word. (See ORA to force 1's). A zero is put in the mask value at the positions to be forced to 0, and all remaining positions are set to 1. Whenever a data byte is ANDed with this mask, a zero will be forced at each position marked with a zero in the mask, while all other positions will be unaffected, remaining 0's or 1's as was their original condition.

In graphics operations, AND has the effect of creating the result of the intersection of two other images. For example:

```
00011000          00000000         00000000
00011000          00000000         00000000
00011000          00000000         00000000
00011000    AND   11111111    =    00011000
00011000          11111111         00011000
00011000          00000000         00000000
00011000          00000000         00000000
00011000          00000000         00000000
```

This is the underlying logical function behind the mask used in the cursor mask or a clipping region.

There are also rather obscure uses for the AND instruction. The first of these is to do the equivalent of a MOD function, involving a piece of data and a power of two. You'll recall that the MOD function produces the remainder in a division operation. For example: 12 MOD 4 = 0; 14 MOD 4 = 2; 18 MOD 4 = 2; 17 MOD 2 = 1; and so on. The general formula is:

Acc. MOD 2^n = RESULT

The actual operation is carried out by using a value of ($2^n - 1$) as the mask value. The theory of operation is that only the last *n* bits of the data byte are let through, thus producing the result corresponding to a MOD function.

Example:

```
LDA  MEM          ;
AND  #$07         ; %00000111 = 2^3 - 1
STA  MEM          ; MEM = MEM MOD 8
```

This technique provides one of several ways of testing for the odd/even attribute of a number:

```
LDA  MEM
AND  #$01         ; %00000001 = 2^1 - 1
BEQ  EVEN
BNE  ODD
```

The result of the AND of any number and #$01 will always be either 0 or 1, depending on whether the number was odd or even. This can also be used to determine if any variable number is an even multiple of a power of 2.

Another application is in determining if a given bit pattern is present among the other data in a number. For example, to test if bits 0, 3, and 7 are on, enter:

```
LDA  MEM
AND  #$89         ; %10001001
CMP  #$89
BEQ  MATCH
BNE  NOMATCH
```

The general technique is to first AND the data against a mask with just the desired bits set to 1 (all others 0), and then to immediately do a CMP to the same value. If the all the specified bits match, a BEQ will succeed.

Note: BIT (described later) can be used to test for one or more matches, but the AND technique described here confirms that all the bits of interest match.

ASL: Arithmetic Shift Left

Description

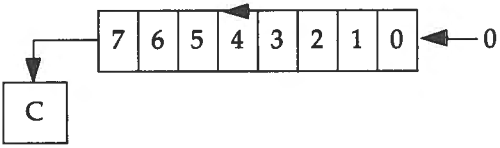
This instruction moves each bit of the Accumulator or memory location specified one position to the left. A zero is forced at the bit 0 position, and the high-order bit of the byte or word (bit 7 for a byte, bit 15 for a word) falls into the carry. The result is left in the Accumulator or memory location.

(See also ROL, also LSR and ROR.)

Flags & Registers Affected

N	V	-	B	D	I	Z	C
•						•	•

Acc	X	Y	Mem
•			•



ASL
(Arithmetic Shift Left)

Addressing Modes Available

Mode	Common Syntax	Hex Coding
Accumulator	ASL	0A
Absolute	ASL $FFff	0E ff FF
Direct Page	ASL $FF	06 FF
Absolute Indexed,X	ASL $FFFF,X	1E ff FF
Direct Page,X	ASL $FF,X	16 FF

Uses

The most common use of ASL is for multiplying by a power of two. You are already familiar with the effect in base ten: 123 * 10 = 1230 (shift left). For example:

```
LDA   MEM
ASL                 ; TIMES 2
ASL                 ; TIMES 2 AGAIN 2
STA   MEM           ; MEM = MEM * 4 (4 = 2 )
```

ASL can also be used in a loop to successively test each bit of a byte or word.

```
        LDX   #$07        ; 7 FOR A BYTE, 15 FOR A WORD
        PHA               ; SAVE VALUE
LOOP    PLA               ; RETRIEVE CURRENT VALUE
        ASL               ; SHIFT HIGH-ORDER BIT INTO CARRY
        PHA               ; SAVE SHIFTED VALUE
        BCC   CLEAR       ; BIT X CLEAR
        BCS   SET         ; BIT X SET
CLEAR   NOP               ; YOUR HANDLER HERE
SET     NOP               ; YOUR HANDLER HERE
        DEX               ; X = X - 1 FOR NEXT BIT
        BPL   LOOP        ; ANOTHER CYCLE
```

BCC: Branch Carry Clear

Description

Executes a branch if the carry flag is clear. Ignored if carry is set. Many assemblers have an equivalent mnemonic, BLT (Branch Less Than, not to be confused with the sandwich), since BCC is often used immediately following a comparison to see if the Accumulator held a value less than the specified value. BCC is limited to a relative branch distance of −128 to +127 bytes. (See also BCS.)

Flags & Registers Affected

N	V	-	B	D	I	Z	C

Acc	X	Y	Mem

Addressing Modes Available

Mode	Common Syntax	Hex Coding
Relative Only	BCC LABEL	6D ff
	or:	
	BCC $FFFF	6D ff

Uses

As mentioned, BCC is used to detect when the Accumulator is less than a specified value. The usual appearance of the code is listed below. Note that in a two-byte or two-word comparison, the high-order bytes/words are checked first. (See also BCS.)

One-Byte (Word) Comparison

```
ENTRY  LDA  MEM
       CMP  MEM2
       BCC  LESS
       BCS  EQ/GRTR
```

Goes to LESS if
MEM < MEM2)

Two-Byte (Word) Comparison

```
ENTRY  LDA  MEM+1(2)
       CMP  MEM2+1(2)
       BCC  LESS
       BEQ  CHK2
       BCS  GRTR

CHK2   LDA  MEM
       CMP  MEM2
       BCC  LESS
       BCS  EQ/GRTR
```

Goes to LESS only if
MEM,MEM+1(2) < MEM2,MEM2+1(2)

BCS: Branch Carry Set

Description

Executes the branch only if the carry flag is set. Some assemblers support the mnemonic BGT (for Branch Greater Than), since this command is used to test for the Accumulator equal to or greater than the specified value. BCS is limited to a relative branch distance of −128 to +127 bytes.

Flags & Registers Affected

N	V	-	B	D	I	Z	C

Acc	X	Y	Mem

Addressing Modes Available

Mode		Common Syntax	Hex Coding
Relative Only		BCS LABEL	B0 ff
	or:	BCS $FFFF	B0 ff

Uses

Used to detect Accumulator equal to or greater than a specified value. Can be combined with BEQ to detect a greater-than relationship. Note that in the 2-byte or 2-word comparison, the high-order bytes/words are checked first.

One-Byte (Word) Comparison

```
ENTRY  LDA  MEM
       CMP  MEM2
       BCC  LESS
       BEQ  EQUAL
       BCS  GREATER
```

Goes to GREATER if
MEM > MEM2, or EQUAL
if MEM = MEM2

Two-Byte (Word) Comparison

```
ENTRY  LDA  MEM+1(2)
       CMP  MEM2+1(2)
       BCC  LESS
       BEQ  CHK2
       BCS  GREATER

CHK2   LDA  MEM
       CMP  MEM2
       BCC  LESS
       BEQ  EQUAL
       BCS  GREATER
```

Goes to GREATER only if
MEM,MEM+1(2) > MEM2,MEM2+1(2), or
to EQUAL if MEM,MEM+1 = MEM2,MEM2+1

BEQ: Branch if Equal

Description

Executes a branch if the Z flag (zero flag) is set, indicating that the result of a previous operation was zero. See BCS to see how a comparison for the Accumulator equal to a value is done. BEQ is limited to a relative branch distance of −128 to +127 bytes.

Flags & Registers Affected

N	V	-	B	D	I	Z	C		Acc	X	Y	Mem

Addressing Modes Available

Mode		Common Syntax	Hex Coding
Relative Only		BEQ LABEL	F0 ff
	or:		
		BEQ $FFFF	F0 ff

Uses

In addition to being used in conjunction with compare operations, BEQ is used to test whether the result of a variety of other operations has resulted in a value of zero. The common classes of these operations are increment/decrement, logical operators, shifts, and register loads. Even easier to remember is the general principle that whenever you've done something that results in zero, chances are good the Z flag has been set. Likewise, any nonzero result of an operation is likely to clear the Z flag.

BEQ is used to check for the end of a string by using zero as a delimiter.

```
        LDX  #$00          ; BEGINNING OF DATA
LOOP    LDA  DATA,X        ; GET A CHARACTER (8 BIT)
        BEQ  DONE          ; CHAR = 0 = END OF STRING
WORK    NOP                ; YOUR PROGRAM HERE
        INX                ; NEXT CHARACTER IN STRING
        JMP  LOOP
DONE    RTS
```

BEQ can be used to terminate a loop by waiting for the counter to reach zero. (See BNE also.) When BEQ follows the decrement instruction at the end of the loop, the counter is initialized with the value for the number of times for the loop to execute.

```
        LDX  #25           ; LOOP 25 TIMES
LOOP    JSR  ROUTINE       ; DO SOMETHING
        DEX                ; COUNT DOWN
        BEQ  DONE          ; X = 0 = FINISHED
        JMP  LOOP          ; BACK FOR MORE
```

BIT: Compare Accumulator Bits with Contents of Memory

Description

Performs a logical AND on the bits of the Accumulator and the contents of the memory location. The result of the AND will be zero or nonzero, and the Z flag is conditioned accordingly. What this means is that if any bits set in the Accumulator happen to match any set in the value specified, the Z flag will be cleared. If no match is found, it will be set. BNE is used to detect a match, BEQ detects a no-match condition.

Fully understanding the function and various applications of this instruction is a sign of having arrived as an assembly language programmer, and suggests you are probably the hit of parties, thrilling your friends by doing hex arithmetic in your head and reciting ASCII codes on command.

Flags & Registers Affected

N	V	-	B	D	I	Z	C
*	*					•	
↑	↑						

Acc	X	Y	Mem

m7, m6 for byte operations,
m15, m14 for word operations.

Addressing Modes Available

	Common	Hex
Mode	**Syntax**	**Coding**
Absolute	BIT $FFff	2C ff FF
Direct Page	BIT $FF	24 FF
Immediate	BIT #$FF	89 FF
Absolute Indexed,X	BIT $FFff,X	3C ff FF
Direct Page Indexed,X	BIT $FF,X	34 FF

Uses

BIT provides a means of testing whether a given bit is on in a byte of data. **Important:** BIT will only indicate that at least one of the bits in question match. It does not indicate how many actually do match. See the AND instruction on how to do a check for all matching. The mask is created by setting 1's in the bit positions you are interested in, and leaving all remaining positions set to 0. Thus, if you are only interested in testing a specific bit, your mask should only have that bit set. BIT is almost always used in conjunction with branch instructions including BMI, BPL, BEQ and BNE. Be sure to look over the descriptions of these instructions as well.

Examples:

Showing the results of the BIT operation:

```
Acc:     1 0 0 1 1 0 1 1
Mem:     0 1 0 1 0 1 0 1       Z flag  effect:
         _______________
Result:  0 0 0 1 0 0 0 1 → 1    clr    BNE works
                                       BEQ not taken
```

Status Register

N	V	-	B	D	I	Z	C
0	1					0	
m7	m6						

```
Acc:     1 0 0 1 1 0 1 1
Mem:     0 1 0 0 0 1 0 0       Z flag  effect:
         _______________
Result:  0 0 0 0 0 0 0 0 → 0    set    BEQ works
                                       BNE not taken
```

Status Register

N	V	-	B	D	I	Z	C
0	1					1	
m7	m6						

Testing a given bit:

Test Acc. for bit 4 on

```
ENTRY  LDA  DEVICE
       BIT  #$10       ; %00010000
       BNE  MATCH
       BEQ  NOMATCH
```

Test memory for bit 4 on

```
LDA  #$10       ; %00010000
BIT  MEM
BNE  MATCH
BEQ  NOMATCH
```

Also important is the fact that a BIT instruction does not change the contents of the Accumulator. Here is an example of an 8-bit mode program that waits for a keypress while maintaining a unique value in the Accumulator.

```
       LDA  #$41       ; "A"
LOOP   BIT  KYBD       ; $C000
       BPL  LOOP       ; VAL < 128 = NO PRESS
       BIT  STROBE     ; $C010
       JSR  COUT       ; PRINTS LETTER "A"
DONE   RTS
```

Notice that in this example, no data is actually retrieved from the keyboard. Only a wait is done until the keypress.

The BIT STROBE step in the previous example also provides an illustration of a another application of BIT, which is to access a hardware location (often called a softswitch) without changing the contents of the Accumulator.

Important: Many ProDOS 8 and Applesoft BASIC routines set softswitches using the BIT instruction. For example, the instruction BIT $C050 enables the graphics display, BIT $C051 switches to text. However, this only works in the 8-bit mode. This is because in the 16-bit mode, the instruction BIT $C050 accesses *both* $C050 *and* $C051 (remember, it is then a 2-byte operation). The result is that $C051 is accessed last, and the final state is the text display, which is probably not what you intended. BIT instructions of softswitches should only be done in the 8-bit mode.

BIT also sets the N and V flags, and thus provides a very fast way of testing bits 6 and 7 of a byte or bits 14 and 15 of a word. When examining hardware registers, BIT can be combined with BMI to test for a high bit set. For example, in the Apple IIGS, location $C036 uses the high-order bit to indicate whether the system speed is configured to the normal or fast modes. BIT and BMI can be used to easily test this (in the 8-bit mode, of course).

```
TEST    BIT   $C036         ; CONFIGURATION REGISTER
        BMI   FAST          ; BIT 7 = 1 = FAST MODE
        BPL   SLOW          ; BIT 6 = 0 = SLOW MODE
```

Some applications use BIT to facilitate using a single byte or word as a flag to hold several status bits. For example, suppose our application wanted to set up a flag for whether the screen was black-and-white or color, and whether the printer was an ImageWriter or LaserWriter. Bit 7 could hold the color flag, bit 6 the printer code, and one BIT instruction could test for everything.

Bit 7: 0 = black-and-white, 1 = color
Bit 6: 0 = ImageWriter, 1 = LaserWriter

```
TEST    BIT   FLAG
        BPL   COLOR         ; BIT 7 = 0
        BMI   BLACKWH       ; BIT 7 = 1
        BVC   IMAGE         ; BIT 6 = 0
        BVS   LASER         ; BIT 6 = 1
```

This routine works because the BIT instruction automatically transfers bits 6 and 7 to the Status Register. In the 16-bit mode, bits 14 and 15 would have to store the flags for transfer to the N and V bits of the Status Register.

BMI: Branch on Minus

Description

Executes branch only if the N flag (sign flag) is set. N flag is set by any operation producing a result in the range of $80 to $FF for byte operations, and $8000 to $FFFF for word operations (for example, high bit set). BMI is limited to a relative branch distance of −128 to +127 bytes.

Flags & Registers Affected

N	V	-	B	D	I	Z	C

Acc	X	Y	Mem

Addressing Modes Available

Mode		Common Syntax	Hex Coding
Relative Only		BMI LABEL	30 ff
	or:		
		BMI $FFFF	30 ff

Uses

BMI is used to detect negative numbers when signed binary math is used. However, because the high-order bit is frequently used to indicate a wide variety of special conditions, BMI, along with BPL, is used to test the high-order bit, irrespective of its negative number connotations. See also the BIT instruction.

The high-order bit of many hardware registers is used to indicate significant conditions. BMI is usually used to test these. Because the registers use only a single byte, this testing is usually done in the 8-bit mode. For example, here's a typical way of watching the keyboard hardware location, $C000, for a keypress. (See BIT.)

```
LOOP    LDA   KYBD          ; 8-BIT MODE
        BMI   PRESS         ; DATA > $7F
        BPL   LOOP          ; DATA < $80
```

Since bit 7 is the high-order bit and has no effect on the ASCII character associated with a byte, this can be quite handy. For example, some word processing applications store formatting characters (such as flags for underlining, bold, and so forth among the text of a document. The high-order bit of each byte is used to indicate whether that byte is a text byte (high bit clear) or a formatting byte (high bit set).

```
READ    LDA   CHAR          ; GET CHARACTER FROM TEXT
        BMI   FORMAT        ; SPECIAL FORMAT ENCODING
CONT    NOP                 ; CONTINUE WITH TEXT READER HERE
```

BMI is also useful for terminating a loop that you want to reach 0, and where the loop will otherwise stay out of the $80 to $FF range. Notice that a loop terminated by a decrement and a BMI test will loop n + 1 times, where *n* is the starting value of the counter.

```
ENTRY   LDX   #$20         ; TO LOOP 33 TIMES
LOOP    DEX
        BMI   DONE         ; WHEN X = $FF
        BPL   LOOP         ; WHILE X > $FF
DONE    RTS
```

BNE: Branch Not Equal

Description

Executes the branch if the Z flag (zero flag) is clear, that is to say, if the result of an operation was a nonzero value. BNE is limited to a relative branch distance of −128 to +127 bytes.

Flags & Registers Affected

N	V	-	B	D	I	Z	C		Acc	X	Y	Mem

Addressing Modes Available

Mode		Common Syntax	Hex Coding
Relative Only		BNE Label	D0 FF
	or:	BNE $FFFF	D0 ff

Uses

Often used in loops to branch until the counter reaches zero. Also used in data input loops to verify the nonzero nature of the last byte loaded, as when checking for the end of a string.

BNE can be used to terminate a loop by waiting for the counter to reach zero. (See BEQ also.) When BNE follows the decrement instruction at the end of the loop, the counter is initialized with the value for the number of times for the loop to execute.

```
        LDX   #25          ; LOOP 25 TIMES
LOOP    JSR   ROUTINE      ; DO SOMETHING
        DEX                ; COUNT DOWN
        BNE   LOOP         ; BACK FOR MORE
DONE    RTS                ; COUNTER HAS REACHED ZERO
```

BNE can be used in a way similar to that for BEQ to check for the end of a string by using zero as a delimiter.

Example:

```
        LDX   #$00         ; BEGINNING OF DATA
LOOP    LDA   DATA,X       ; GET A CHARACTER
        BNE   WORK         ; CHAR NOT END OF STRING
        JMP   DONE         ; 0 = END OF STRING
WORK    NOP                ; YOUR PROGRAM HERE
        INX                ; NEXT CHARACTER IN STRING
        JMP   LOOP
DONE    RTS
```

BPL: Branch on Plus

Description

Executes branch only if the N flag (Sign Flag) is clear, as would be the case when the result of an operation is in the range of $00 to $7F (high bit clear) for byte operations, and $0000 to $7FFF for word operations. BPL is limited to a relative branch distance of −128 to +127 bytes. (See also BMI.)

Flags & Registers Affected

N	V	-	B	D	I	Z	C

Acc	X	Y	Mem

Addressing Modes Available

Mode		Common Syntax	Hex Coding
Relative Only		BPL LABEL	10 ff
	or:		
		BPL $FFFF	10 ff

Uses

BPL is an easy way of staying in a loop until the high bit is set. It is also used in general to detect the status of the high bit.

Here's our familiar keypress check using BPL:

```
ENTRY   LDA   KYBD        ; $C000, 8-BIT MODE
        BPL   ENTRY       ; LOOP UNTIL DATA > $7F
        BIT   STROBE      ; CLR $C010
        STA   MEM         ; SAVE VALUE
DONE    RTS
```

Also used for short loops (counters less than 128) that you want to reach zero.

```
ENTRY   LDX   #$20        ; WILL LOOP 33 TIMES
LOOP    DEX               ; X = X - 1
        BPL   LOOP        ; UNTIL X = $FF
DONE    RTS
```

BRA: Branch Always

Description

Always executes a branch. BRA is limited to a relative branch distance of −128 to +127 bytes. (See BRL.)

Flags & Registers Affected

N	V	-	B	D	I	Z	C

Acc	X	Y	Mem

Addressing Modes Available

Mode		Common Syntax	Hex Coding
Relative Only		BRA LABEL	80 FF
	or:		
		BRA $FFFF	80 FF

Uses

BRA is used mainly as a substitute for a JMP instruction in code that must be position independent without the benefit of a relocating loader like the System.Loader. In situations where the routine must be as small as possible, BRA also takes fewer bytes (2 vs. 3) than a JMP instruction.

Here's a loop that uses a BRA instead of a JMP:

```
        LDX  #25          ; LOOP 25 TIMES
LOOP    JSR  ROUTINE      ; DO SOMETHING
        DEX               ; COUNT DOWN
        BEQ  DONE         ; X = 0 = FINISHED
        BRA  LOOP         ; BACK FOR MORE
```

BRK: Break (Software Interrupt)

Description

When a BRK is encountered in a program, program execution halts, and the user generally sees something like the following:

```
00/0308: 00 00              BRK 00
 A=00A0 X=0000 Y=0001 S=0137 D=0000 P=D9
 B=00 K=00 M=0C Q=80 L=1 m=1 x=1 e=1
```

Flags & Registers Affected

N	V	-	B	D	I	Z	C		Acc	X	Y	Mem
			•									

↑
Emulation mode only (e = 1)

Addressing Modes Available

Mode	Common Syntax	Hex Coding
Implied Only	BRK 00	00 00

What happens is that the program counter plus two is saved on the stack. What happens next depends on which mode—emulation or native—the 65816 is in when the BRK occurs.

Emulation mode. The status register, where the BRK bit has been set, is pushed on the stack. The processor jumps to the address pointed to by the bytes at $00/FFFE,FFFF. This currently points to $00/C074, which jumps again to the Apple IIGS break handler at $E1/0010. For ProDOS 8 applications, control ultimately passes to a vector at $3F0,3F1.

Native mode. There's not a BRK bit in the status register, so, instead of setting a bit, the processor jumps to a vector pointed to by locations $00/FFE6,FFE7—the native mode BRK handler.

Uses

BRK can be very useful in debugging ML programs. Insert a BRK into the code at stategic points in the routine. When the program halts, examine the status of various memory locations and registers to see if all is as it should be. This process can be formalized, and considerably improved, by using a software utility called a *debugger*, which allows you to step through a program one instruction at a time.

Because BRK advances the program counter two bytes, the Monitor disassembles it as a two-byte instruction. Although *Merlin* lets you enter a single-byte BRK instruction in a source listing, your programs will disassemble better if you create each one in the BRK $00 form. If conserving memory is an issue, once your program is debugged, go back and replace the BRK $00 instructions with a simple one-byte BRK.

BRL: Branch Always Long

Description

Always executes a branch. BRL is different from BRA in that it supports a two-byte displacement and is limited only to a target address within the current program bank.

Flags & Registers Affected

N	V	-	B	D	I	Z	C

Acc	X	Y	Mem

Addressing Modes Available

Mode		Common Syntax	Hex Coding
Relative Only		BRL LABEL	80 FF
	or:		
		BRL $FFFF	80 FF

Uses

BRL is used mainly as a substitute for a JMP instruction in code that must be position independent without the benefit of a relocating loader like the System.Loader.

Here's a loop that uses a BRL instead of a JMP:

```
        LDX   #25          ; LOOP 25 TIMES
LOOP    JSR   ROUTINE      ; DO SOMETHING
        DEX                ; COUNT DOWN
        BEQ   DONE         ; X = 0 = FINISHED
        BRL   LOOP         ; BACK FOR MORE
```

BVC: Branch on Overflow Clear

Description

Executes a branch only if the V flag (overflow flag) is clear. The overflow flag is cleared whenever the result of an operation did not entail the carry of a bit from position 6 to position 7 (or bit 14 to 15 for words). The overflow flag can also be cleared with a CLV command. BVC is limited to a relative branch distance of −128 to +127 bytes.

Flags & Registers Affected

N	V	-	B	D	I	Z	C

Acc	X	Y	Mem

Addressing Modes Available

Mode		Common Syntax	Hex Coding
Relative Only		BVC LABEL	50 ff
	or:		
		BVC $FFFF	50 ff

The overflow bit is only conditioned by the instructions ADC, SBC, BIT, PLP, REP and SEP. That is to say, just loading a value into the Accumulator or a register doesn't automatically condition the V flag, as is the case with the N flag.

Uses

BVC is used primarily in detecting a possible overflow from the data portion of the byte into the sign bit when using signed binary numbers. For example:

```
ENTRY   CLC
        LDA  #$64          ; %01100100 = +100
        ADC  #$40          ; %01000000 = + 64
        BVC  STORE         ; NOT TAKEN HERE
ERR     RTS                ; RESULT = +164 = %10100100 > $7F
STORE   STA  MEM
```

BVC can also be used as a forced branch when writing position-independent code. The advantage is that the carry remains unaffected, thus allowing it to be tested later in the conventional manner.

```
        CLV                ; CLEAR V FLAG
        BVC  LABEL         ; (ALWAYS)
```

BVS: Branch Overflow Set

Description

Executes the branch only when the V flag (overflow flag) is set. The overflow flag is set only when the result of an operation causes a carry of a bit from position 6 to position 7 (or bit 14 to 15 for words). Note that there is not a command to specifically set the overflow flag (as would correspond to a SEC command for the carry.) BVS is limited to a relative branch distance of −128 to +127 bytes.

Flags & Registers Affected

N	V	-	B	D	I	Z	C

Acc	X	Y	Mem

Addressing Modes Available

Mode		Common Syntax	Hex Coding
Relative Only		BVS LABEL	70 ff
	or:	BVS $FFFF	70 ff

The overflow bit is only conditioned by the instructions ADC, SBC, BIT, PLP, REP and SEP. That is to say, just loading a value into the Accumulator or a register does not automatically condition the V flag as is the case with the N flag.

Uses

BVS is used primarily in detecting a possible overflow from the data portion of the byte into the sign bit, when using signed binary numbers. For example:

```
ENTRY   CLC
        LDA   #$64          ; %01100100 = +100
        ADC   #$40          ; %01000000 = + 64
        BVS   ERR           ; RESULT = +164 = %10100100 > $7F
STORE   STA   MEM
DONE    RTS
ERR     JSR   BELL          ; ALERT TO OVERFLOW
```

The overflow bit can be explicitly set by using the BIT instruction on an Accumulator or memory location value with the appropriate bit (bit 6 or bit 14) set. (See also BVC.) For example:

```
                            ; ASSUMES 8-BIT MODE . . .
        BIT   $FF58         ; GUARANTEED TO BE #$60
        BVS   SET           ; BRANCH ON OVERFLOW SET
```

CLC: Clear Carry

Description

Clears the carry bit of the status register.

Flags & Registers Affected

N	V	-	B	D	I	Z	C
							clr

Acc	X	Y	Mem

Addressing Modes Available

Mode	Common Syntax	Hex Coding
Implied Only	CLC	18

Uses

CLC is usually required before the first ADC instruction of an addition operation, to make sure the carry hasn't inadvertently been set somewhere else in the program, and thus incorrectly added to the values used in the routine itself.

```
CLC               ; PREPARE TO ADD
LDA   MEM         ; GET FIRST VALUE
ADC   MEM2        ; ADD 2ND VALUE
STA   RSLT        ; SAVE RESULT
```

CLC is also prior to an XCE instruction to set the 65816 microprocessor to the native mode.

```
CLC
XCE               ; e = 0 = NATIVE MODE
```

A CLC can also be used to force a branch when writing position-independent code, such as:

```
CLC
BCC   LABEL       ; (ALWAYS)
```

CLD: Clear Decimal Mode

Description

CLD is used to enter the binary mode (which the Apple is usually in by default), so as to properly use the ADC and SBC instructions. (See SED for setting decimal mode.)

Flags & Registers Affected

N	V	-	B	D	I	Z	C
				clr			

Acc	X	Y	Mem

Addressing Modes Available

Mode	Common Syntax	Hex Coding
Implied Only	CLD	D8

Uses

The arithmetic mode of the 65816 is an important point to keep in mind when using the ADC and SBC instructions. If you are in the wrong mode from what you might assume, rather unpredictable results can occur. See the SED instruction entry for more details on the other mode.

CLI: Clear Interrupt Mask

Description

This instruction enables interrupts by clearing bit 2 of the Status Register.

Flags & Registers Affected

N	V	-	B	D	I	Z	C
					clr		

Acc	X	Y	Mem

Addressing Modes Available

Mode	Common Syntax	Hex Coding
Implied Only	CLI	58

Uses

CLI tells the 65816 to recognize incoming IRQ (Interrupt ReQuest) signals. The Apple's default is to have interrupts enabled, but after the first interrupt, all succeeding interrupts are disabled by the 65816 until a CLI is re-issued, which usually happens automatically at the end of the given interrupt routine. Because timing-dependent operations such as writing to a disk drive cannot be interrupted without damaging the data being written, interrupts are usually disabled during a disk access. That's why you can't always get to the Classic Desk Accessory menu with Control–Open Apple–Escape when the disk drive is on. Certain operating systems like Pascal and ProDOS 8 version 1.1.1 disable interrupts when they first start up. If you wish to enable the Desk Accessory menu in these operating systems, you must execute a CLI instruction. (See also SEI.)

CLV: Clear Overflow Flag

Description

This clears the overflow flag by setting the V bit of the status register to 0.

Flags & Registers Affected

N	V	-	B	D	I	Z	C
	clr						

Acc	X	Y	Mem

Addressing Modes Available

Mode	Common Syntax	Hex Coding
Implied Only	CLV	B8

Uses

Because the overflow flag is automatically cleared by a non-overflow result of an ADC instruction, it is not usually necessary to clear the flag prior to an addition operation. It is, however, occasionally used as a way of forcing a branch instruction when writing position-independent code.

```
CLV                 ; CLEAR OVERFLOW FLAG
BVC   ROUTINE       ; BRANCH TO ROUTINE
```

This technique has the advantage of leaving the carry flag undisturbed should your program wish to test the carry flag after the forced branch.

CMP: Compare to Accumulator

Description

CMP compares the Accumulator to a specified value or memory location. The N (sign), Z (zero), and C (carry) flags are conditioned. A conditional branch is usually then done to determine whether the Accumulator was less than, equal to, or greater than the data.

Flags & Registers Affected

N	V	-	B	D	I	Z	C
•						•	•

Acc	X	Y	Mem

Addressing Modes Available

Mode	Common Syntax	Hex Coding
Absolute	CMP $FFff	CDff FF
Absolute Long	CMP $00FFff	CF ff FF 00
Direct Page	CMP $FF	C5 FF
Direct Page Indirect	CMP ($FF)	D2 FF
Direct Page Indirect Long	CMP [$FF]	C7 FF
Immediate	CMP #$FF	C9 FF
Absolute Indexed,X	CMP $FFff,X	DDff FF
Absolute Long Indexed,X	CMP $00FFff,X	DF ff FF 00
Absolute Indexed,Y	CMP $FFff,Y	D9 ff FF
Direct Page Indexed,X	CMP $FF,X	D5 FF
Direct Page Indexed Indirect,X	CMP ($FF,X)	C1 FF
Direct Page Indirect Indexed,Y	CMP ($FF),Y	D1 FF
Direct Page Indirect Long Indexed,Y	CMP [$FF],Y	D7 FF
Stack Relative	CMP $FF,S	C3 FF
Stack Relative Indirect Indexed,Y	CMP ($FF,S),Y	D3 FF

Uses

CMP is used to check the value of a byte against certain values such as would be done in loops, or in data processing routines. The routine typically decides whether the result is less than, equal to, or greater than a critical value. The usual pattern is:

```
BCC: Acc. < value
BCS: Acc. >= value
BEQ, BCS: Acc. > value
```

See the sections on BCC through BCS for specific examples.

Important: A CMP #$00 followed by a BCC or BCS as the test to the end of a loop should never be done. Consider this example:

```
ENTRY  LDY  #$FF
LOOP   DEY
       CPY  #$00
       BCS  LOOP        ; (ALWAYS TAKEN!)
       BCC  DONE
DONE   RTS
```

Because $01 through $FF is larger than zero, the branch will be taken while the Y register is in this range. Since $0 = $0, when Y reaches 0, the branch will still be taken. Therefore, the example creates an endless loop which will never terminate.

Similarly, if a BCC is done first, it will never be taken, since there is no value less than zero to trigger it.

This bug is most likely to show up when you design a loop that uses a memory location to store, for example, the length of a string.

```
ENTRY  LDY  #$FF
LOOP   DEY
       CPY  LEN         ; LEN HOLDS LENGTH OF STRING
       BCS  LOOP        ; ALWAYS TAKEN IF (LEN) = 0
DONE   RTS
```

As long as the length of the string is nonzero, everything works fine. However, a zero-length string will cause the routine to loop forever, making the system appear to hang up.

COP: Co-Processor Enable

Description

This is a special instruction similar to the BRK instruction, but which is designed to allow access to a secondary microprocessor to the 65816. For example, the Apple IIGS contains additional microprocessors for the keyboard and sound generation operations.

Flags & Registers Affected

N	V	-	B	D	I	Z	C
				clr	set		

Acc	X	Y	Mem

Addressing Modes Available

Mode	Common Syntax	Hex Coding
Implied Only	COP 00	02 00

Like the BRK instruction, a COP instruction causes the program counter plus two to be saved on the stack. The 65816 then jumps to the address indicated by the vector stored in locations $00/FFF4,FFF5. Unlike the BRK instruction, the byte following the COP instruction is presumed to have a specific meaning, and is used to pass an instruction to the other microprocessor. Operands in the range of $80 to $FF have been reserved by Western Design Center, the designer of the 65816. Operands in the range of $00 to $7F are available.

CPX: Compare data to the X Register.

Description

CPX compares the contents of the X Register against a specified value or memory location. (See also CMP.)

Flags & Registers Affected

N	V	-	B	D	I	Z	C
•						•	•

Acc	X	Y	Mem

Addressing Modes Available

Mode	Common Syntax	Hex Coding
Absolute	CPX $FFff	EC ff FF
Direct Page	CPX $FF	E4 FF
Immediate	CPX #$FF	E0 FF

Uses

CPX is primarily used in loops which read data tables, with the X-Register being used as the offset in the Absolute,X addressing mode. The X Register is usually loaded with zero and then is incremented until it reaches the length of the data stream to be read. For example:

```
ENTRY   LDX   #$00          ; INITIALIZE OFFSET
LOOP    LDA   DATA,X        ; GET A CHARACTER
        JSR   PRINT         ; PRINT IT
        INX                 ; X = X + 1
        CPX   #$05          ; DONE WITH THE LOOP?
        BCC   LOOP          ; NOPE (LESS THAN 5)
DONE    RTS                 ; ALL DONE
DATA    ASC   "TEST!"       ; STRING DATA TO PRINT
```

For the same reasons discussed under CMP, a CPX #$00 or CPX MEM followed by BCC or BCS should not be used. (See CMP for details.)

CPY: Compare Data to the Y Register

Description

CPY compares the contents of the Y Register against a specified value or memory location. (See also CMP.)

Flags & Registers Affected

N	V	-	B	D	I	Z	C
•						•	•

Acc	X	Y	Mem

Addressing Modes Available

Mode	Common Syntax	Hex Coding
Absolute	CPY $FFff	CC ff FF
Direct Page	CPY $FF	C4 FF
Immediate	CPY #$FF	C0 FF

Uses

The Y Register is used when reading a stream of data indirectly from a direct-page pointer. CPY allows for checking the current value of the Y Register against a critical value. In this example, the Y Register is used to retrieve and print the first five bytes of a string.

```
ENTRY  LDY  #$00       ; INITIALIZE OFFSET
       LDA  #<DATA     ; LOW BYTE OF DATA
       STA  PTR
       LDA  #>DATA     ; HIGH BYTE OF DATA
       STA  PTR+1      ; (PTR) = DATA

LOOP   LDA  (PTR),X    ; GET A CHARACTER
       JSR  PRINT      ; PRINT IT
       INY             ; X = X + 1
       CPY  #$05       ; DONE WITH THE LOOP?
       BCC  LOOP       ; NOPE (LESS THAN 5)
DONE   RTS             ; ALL DONE
DATA   ASC  "TEST!"    ; STRING DATA TO PRINT
```

For the same reasons discussed under CMP, a CPY #$00 or CPY MEM followed by BCC or BCS should not be used. (See CMP for details.)

DEC: Decrement a Memory Location

Description

The contents of the specified memory location (byte or word) are decremented by one. If the original contents were equal to #$00, then the result would wrap around, giving a result of #$FF (or #$FFFF for a word).

Flags & Registers Affected

N	V	-	B	D	I	Z	C
•						•	

Acc	X	Y	Mem

Addressing Modes Available

Mode	Common Syntax	Hex Coding
Implied (Accumulator)	DEC	3A
Absolute	DEC $FFff	CE ff FF
Direct Page	DEC $FF	C6 FF
Absolute Indexed,X	DEC $FFff,X	DE ff FF
Direct Page Indexed,X	DEC $FF,X	D6 FF

Uses

DEC is usually used when decrementing a one-byte memory value (such as a counter), or a two-byte memory pointer (word). Here are the common examples:

One-Byte or Word Value

```
ENTRY   DEC   MEM
DONE    RTS
```

Two-Byte Pointer

```
ENTRY   DEC   MEM           ; 8-BIT MODE
        LDA   MEM           ; GET LOW BYTE
        CMP   #$FF          ; WRAP AROUND?
        BNE   DONE          ; NO
        DEC   MEM+1         ; YES: DEC MEM+1
DONE    RTS
```

Two-Word Pointer:

```
ENTRY   DEC   MEM         ; LOW WORD
        LDA   MEM
        CMP   #$FFFF      ; WRAP AROUND?
        BNE   DONE        ; NO
        DEC   MEM+1       ; HIGH WORD
```

After the DEC operation, the N and Z flags are often checked to see if the result was negative or a zero/nonzero value, respectively.

The technique shown for the two-byte decrement operation is not necessarily the most efficient for a two-word (or two-byte in the 8-bit mode) decrement. See the SBC entry for an alternative method.

DEX: Decrement the X Register

Description

The X Register is decremented by 1. When the original value was #$00, the result will wrap around to give a result of #$FF—or of #$FFFF, for a word. (See also DEC.)

Flags & Registers Affected

N	V	-	B	D	I	Z	C
•						•	

Acc	X	Y	Mem
	•		

Addressing Modes Available

Mode	Common Syntax	Hex Coding
Implied Only	DEX	CA

Uses

DEX is often used in reading a data block via indexed addressing, for example, LDA $1234,X. Here is a simple example:

```
ENTRY  LDX  #$05        ; START COUNTER = 5
LOOP   LDA  DATA-1,X    ; 8-BIT ACCUMULATOR
       JSR  PRINT       ; PRINT THE CHARACTER
       DEX              ; X = X - 1
       BNE  LOOP        ; NOT DONE YET
DONE   RTS
DATA   ASC  "!TSET"
```

Note: There are several points of interest in this example. Besides the general use of the X Register in the indexed addressing mode, notice that the loop runs backward from #$05 to #$01. The loop is terminated when the X Register reaches zero. Because the loop runs from high memory down, the ASCII string is put in memory in reverse order, as evidenced in the listing. Also note that the base address of the loop is DATA−1. This allows the use of the #$05 to #$01 values of the X Register.

DEY: Decrement the Y Register

Description

The Y Register is decremented by 1. When the original value was #$00, the result will wrap around to give a result of #$FF, or a result of #$FFFF, for a word. (See also DEC.)

Flags & Registers Affected

N	V	-	B	D	I	Z	C
•						•	

Acc	X	Y	Mem
		•	

Addressing Modes Available

Mode	Common Syntax	Hex Coding
Implied Only	DEY	88

Uses

DEY is usually used when decrementing a reverse scan of a data block, using a direct-page pointer via indirect indexed addressing (such as LDA ($FF),Y). Reverse scans are often used because it's so easy to use a BEQ instruction to detect when you're done. DEY is also used when making a counter for a small number of cycles. Here's a routine which outputs a variable number of carriage returns, as indicated by the contents of MEM.

```
ENTRY   LDY   MEM          ; GET COUNTER VALUE
        BEQ   DONE         ; PROTECT AGAINST (MEM) = 0
LOOP    LDA   #$8D         ; <RETURN>
        JSR   COUT         ; PRINT IT
        DEY
        BNE   LOOP         ; TILL Y=0
DONE    RTS
```

EOR: Exclusive Or with Accumulator

Description

The contents of the Accumulator are exclusive ORed with the specified data. The N (sign) and Z (zero) flags are also conditioned depending on the result. The result is put back in the Accumulator. The memory location (if specified) is unaffected.

The truth table used is:

AND:

	0	1
0	0	1
1	1	0

Example:

Accumulator: 0 0 1 1 0 0 1 1
Memory: 0 1 0 1 0 1 0 1

Result: 0 1 1 0 0 1 1 0

Flags & Registers Affected

N	V	-	B	D	I	Z	C
•						•	

Acc	X	Y	Mem
•		•	

Addressing Modes Available

Mode	Common Syntax	Hex Coding
Absolute	EOR $FFff	4D ff FF
Absolute Long	EOR $00FFff	4F ff FF 00
Direct Page	EOR $FF	45 FF
Direct Page Indirect	EOR ($FF)	52 FF
Direct Page Indirect Long	EOR [$FF]	47 FF
Immediate	EOR #$FF	49 FF
Absolute Indexed,X	EOR $FFff,X	5D ff FF
Absolute Long Indexed,X	EOR $00FFff,X	5F ff FF 00
Absolute Indexed,Y	EOR $FFff,Y	59 ff FF
Direct Page Indexed,X	EOR $FF,X	55 FF
Direct Page Indexed Indirect,X	EOR ($FF,X)	41 FF
Direct Page Indirect Indexed,Y	EOR ($FF),Y	51 FF
Direct Page Indirect Long Indexed,Y	EOR [$FF],Y	57 FF
Stack Relative	EOR $FF,S	43 FF
Stack Relative Indirect Indexed,Y	EOR ($FF,S),Y	53 FF

Uses

EOR has a wide variety of uses. One is to encode data by doing an EOR with an arbitrary one-byte key. The data may then be decoded later by again doing an EOR of each data byte with the same key again.

```
CODE    LDX  #$05        ; INITIALIZE COUNTER
LOOP    LDA  DATA-1,X    ; GET CHARACTER
        EOR  #$7D        ; ARBITRARY "KEY"
        STA  $300,X      ; REWRITE TABLE
        DEX
        BNE  LOOP        ; TILL X=0
DONE    RTS
DATA    ASC  "TEST!"

DECODE  LDX  #$05        ; INITIALIZE COUNTER
LOOP    LDA  $300,X      ; RETRIEVE CODED DATA
        EOR  #$7D        ; REVERT TO ORIG. VALUE
        STA  $380,X      ; PUT IN NEW LOC.
        DEX
        BNE  LOOP
DONE    RTS
```

Another application of EOR is to reverse a given bit of a data byte. The mask is created by putting 1 in the positions that you wish to have reversed. A zero is put in all remaining positions. When the EOR with the mask is done, bits in the specified positions will reverse; for example, ones will become zeroes, and vice versa. See the truth table for this entry to verify this effect.

The Z (zero) flag will be set if either the Accumulator or memory or both equal zero:

```
ENTRY  LDA  MEM
       EOR  MEM2
       BEQ  ZERO          ; MEM = 0 and/or MEM2 = 0
       BNE  NOTZ          ; NEITHER MEM NOR MEM2 = 0
```

EOR is useful in producing the twos complement of a number for use in signed binary arithmetic.

```
ENTRY  LDA  #$34          ; %00110100 = +52
                          ; TO BE CVRTD TO -52
       EOR  #$FF          ; %11111111 = $FF
                          ; RSLT = %11001011
       CLC
       ADC  #$01          ; RSLT = RSLT + 1
                          ;      = %11001100 = $CC
       STA  MEM           ; STORE RSLT
DONE   RTS
```

And to convert signed negative numbers back:

```
ENTRY  LDA  #$CC       ; %11001100 = $CC = -52
                       ; TO BE CVRTD BACK
       SEC
       SBC  #$01       ; ACC = ACC - 1
                       ;     = %11001011 = $CB
       EOR  #$FF       ; REVERSE ALL BITS
                       ; RSLT = %00110100 = $34 = +52
       STA  MEM        ; STORE RESULT
DONE   RTS
```

In graphics, doing an EOR using #$FF (or #$FFFF for words) will reverse the visible image:

```
10000000        11111111        01111111
01000000        11111111        10111111
00100000        11111111        11011111
00010000  EOR   11111111   =    11101111
00001000        11111111        11110111
00000100        11111111        11111011
00000010        11111111        11111101
00000001        11111111        11111110
```

INC: Increment Memory

Description

The contents of a specified memory location are incremented by 1. If the original value was #$FF (or #$FFFF for a word), then incrementing will result in a wrap around, giving a result of #$00. The N (sign) and Z (zero) flags are conditioned depending on the result.

Flags & Registers Affected

N	V	-	B	D	I	Z	C
•						•	

Acc	X	Y	Mem
			•

Addressing Modes Available

Mode	Common Syntax	Hex Coding
Implied (Accumulator)	INC	1A
Absolute	INC $FFff	EE ff FF
Direct Page	INC $FF	E6 FF
Absolute Indexed,X	INC $FFff,X	FE ff FF
Direct Page Indexed,X	INC $FF,X	F6 FF

Uses

INC is most often used for incrementing a one-byte (or word) value (such as a counter) or a two-byte or two-word pointer. Here are the most common forms:

8-bit Accumulator/Memory (e = 1):

```
One-Byte Value           Two-Byte Pointer
ENTRY   INC   MEM        ENTRY   INC   MEM
        RTS                      BNE   DONE
                                 INC   MEM+1
                         DONE    RTS
```

16-bit Accumulator/Memory (e = 0, m = 0):

```
One-Word Value           Two-Word Pointer
ENTRY   INC   MEM        ENTRY   INC   MEM
        RTS                      BNE   DONE
                                 INC   MEM+2
                         DONE    RTS
```

After the INC operation, the N and/or Z flags are often checked to see if the result was negative or a zero/nonzero value, respectively.

INX: Increment the X Register

Description

The contents of the X Register are incremented by one. If the original value was #$FF (or #$FFFF for a word), then incrementing will result in a wrap around, giving a result of #$00. The N (sign) and Z (zero) flags are conditioned depending on the result.

Flags & Registers Affected

N	V	-	B	D	I	Z	C
•						•	

Acc	X	Y	Mem
	•		

Addressing Modes Available

Mode	Common Syntax	Hex Coding
Implied Only:	INX	E8

Uses

INX is used in forward scanning loops which digest a DATA stream as shown here:

```
ENTRY   LDX  #$00        ; INITIALIZE INDEX
LOOP    LDA  DATA,X      ; GET A CHARACTER
        BEQ  DONE        ; DELIMITER?
        JSR  PRINT
        BRA  LOOP        ; NEXT CHAR
DONE    RTS
DATA    ASC  "TEST!"
        HEX  00          ; END OF DATA
```

INX can also be used as a general purpose counter for miscellaneous routines.

```
ENTRY   LDX  #$00
        LDA  #$8D        ; <RETURN>
LOOP    JSR  PRINT
        INX
        CPX  #$05
        BCC  LOOP        ; TILL X = 5
DONE    RTS              ; PRINTS 5 CR'S
```

Note that in forward scanning loops that check a length or limit value, the base address can be DATA itself. (See DEX for another situation.)

INY: Increment the Y Register

Description

The contents of the Y Register are incremented by one. If the original value was #$FF (or #$FFFF for a word), then incrementing will result in a wrap around giving a result of #$00. The N (sign) and Z (zero) flags are conditioned depending on the result.

Flags & Registers Affected

N	V	-	B	D	I	Z	C
•						•	

Acc	X	Y	Mem
		•	

Addressing Modes Available

Mode	Common Syntax	Hex Coding
Implied Only	INY	C8

Uses

INY is used in forward scanning loops that use the indirect indexed addressing mode (for example, LDA ($FF),Y). This is quite common in routines which process strings for certain characters, such as search routines. Here is a routine that scans an input buffer for the first carriage return:

```
ENTRY  LDA  #<BUF      ; LOW BYTE OF BUFFER ADDRESS
       STA  PTR        ; LOW BYTE OF POINTER
       LDA  #>BUF      ; HIGH BYTE OF BUFFER ADDRESS
       STA  PTR        ; (PTR) = BUFFER
       LDY  #$00       ; INITIALIZE INDEX
LOOP   LDA  (PTR),Y    ; GET A CHARACTER
       CMP  #$8D       ; CHR = <CR>?
       BEQ  FOUND      ; LEAVE LOOP
       INY             ; Y = Y + 1
       BNE  LOOP       ; 'TILL Y = $00 AGAIN
DONE   RTS
FOUND  STY  MEM        ; SAVE POSITION OF FOUND CHAR.
       BRA  DONE       ; (ALWAYS)
```

JML/JMP: Jump to Address

Description

Causes program execution to jump to the address specified. Except for the long address form of JMP (JML), a JMP instruction always goes to the operand address within the current program bank. A JML automatically changes the Program Bank Register to the bank of the target address.

Flags & Registers Affected (none)

N	V	-	B	D	I	Z	C

Acc	X	Y	Mem

Addressing Modes Available

	Common	Hex
Mode	**Syntax**	**Coding**
Absolute	JMP $FFff	4C ff FF
Absolute Long	JML $00FFff	5C ff FF 00
Absolute Indirect	JMP ($FFff)	6C ff FF
Absolute Indexed Indirect	JMP ($FFff,X)	7C ff FF
Absolute Indirect Long	JML [$FFff]	DCff FF

Uses

Besides the obvious application of the usual absolute addressed JMP instruction, the indirect JMP is used when creating vectored jumps. The Apple IIGS makes extensive use of these vectors for handling everything from the RESET vector to the patches to the tool set calls.

By creating a table of vectors, your application can use an input value and the Absolute Indexed Indirect JMP to go to a particular routine.

```
        LDA   CMD          ; GET COMMAND VALUE $0 TO $2
        ASL                ; MULTIPLY BY 2 = 0,2,4
        JMP   (CMDTBL,X)   ; GO TO VECTORED ROUTINE

CMDTBL  DA    ROUTINE1     ; ADDRESS OF ROUTINE1 (2 BYTES)
        DA    ROUTINE2     ; ADDRESS OF ROUTINE2 (2 BYTES)
        DA    ROUTINE3     ; ADDRESS OF ROUTINE3 (2 BYTES)
```

JSL/JSR: Jump to Subroutine

Description

The address of the last byte of the JSR instruction is pushed onto the stack. This is equivalent to the return address minus one. The address of the operand for the JSR is then jumped to. When an RTS in the called subroutine is encountered, a return to the location on the stack plus one (the address of the next instruction after the JSR) is done. This is analgous to a GOSUB in BASIC. Except for the long address form of JSR (JSL), a JSR always goes to the operand address within the current program bank.

Flags & Registers Affected (none)

N	V	-	B	D	I	Z	C

Acc	X	Y	Mem

Addressing Modes Available

Mode	Common Syntax	Hex Coding
Absolute	JSR $FFff	20 ff FF
Absolute Indexed Indirect	JSR ($FFff,X)	FC ff FF
Absolute Long	JSL $00FFff	22 ff FF 00

Uses

JSR is one of the most commonly used instructions, being used to call often needed subroutines. The disadvantage of the instruction is that if the JSR's reference addresses within the code (as opposed to routines external to the program, such as in the ROM), the code can only be executed at the location for which the code was originally assembled. This problem can be avoided by using the System Loader and creating ProDOS 16 files in a relocatable format, or by writing the program so as to be position independent (no internal address references).

Because the calling address is saved on the stack, a JSR to a known RTS can be done, and the data can be retrieved to determine where in memory the routine is currently being executed. (See PER.)

The Absolute Indexed Indirect form of the JSR is often used in Apple IIGS programs using the Event Manager and Menu Manager because of the easy vectoring to an appropriate subroutine. The addresses for each subroutine to be called are defined in a common table, and the command value times 2 is used as the offset for the JSR.

```
        LDA  CMD          ; GET COMMAND VALUE $0 TO $2
        ASL               ; MULTIPLY BY 2 = 0,2,4
        JSR  (CMDTBL,X)   ; GO TO VECTORED ROUTINE
        JMP  MAIN         ; BACK TO MAIN ROUTINE

CMDTBL  DA   ROUTINE1     ; ADDRESS OF ROUTINE1 (2 BYTES)
        DA   ROUTINE2     ; ADDRESS OF ROUTINE2 (2 BYTES)
        DA   ROUTINE3     ; ADDRESS OF ROUTINE3 (2 BYTES)
```

LDA: Load Accumulator

Description

Loads the Accumulator with either a specified value or the contents of the designated memory location. One byte is loaded in the 8-bit mode, 2 bytes (a word) in the 16-bit mode. The N (Sign) and Z (Zero) flags are conditioned when a value with either the high bit set or a zero value are loaded, respectively.

Flags & Registers Affected

N	V	-	B	D	I	Z	C
•						•	

Acc	X	Y	Mem
•			

Addressing Modes Available

	Common	Hex
Mode	Syntax	Coding
Absolute	LDA $FFff	ADff FF
Absolute Long	LDA $00FFff	AF ff FF 00
Direct Page	LDA $FF	A5 FF
Direct Page Indirect	LDA ($FF)	B2 FF
Direct Page Indirect Long	LDA [$FF]	A7 FF
Immediate	LDA #$FF	A9 FF
Absolute Indexed,X	LDA $FFff,X	BD ff FF
Absolute Long Indexed,X	LDA $00FFff,X	BF ff FF 00
Absolute Indexed,Y	LDA $FFff,Y	B9 ff FF
Direct Page Indexed,X	LDA $FF,X	B5 FF
Direct Page Indexed Indirect,X	LDA ($FF,X)	A1 FF
Direct Page Indirect Indexed,Y	LDA ($FF),Y	B1 FF
Direct Page Indirect Long Indexed,Y	LDA [$FF],Y	B7 FF
Stack Relative	LDA $FF,S	A3 FF
Stack Relative Indirect Indexed,Y	LDA ($FF,S),Y	B3 FF

Uses

LDA is probably the most used of any instruction. The vast majority of operations center around the Accumulator, and this instruction is used to get data into the important register.

LDX: Load the X Register

Description

Loads the X Register with either a specified value, or the contents of the designated memory location. The N (sign) and Z (zero) flags are conditioned when a value with either the high bit set or a zero value are loaded, respectively. One byte is loaded when the *x* bit is 1, a word (2 bytes) is loaded when *x* is 0.

Flags & Registers Affected

N	V	-	B	D	I	Z	C
•						•	

Acc	X	Y	Mem
	•		

Addressing Modes Available

	Common	Hex
Mode	**Syntax**	**Coding**
Absolute	LDX $FFff	AE ff FF
Direct Page	LDX $FF	A6 FF
Immediate	LDX #$FF	A2 FF
Absolute Indexed,Y	LDX $FFff,Y	BE ff FF
Direct Page Indexed,Y	LDX $FF,Y	B6 FF

Uses

This is the primary way in which data is placed into the X Register.

LDY: Load the Y Register

Description

Loads the Y Register with either a specified value or the contents of the designated memory location. The N (sign) flag is conditioned when the high bit is set, and the Z (zero) flag is conditioned when a zero value is loaded. One byte is loaded when the x = 1, a word (2 bytes) when x = 0.

Flags & Registers Affected

N	V	-	B	D	I	Z	C
•						•	

Acc	X	Y	Mem
		•	

Addressing Modes Available

	Common	Hex
Mode	**Syntax**	**Coding**
Absolute	LDY $FFff	AC ff FF
Direct Page	LDY $FF	A4 FF
Immediate	LDY #$FF	A0 FF
Absolute Indexed,X	LDY $FFff,X	BC ff FF
Direct Page Indexed,X	LDY $FF,X	B4 FF

Uses

This is the primary way in which data is placed into the Y Register.

LSR: Logical Shift Right

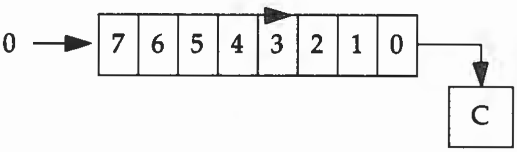
Description

This instruction moves each bit of the Accumulator or memory location specified one position to the right. A zero is forced at the bit 7 position (the high-order bit) for a byte, and bit 15 for a word. Bit zero falls into the carry. The result is left in the Accumulator or memory location. (See also ROL, ASL, and ROR.)

Flags & Registers Affected

N	V	-	B	D	I	Z	C
clr						•	•

Acc	X	Y	Mem
•			•



LSR
(Logical Shift Right

Addressing Modes Available

Mode	Common Syntax	Hex Coding
Accumulator	LSR	4A
Absolute	LSR $FFff	4E ff FF
Direct Page	LSR $FF	46 FF
Absolute Indexed,X	LSR $FFff,X	5E ff FF
Direct Page Indexed,X	LSR $FF,X	56 FF

Uses

ASL provides an easy way of dividing by a power of two. The corresponding effect in decimal arithmetic is well known: 123/10 = 12.3 (shift right). As an example:

```
ENTRY  LDA  MEM       ; GET ORIGINAL VALUE
       LSR            ; DIV BY 2
       LSR            ; DIV BY 2 AGAIN 2
       STA  MEM       ; MEM = MEM/4 (4 = 2 )
```

ASL also provides a way of detecting whether a number is odd or even:

```
ENTRY  LDA  MEM
       LSR
       BCS  EVEN
       BCC  ODD
```

Since bit 0 determines the odd/even nature of a number, this is easily transferred to the carry via the LSR, and then checked via the BCS/BCC instructions.

In double hi-res graphics and 80-column text, the bytes that make up the screen display are interleaved. For example, in 80-column text, each even position character (0, 2, 4, and so on) is located in bank 1 (AuxMem). Each odd position character is located in bank 0 (MainMem). Thus, the actual byte offset from the base address for the left edge of the screen for each line is equal to the horizontal position divided by two. Which bank is used is determined by whether the given horizontal position is an even or an odd number. These characteristics are ideal for the use of LSR in an 80-column print routine:

```
PRINT  LDA  CV         ; VERTICAL POSITION
       JSR  VTAB       ; MONITOR ROUTINE TO CALCULATE BASE ADDRESS
       LDA  CH         ; HORIZONTAL POSITION
       LSR             ; DIVIDE BY TWO, CARRY SET IF ODD
       TAY             ; PUT RESULT IN Y REGISTER
       BCS  MAIN       ; MAIN MEMORY IF ODD
AUX    BIT  PAGE2      ; SOFTSWITCH FOR BANK 1
       STA  BASL,Y     ; WRITE CHARACTER
       BRA  CONT       ; ALWAYS BRANCH TO CONTINUE
MAIN   BIT  PAGE1      ; SOFTSWITCH FOR BANK 0
       STA  BASL,Y     ; WRITE CHARACTER
CONT   NOP             ; PROGRAM CONTINUES HERE
```

MVN/MVP: Block Move Next/Previous

Description

Moves an entire block of memory from one location to another. The source and destination blocks must not cross bank boundaries, but the destination block may be in a different bank than the source.

The *next* in MVN refers to the source block being *after* the destination block, but within the same bank. MVN (vs. MVP) is specifically required when the destination block is lower in memory, but within the same bank, as the source block. Otherwise either MVN or MVP may be used.

The previous in MVP refers to the source block being *ahead* of, or previous to, the destination block, but within the same bank. MVP is specifically required in that case.

Flags & Registers Affected

N	V	-	B	D	I	Z	C

Acc	X	Y	Mem
•	•	•	•

(Requires use of A, X and Y Registers.)

Addressing Modes Available

Mode	Common Syntax	Hex Coding
Implied Only	MVN $00,$FF	54 00 FF
	MVP $00,$FF	54 00 FF

Uses

In processors previous to the 65816, such as the 65C02 in the Apple IIe and IIc, moving data was accomplished by calling a routine. For small amounts of memory, this was perfectly adequate. However, for a machine with the large amounts of memory like the Apple IIGS, conventional methods of moving memory would just be too slow. Fortunately, the 65816 includes two move instructions, MVN and MVP which automate the moving of memory to enable large blocks of memory to be moved much faster.

In practice, it's usually easier to use the Memory Manager calls PtrToHand, PtrToPtr, HandToHand, and BlockMove to move blocks of memory than it is to use the MVN or MVP instructions. That's because the operands that describe the source and destination banks for MVN and MVP must be hard coded into the instruction. This means that you must either limit your moves to within predefined banks (fine for ProDOS 8 and Applesoft BASIC), or you must use self-modifying code to achieve flexibility for inter-bank transfers. In addition, should the source or destination blocks cross a bank boundary, additional code must be included to handle the separate blocks of memory. The built-in routines of the Memory Manager already take all these considerations into account and use the MVN and MVP instructions to their best advantage while the machinations remain transparent to the programmer.

You have already seen from the demonstration program in Chapter 17 that the Memory Manager can move large blocks of memory quite quickly with the standard tool calls. However, in the event you should ever wish to use the MVN or MVP instructions explicitly, here is an appropriate code segment:

```
ENTRY  LDX  START       ; STARTING ADDRESS
       LDY  DEST        ; DESTINATION ADDRESS
       LDA  LENGTH      ; NUMBER OF BYTES TO MOVE - 1
       MVN  SBNK,DBNK   ; SOURCE BANK, DESTINATION BANK
                        ; OR MVP IF NECESSARY
```

Note that normal use presumes that both *m* and *x* are equal to 0 (full 16-bit mode), but that MVN and MVP can be used with 8-bit *m* or *x* bits—or even in emulation mode. In any particular case, if the X or Y register has a high-order byte equal to zero (as would be the case with e = 1 or x = 1), then the source and destination will be limited to page zero ($00 to $FF), irrespective of the direct-page register. The complete Accumulator (C) is used for the length, regardless of the setting of the *e* or *m* bits.

NOP: No Operation

Description

Does nothing for one instruction.

Flags & Registers Affected (none)

N	V	-	B	D	I	Z	C

Acc	X	Y	Mem

Addressing Modes Available

Mode	Common Syntax	Hex Coding
Implied Only	NOP	EA

Uses

NOP is used primarily to disable portions of code written by other programmers that you have decided you can live without. Additionally, NOPs may be used during debugging to disable certain steps.

ORA: Inclusive OR with the Accumulator

Description

This instruction takes each bit of the Accumulator and performs a logical OR with each corresponding bit of the specified memory location or immediate value. The result is put back in the Accumulator. The memory location, if specified, is unaffected. Conditions the N (Sign) and Z (Zero) flags depending on the result. One byte is operated on when the *m* bit = 1, a word (2 bytes) is operated on when m = 0. (See ORA and AND also.)

Inclusive OR means if *either* or *both* bits are 1 then the result is 1. Only when both bits are 0 is the result 0.

The truth table used is:

ORA:

	0	1
0	0	1
1	1	1

Example:

Accumulator:	0 0 1 1 0 0 1 1
Memory:	0 1 0 1 0 1 0 1
Result	0 1 1 1 0 1 1 1

Flags & Registers Affected

N	V	-	B	D	I	Z	C
•						•	

Acc	X	Y	Mem
•			•

Addressing Modes Available

Mode	Common Syntax	Hex Coding
Absolute	ORA $FFff	0D ff FF
Absolute Long	ORA $00FFff	0F ff FF 00
Direct Page	ORA $FF	05 FF
Direct Page Indirect	ORA ($FF)	12 FF
Direct Page Indirect Long	ORA [$FF]	07 FF
Immediate	ORA #$FF	09 FF
Absolute Indexed,X	ORA $FFff,X	1D ff FF
Absolute Long Indexed,X	ORA $00FFff,X	1F ff FF 00
Absolute Indexed,Y	ORA $FFff,Y	19 ff FF
Direct Page Indexed,X	ORA $FF,X	15 FF
Direct Page Indexed Indirect,X	ORA ($FF,X)	01 FF
Direct Page Indirect Indexed,Y	ORA ($FF),Y	11 FF
Direct Page Indirect Long Indexed,Y	ORA [$FF],Y	17 FF
Stack Relative	ORA $FF,S	03 FF
Stack Relative Indirect Indexed,Y	ORA ($FF,S),Y	13 FF

Uses

ORA is used primarily as a mask to force 1's in specified bit positions. (See AND to force 0's.) To create the mask, 1 is put in each bit position which is to be forced to one. All other positions are set to 0. For example, here is a routine which will set the high bit on any ASCII data going out through a print routine in your application:

```
ENTRY   LDA   DATA,X          ; GET CHARACTER TO PRINT
        ORA   #$80            ; %10000000
                              ; SET HIGH BIT
        JSR   PRINT
        RTS
```

In graphics, ORA has the effect of blending two images on a common background:

```
00011000          00000000          00011000
00011000          00000000          00011000
00011000          00000000          00011000
00011000   ORA    11111111    =     11111111
00011000          11111111          11111111
00011000          00000000          00011000
00011000          00000000          00011000
00011000          00000000          00011000
```

ORA can also be used when checking for a pointer equal to zero that is stored in two bytes in the 8-bit mode, or in four bytes, as would be the case for a handle in the 16-bit mode:

8-Bit Mode, Two Bytes

```
LDA   MEM1          ; LOW-ORDER BYTE
ORA   MEM1+1        ; HIGH-ORDER BYTE
BEQ   ZERO          ; BEQ TAKEN IF BOTH = ZERO
```

16-Bit Mode, Two Words

```
LDA   MEM1          ; LOW-ORDER WORD
ORA   MEM1+2        ; HIGH-ORDER WORD
BEQ   ZERO          ; BEQ TAKEN IF BOTH = ZERO
```

PEA: Push Effective Address

Description

Pushes 16-bit address indicated by operand onto stack, regardless of the *e*, *m*, or *x* bits.

Flags & Registers Affected (none)

N	V	-	B	D	I	Z	C

Acc	X	Y	Mem

Addressing Modes Available

Mode	Common Syntax	Hex Coding
Implied Only	PEA	F4

Uses

PEA is most often used to push an immediate value onto the stack in preparation for a call to an Apple IIGS tool set routine. This value may either be an immediate value, for example the X coordinate of a point, or an address, such as that of a label:

```
        PEA  $0002       ; PUSH #$2 ON STACK
        PEA  LABEL       ; PUSH LOW WORD OF LABEL ON STACK
        PEA  ^LABEL      ; PUSH HIGH WORD OF LABEL ON STACK
```

Note that even though the immediate mode character (#) is not used, the value of LABEL, *not* its contents, will be pushed on the stack.

PEA could also be used to push an artificial return address on the stack for a subroutine. By using a JMP to access the routine which then ended in an RTS, program execution would resume at the byte immediately after the address pushed on the stack:

```
        PEA  LABEL-1     ; RETURN ADDRESS-1
        JMP  SUBR        ; ROUTINE TO 'JSR' TO
        BRK  $00         ; SHOULD NEVER GET HERE . . .
LABEL   NOP              ; PROGRAM RESUMES HERE

SUBR    NOP              ; SOME SORT OF SUBROUTINE
        RTS              ; RETURNS TO 'LABEL'
```

As long as the subroutine knows that an alternate return address is on the stack, you can also use PEA with a JSR for two or more possible return addresses:

```
       PEA   RTRN2-1     ; ALTERNATE RETURN ADDRESS-1
       JSR   SUBR        ; ROUTINE TO JSR TO
RTRN1  NOP               ; NORMAL RETURN ADDRESS
       PLA               ; PULL UNUSED PEA ADDRESS OFF
       NOP               ; MORE OF YOUR PROGRAM HERE
RTRN2  NOP               ; ALTERNATE RETURN ADDRESS
       NOP               ; MORE OF YOUR PROGRA HERE . . .

SUBR   NOP               ; SOME SORT OF SUBROUTINE
       BEQ   NORML       ; ARBITRARY FLAG FOR NORMAL RETURN
       PLA               ; PULL NORMAL RETURN OFF
                         ; NEXT RTS WILL BE TO RTRN2!
NORML  RTS
```

PEI: Push Effective Indirect Address

Description

Pushes 16-bit address found at the direct-page address (low byte, high byte) in the operand onto the stack, regardless of the *e*, *m*, or *x* bits. The high byte of the address is pushed first, followed by the low byte.

Flags & Registers Affected (none)

N	V	-	B	D	I	Z	C		Acc	X	Y	Mem

Addressing Modes Available

	Common	Hex
Mode	**Syntax**	**Coding**
Implied Only	PEI	D4

Uses

This instruction allows the program to push a vector or other 16-bit address stored on the direct page onto the stack. For example, suppose the direct page register is set to $8000, and you use the instruction

```
        PEI    ($25)           ; PUSH EFFECTIVE INDIRECT
```

The microprocessor will go to locations $8025, $8026 (low-byte, high-byte) for the address held there. Assuming the contents of $8025, $8026 = $1234, the value $1234 would then be pushed on the stack.

Like PEA, PEI can also be used to push an artificial return address on the stack for a subroutine, the only difference being that the source of the return address would be a direct-page pointer. See PEA for examples of the general technique.

PER: Push Effective Relative Address

Description

Pushes a 16-bit address relative to the current program counter, regardless of the *e*, *m* or *x* bits. This is more or less equivalent in function to doing a PEA with a LABEL of an address (as opposed to a constant), except that no absolute address is used in the PER instruction, and it can thus be used to create position-independent code.

Flags & Registers Affected (none)

N	V	-	B	D	I	Z	C

Acc	X	Y	Mem

Addressing Modes Available

Mode	Common Syntax	Hex Coding
Implied Only	PER	62

USE

This instruction allows the program to push a 16-bit address determined by the relative offset generated as the operand by the assembler label. For example, consider the following code segment located at $8000:

```
8000:  62  05  00           PER   LABEL
8003:  20  08  80           JSR   SUBR          ; JSR TO A SUBROUTINE
8006:  EA           LABEL   NOP                 ; MORE OF YOUR PROGRAM
8007:  60                   RTS                 ; THIS PART IS DONE

8008:  EA           SUBR    NOP                 ; SOME SUBROUTINE
8009:  68                   PLA                 ; RETRIEVE VALUE OF LABEL
800A:  EA                   NOP                 ; SOME MORE PROGRAM
800B:  60                   RTS                 ; RETURN
```

The microprocessor will take the relative offset of 5 (the operand of the PER instruction), add this to the program counter for the next instruction ($8003), and push the result ($8008) on the stack. The result is the actual address of the assembler operand, LABEL. This value is then available to SUBR. With ProDOS 16 and the System Loader, it is just as easy to use a PEA LABEL to achieve the same result, but you may find this variation useful.

A more likely scenario would be in writing position-independent code that for whatever reason did not have the benefit of the ProDOS 16 System Loader (for example a ProDOS 8 application). In such a case, the PER can be used to generate the current address that the program is running at for an indirect accessing of data.

```
        PER   DATA          ; PUSH WHERE DATA IS ON THE STACK
        PLA                 ; RETRIEVE IT
        STA   PTR           ; WRITE DIRECT-PAGE PTR (2 BYTES)
        LDX   #$00          ; INITIALIZE INDEX
LOOP    LDA   (PTR),X       ; GET A CHARACTER
        BEQ   DONE          ; 0 = END OF STRING
        NOP                 ; DO SOMETHING WITH IT
        INX                 ; NEXT CHARACTER
        BNE   LOOP          ; UNTIL X REACHES 0 AGAIN
        RTS                 ; WE'RE DONE HERE

DATA    ASC   "TEST",00     ; SAMPLE DATA
```

This code segment can read the characters at DATA, and yet it uses no absolute addressing that would prevent it from running anywhere in memory.

Like PEA, PER can also be used to push an artificial return address on the stack for a subroutine. See PEA for examples of the general technique.

PER can also be used to simulate a JSR to an internal address in position-independent code:

```
ENTRY   PER   RTRN-1        ; RETURN ADDRESS-1
        PER   SUBR-1        ; SUBROUTINE TO "JSR" TO
        RTS                 ; DO EQUIV. OF JSR TO SUBR
RTRN    NOP                 ; YOUR PROGRAM CONTINUES HERE

SUBR    NOP                 ; SOME SUBROUTINE
        RTS                 ; RETURNS TO "RTRN"
```

PHA: Push Accumulator

Description

This pushes the contents of the Accumulator onto the stack. The Accumulator and status register are unaffected. When two bytes are pushed (a word, m = 0), the high byte is pushed first; then the low byte is pushed. (See also PLA.)

Flags & Registers Affected (none)

N	V	-	B	D	I	Z	C	Acc	X	Y	Mem

Addressing Modes Available

Mode	Common Syntax	Hex Coding
Implied Only	PHA	48

Uses

This is one of the most common ways of temporarily storing a byte or two. It is combined with PLA to retrieve the data. Generally speaking, each PHA must be matched by a PLA later in the routine. Otherwise the final RTS of your routine will deliver you, not back to the calling BASIC program or immediate mode, but rather to some unpredictable location.

This and other stack operations are used extensively in sending data to the various tool set routines by pushing the input data onto the stack and then doing a JSL $E10000.

A more obscure use of PHA is to set up an artificial JMP by executing an RTS for which a JSR was never done. Providing two PHAs have been done prior to the RTS, the pseudo-jump will be executed. This is similar to the approach used to adjust the return address of a pending RTS as was discussed in Chapter 11, and the fourth example in the description of PER.

PHB: Push Data Bank Register

Description

Pushes the single byte value of the data bank register on the stack, regardless of the condition of the *e*, *m*, and *x* bits.

Flags & Registers Affected (none)

N	V	-	B	D	I	Z	C

Acc	X	Y	Mem

Addressing Modes Available

Mode	Common Syntax	Hex Coding
Implied Only	PHB	8B

Uses

This is done to save the current data bank value, in antipation of changing and then later restoring it. This could be because your application wishes to access data in another bank or because your subroutine has been called by another program elsewhere. An example of this is the UPDATE routine used in a program that uses the Window Manager.

In general, the procedure for saving and restoring the data bank register would look like this:

```
PHB             ; SAVE CURRENT DATA BANK
PHK             ; PUSH OUR PROGRAM BANK
PLB             ; SET DATA BANK = OUR PROGRAM BANK
NOP             ; MORE PROGRAM HERE . . .
PLB             ; RESTORE DATA BANK TO ORIGINAL
RTL             ; BACK TO WHEREVER
```

PHD: Push Direct-Page Register

Description

Pushes the 16-bit value of the data bank register on the stack, regardless of the condition of the *e*, *m*, or *x* bits.

Flags & Registers Affected (none)

N	V	-	B	D	I	Z	C

Acc	X	Y	Mem

Addressing Modes Available

	Common	Hex
Mode	**Syntax**	**Coding**
Implied Only	PHD	0B

Uses

This is done to save the current direct-page value, in anticipation of changing and then later restoring it. This could be because a subroutine in your application wishes to use a different direct page than the rest of the application or because your subroutine has been called by another program with its own direct page elsewhere. An example of this is the UPDATE routine used in a program that uses the Window Manager.

In general, the procedure for saving and restoring the direct page register would look like this:

```
PHD                 ; SAVE CURRENT DIRECT PAGE
LDA   MYDP          ; DP ADDRESS FOR OUR ROUTINE
TCD                 ; SET DP = MYDP
NOP                 ; MORE PROGRAM HERE . . .
PLD                 ; RESTORE DIRECT PAGE TO ORIGINAL
RTS                 ; BACK TO WHEREVER
```

PHK: Push Program Bank Register

Description

Pushes the single-byte value of the program bank register on the stack.

Flags & Registers Affected (none)

N	V	-	B	D	I	Z	C

Acc	X	Y	Mem

Addressing Modes Available

	Common	Hex
Mode	**Syntax**	**Coding**
Implied Only	PHK	4B

Uses

This is usually done to determine the current program bank value, so as to be able to set the data bank equal to the bank the program was running in. This is required for the proper operation of all JSRs and JMPs (non-long address) and internal references to data such as LDA LABEL.

In general, the procedure for using the program bank to set the data bank would look like this:

```
PHB              ; SAVE CURRENT DATA BANK
PHK              ; PUSH OUR PROGRAM BANK
PLB              ; SET DATA BANK = OUR PROGRAM BANK
NOP              ; MORE PROGRAM HERE . . .
PLB              ; RESTORE DATA BANK TO ORIGINAL
RTL              ; BACK TO WHEREVER
```

PHP: Push Processor Status

Description

This pushes the status register onto the stack for later retrieval. The status register itself is unchanged, and none of the registers are effected. PHP *always* pushes only one byte onto the stack, regardless of the condition of the *e*, *m*, and *x* bits.

Flags & Registers Affected (none)

N	V	-	B	D	I	Z	C	Acc	X	Y	Mem

Addressing Modes Available

Mode	Common Syntax	Hex Coding
Implied Only	PHP	08

Uses

PHP is done to preserve the status register for later testing for a specific condition. This is handy if you don't want to test a flag right then, but the next instruction would ruin what you want to test for. By putting the status register on the stack, and then later retrieving it, you can test things like the sign flag or carry when it's most convenient.

```
ENTRY   CLC                 ; CLR CARRY
        PHP                 ; SAVE REG
        SEC                 ; SET CARRY
        PLP                 ; RETRIEVE REG
        BCC   DONE          ; (ALWAYS!)
        BRK                 ; (NEVER)
DONE    RTS
```

```
ENTRY   LDA   #$00          ; SET Z FLAG
        PHP                 ; SAVE REG
        LDA   #$FF          ; DESTROY
        PLP                 ; RETRIEVE
        BEQ   DONE          ; (ALWAYS!)
        BRK                 ; (NEVER)
DONE    RTS
```

If it's ever necessary for your application to disable interrupts, it should use the PHP and PLP instructions to properly save and restore the interrupt status external to your routine. This is done by first saving the Status Register with a PHP instruction, and then later restoring it with PLP. This has the effect of re-enabling interrupts (CLI) if they, in fact, had been previously enabled, and does not enable them if the interrupt disable bit (bit 2 in the Status Register) had been set (no interrupts).

```
START    PHP                ; SAVE INTERRUPT STATUS
         SEI                ; SET INTERRUPT DISABLE
         NOP                ; DO YOUR STUFF HERE...
         PLP                ; RESTORE INTERRUPT STATUS
DONE     RTS                ; BACK TO WHEREVER
```

Important: Like the PHA instruction, PHP should always be accompanied by an equal number of PLP instructions to keep the Apple happy. A common cause of problems in programs is to use a PHP to push the Status Register on the stack (1 byte), and to then use a PLA in the 16-bit mode to examine the value later, resulting in pulling a byte of your return address off with the byte put there by the PHP.

PHX: Push X Register

Description

This pushes the contents of the X Register onto the stack. The X Register and status register are unaffected. When two bytes are pushed (a word, x = 0), the high byte is pushed first, then the low byte. (See also PLX.)

Flags & Registers Affected (none)

N	V	-	B	D	I	Z	C

Acc	X	Y	Mem

Addressing Modes Available

	Common	Hex
Mode	**Syntax**	**Coding**
Implied Only	PHX	DA

Uses

This is one of the most common ways of temporarily storing the contents of the X Register. It is combined with PLX to retrieve the data.

PHY: Push Y Register

Description

This pushes the contents of the Y Register onto the stack. The Y Register and status register are unaffected. When two bytes are pushed (a word, x = 0), the high byte is pushed first, then the low byte. (See also PLY.)

Flags & Registers Affected (none)

N	V	-	B	D	I	Z	C

Acc	X	Y	Mem

Addressing Modes Available

Mode	Common Syntax	Hex Coding
Implied Only	PHY	5A

Uses

This is one of the most common ways of temporarily storing the contents of the Y Register. It is combined with PLY to retrieve the data.

PLA: Pull Accumulator

Description

This is the converse of the PHA instruction. PLA retrieves one byte (8-bit mode, m = 1) or one word (16-bit mode, m = 0) from the stack and places it in the Accumulator. This accordingly conditions the N (sign) and Z (zero) flags, just as though an LDA instruction had been done.

Flags & Registers Affected

N	V	-	B	D	I	Z	C
•						•	

Acc	X	Y	Mem
•			

Addressing Modes Available

Mode	Common Syntax	Hex Coding
Implied Only	PLA	68

Uses

This is combined with PHA to retrieve data from the stack. See PHA for an example of this.

Description

Pulls a single byte from the stack, and sets the data bank register to that value, regardless of the condition of the *e*, *m*, and *x* bits.

PLB: Pull Data Bank Register

Description

Pulls a single byte from the stack, and sets the data bank register to that value, regardless of the condition of the *e*, *m* and *x* bits.

Flags & Registers Affected

N	V	-	B	D	I	Z	C
•						•	

Acc	X	Y	Mem

Addressing Modes Available

Mode	Common Syntax	Hex Coding
Implied Only	PLB	AB

Uses

This is used to set the current data bank value. This could be because your application wishes to access data in another bank or because your application or subroutine has been called by another program elsewhere. This should always be done as one of the first instructions in a ProDOS 16 application that is running in an indeterminant bank of memory.

In general, the procedure for saving and restoring the data bank register looks like this:

```
PHB        ; SAVE CURRENT DATA BANK
PHK        ; PUSH OUR PROGRAM BANK
PLB        ; SET DATA BANK = OUR PROGRAM BANK
NOP        ; MORE PROGRAM HERE . . .
PLB        ; RESTORE DATA BANK TO ORIGINAL
RTL        ; BACK TO WHEREVER
```

Changing the data bank register *does not* change direct page references, for example LDA ($25),Y, within the program because by definition these are restricted to bank zero. However, the indirect address indicated on the direct page in bank zero will be interpreted to reside in the bank indicated by the current bank register, unless Indirect Indexed Long addressing is used.

PLD: Pull Direct-Page Register

Description

Pulls a 16-bit value from the stack and sets the direct page register to that value, regardless of the condition of the *e*, *m*, or *x* bits. If e = 1 (emulation mode), this instruction pulls two bytes from the stack and changes the direct-page register accordingly.

Flags & Registers Affected

N	V	-	B	D	I	Z	C
•						•	

Acc	X	Y	Mem

Addressing Modes Available

Mode	Common Syntax	Hex Coding
Implied Only	PLD	2B

Uses

This is used to set the current direct page value from a value stored on the stack. This could be because a subroutine in your application wishes to use a different direct page then the rest of the application or because your subroutine has been called by another program with its own direct page elsewhere. An example of this is the UPDATE routine used in a program that uses the Window Manager.

In general, the procedure for saving and restoring the direct page register would look like this:

```
PHD             ; SAVE CURRENT DIRECT PAGE
LDA   MYDP      ; DP ADDRESS FOR OUR ROUTINE
TCD             ; SET DP = MYDP
NOP             ; MORE PROGRAM HERE . . .
PLD             ; RESTORE DIRECT PAGE TO ORIGINAL
RTS             ; BACK TO WHEREVER
```

PLP: Pull Processor Status

Description

This is used after a PHP to retrieve the status register data from the stack. The byte is put in the status register, and all the flags are conditioned corresponding to the status of each bit in the byte placed there. The Accumulator and other registers are unaffected. This always pulls a single byte, regardless of the condition of the *e*, *m*, and *x* bits. (See PHP.)

Flags & Registers Affected

N	V	-	B	D	I	Z	C	Acc	X	Y	Mem
•	•	•	•	•	•	•	•				

Addressing Modes Available

	Common	Hex
Mode	**Syntax**	**Coding**
Implied Only	PLP	28

Uses

PLP is used to retrieve the status register *after* a PHP has stored the flags at an earlier time. See PHP for examples.

As with the PHA/PLA set, PLPs should always be matched with a corresponding number of PHP instructions in a one-to-one relationship. Failure to observe this requirement can result in some *very* strange results.

PLX: Pull X Register

Description

This pulls one (x = 1) or two (x = 0) bytes off the stack and sets the X Register equal to that value. When two bytes are pulled (a word), the low byte is pulled first, then the high byte is pulled. (See also PHX.)

Flags & Registers Affected

N	V	-	B	D	I	Z	C
•						•	

Acc	X	Y	Mem
	•		

Addressing Modes Available

Mode	Common Syntax	Hex Coding
Implied Only	PLX	FA

If x = 1 (8-bit mode), the high-order byte of the X Register will always be zero.

Uses

This is one of the most common ways of temporarily storing and retrieving the contents of the X Register. It is combined with PHX to store the data.

PLY: Pull Y Register

Description

This pulls one or two bytes off the stack, depending on the condition of the *e* and *x* bits, and it sets the Y Register equal to that value. When two bytes are pulled (a word), the low byte is pulled first, then the high byte is pulled. (See PHY also.)

Flags & Registers Affected

N	V	-	B	D	I	Z	C
•						•	

Acc	X	Y	Mem
		•	

Addressing Modes Available

	Common	**Hex**
Mode	**Syntax**	**Coding**
Implied Only	PLY	7A

If x = 1 (8-bit mode), the high-order byte of the Y Register will always be zero.

Uses

This is one of the most common ways of temporarily storing and retrieving the contents of the Y Register. It is combined with PHY to store the data.

REP: Reset (Clear) Bits in Status Register

Description

This clears bits in the Status Register according to which bits are set in the operand. If the *e* bit is 1 (emulation), bit 4 (break flag) and bit 5 (unused) are ignored. If *e* is 0 (native), then bits 4 and 5 respectively condition the *m* and *x* bits.

Flags & Registers Affected

N	V	-	B	D	I	Z	C
•		*	*			•	

Acc	X	Y	Mem

m *x* only if in native mode (e = 0)

Addressing Modes Available

Mode	Common Syntax	Hex Coding
Immediate	REP $FF	C2 FF

Uses

Although this can be used to condition any of the bits in the Status Register, REP is used most often in the native mode to clear the *m* and/or *x* bits to enable 16-bit operations for the Accumulator and memory locations and/or the index registers (X and Y).

```
REP  $30          ; M AND X = 0 (16 BITS BOTH)
REP  $20          ; M = 0, X UNAFFECTED
REP  $10          ; X = 0, M UNAFFECTED
REP  $00          ; NOTHING IS AFFECTED
```

In the *Merlin* assembler, the assembler will automatically adjust its internal register size assumptions for future instructions, such as LDA and LDX, after each particular REP or SEP instruction. However, if the *m* and *x* bit status within a code segment is ambiguous, or not consistent with the current internal settings, the directive MX may be used.

```
MX   %11          ; M = 1, X = 1
MX   %01          ; M = 0, X = 1
```

In the *APW* assembler, each occurrence of REP or SEP must be accompanied with the appropriate LONGA ON/OFF and/or LONGI ON/OFF directive.

ROL: Rotate Left

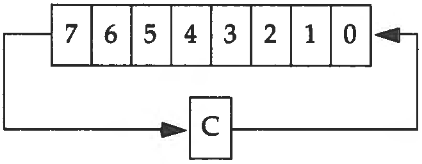
Description

This instruction moves each bit of the Accumulator or memory location specified one position to the left. The carry bit is pushed into position 0 and is replaced by bit 7 (the high-order bit). The N (sign) and Z (zero) flags are also conditioned depending on the result of the shift. ROL shifts either a byte (m = 1) or a word (m = 0). (See also ROR, ASL, and LSR.)

Flags & Registers Affected

N	V	-	B	D	I	Z	C
•						•	•

Acc	X	Y	Mem
•			•



ROL
(Rotate One Bit Left)

Addressing Modes Available

Mode	Common Syntax	Hex Coding
Accumulator	ROL	2A
Absolute	ROL $FFff	2E ff FF
Direct Page	ROL $FF	26 FF
Absolute Indexed,X	ROL $FFff,X	3E ff FF
Direct Page Indexed,X	ROL $FF,X	36 FF

Uses

ROL is used to shift multiple byte or word groups as a unit:

```
SHIFT   ASL   MEM         ; SHIFT LOW BYTE (WORD)
        ROL   MEM+1(2)    ; COMPLETE SHIFT ON HIGH-ORDER BYTE (WORD)
                          ; MEM, MEM+1(2) TIMES 2
```

ROR: Rotate Right

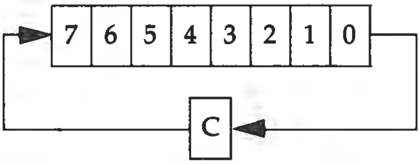
Description

This instruction moves each bit of the Accumulator or memory location specified one position to the right. The carry bit is pushed into position 7 (the high order bit) in a byte operation (bit 15 for a word) and is replaced by bit 0. The N (sign) and Z (zero) flags are also conditioned depending on the result of the shift. (See also ROL, ASL, and LSR.)

Flags & Registers Affected

N	V	-	B	D	I	Z	C
•						•	•

Acc	X	Y	Mem
•			•



ROR
(Rotate One Bit Right)

Addressing Modes Available

Mode	Common Syntax	Hex Coding
Accumulator	ROR	6A
Absolute	ROR $FFff	6E ff FF
Direct Page	ROR $FF	66 FF
Absolute Indexed,X	ROR $FFff,X	7E ff FF
Dircect Page Indexed,X	ROR $FF,X	76 FF

```
SHIFT   ROR   MEM+1(2)   ; SHIFT HIGH-ORDER BYTE (WORD)
        LSR   MEM        ; COMPLETE ON SHIFT LOW BYTE (WORD)
                         ; MEM, MEM+1(2) DIVIDED BY 2
```

RTI: Return from Interrupt

Description

This restores both the program counter and the status register in preparation to resuming the routine being executed at the time of the interrupt. All flags of the status register are reset to the original values. As an RTS is to a JSR, so RTI is the return instruction for an interrupt routine.

Flags & Registers Affected

N	V	-	B	D	I	Z	C
•	•	•	•	•	•	•	•

Acc	X	Y	Mem

Addressing Modes Available

Mode	Common Syntax	Hex Coding
Implied Only	RTI	40

Uses

RTI is used in much the same way that an RTS would be used in returning from a JSR. After an interrupt has been handled and the background operation has been performed, the return is done via the RTI command. Usually the program will want to restore the A, X, and Y registers prior to returning. Because the number of bytes pulled off the stack for the return address depends on whether the processor is in the native or emulation mode, it is essential that the RTI be done with the processor status the same as it was when the interrupt occurred.

RTL/RTS: Return from (Long) Subroutine

Description

This restores the program counter to the address stored on the stack plus one, usually the address of the next instruction after the JSR that called the routine. Analgous to a RETURN to a GOSUB in BASIC. (See also JSL/JSR.) RTS only returns to an address within the current program bank; RTL changes the program bank register, and can return to an address anywhere in addressable memory.

Flags & Registers Affected (none)

N	V	-	B	D	I	Z	C

Acc	X	Y	Mem

Addressing Modes Available

Mode	Common Syntax	Hex Coding
Implied Only	RTS	60
Implied Only	RTL	6B

Uses

RTS is, surprisingly enough, most often used to return from subroutines. It can on occasion be used to simulate a JMP instruction, by using PHA or PER instructions to put a false return address on the stack and then executing the RTS. See the sections on PHA and PER and Chapter 11 for more details.

An RTS can be POPed one level by the execution of two PLA instructions if in the 8-bit mode (m = 1), or one PLA if in the 16-bit mode (m = 0).

RTL is the return instruction for a JSL (Jump Subroutine Long); it pulls three bytes off the stack (Address Low Byte, Address High Byte, then Bank Byte).

SBC: Subtract with Carry

Description

Subtracts the contents of the memory location or a specified value from the Accumulator. The opposite of the carry is also subtracted, and in this instance, the carry is called a borrow. The N (sign), V (overflow), Z (zero), and C (carry) flags are all conditioned by this operation, and are often used to detect the nature of the result of the subtraction. The result of the subtraction is put back in the Accumulator. The memory location, if specified, is unchanged. SBC works for both the binary and BCD arithmetic modes. The operation involves one byte if m = 1, two bytes (a word) if m = 0.

Important: A SEC should always be done prior to the first SBC operation. This is equivalent to clearing the borrow, and is analgous to the CLC done prior to an ADC instruction.

Flags & Registers Affected

N	V	-	B	D	I	Z	C
•	•					•	•

Acc	X	Y	Mem
•			

Addressing Modes Available

Mode	Common Syntax	Hex Coding
Absolute	SBC $FFff	ED ff FF
Absolute Long	SBC $00FFff	EF ff FF 00
Direct Page	SBC $FF	E5 FF
Direct Page Indirect	SBC ($FF)	F2 FF
Direct Page Indirect Long	SBC [$FF]	E7 FF
Immediate	SBC #$FF	E9 FF
Absolute Indexed,X	SBC $FFff,X	FD ff FF
Absolute Long Indexed,X	SBC $00FFff,X	FF ff FF 00
Absolute Indexed,Y	SBC $FFff,Y	F9 ff FF
Direct Page Indexed,X	SBC $FF,X	F5 FF
Direct Page Indexed Indirect,X	SBC ($FF,X)	E1 FF
Direct Page Indirect Indexed,Y	SBC ($FF),Y	F1 FF
Direct Page Indirect Long Indexed,Y	SBC [$FF],Y	F7 FF
Stack Relative	SBC $FF,S	E3 FF
Stack Relative Indirect Indexed,Y	SBC ($FF,S),Y	F3 FF

Uses

SBC is used for subtracting a constant or memory value from the contents of the Accumulator.

One-Byte (Word) Subtraction:

```
ENTRY  SEC                ; PREPARE FOR SUBTRACTION
       LDA  MEM           ; GET 1ST VALUE
       SBC  #$80          ; SUBTRACT #$80
       STA  RSLT          ; STORE RESULT
DONE   RTS
```

Two-Byte (Word) Subtraction:

```
ENTRY  SEC                ; PREPARE FOR SUBTRACTION
       LDA  MEM           ; GET LOW-ORDER BYTE (WORD)
       SBC  #$80          ; SUBTRACT #$80
       STA  RSLT          ; SAVE LOW-ORDER BYTE (WORD)
       LDA  MEM+1(2)      ; GET HIGH-ORDER BYTE (WORD)
       SBC  #$00          ; SUBTRACT HIGH-ORDER BYTE (WORD) OF #$80
       STA  RSLT+1(2)     ; SAVE HIGH-ORDER RESULT
DONE   RTS
```

SEC: Set Carry

Description

This sets the carry flag of the status register.

Flags & Registers Affected

N	V	-	B	D	I	Z	C	Acc	X	Y	Mem
							•				

Addressing Modes Available

Mode	Common Syntax	Hex Coding
Implied Only	SEC	38

Uses

SEC is usually used just prior to a SBC operation. (See SBC.)

The carry is set prior to using the instruction XCE to set the 65816 microprocessor to the emulation mode.

```
SEC
XCE                ; EMULATION MODE
```

The carry is also used very often to indicate an error when returning from a call to a routine, as is done by ProDOS and the Apple IIGS tool sets. In these instances, the carry is set to indicate an error. This would be detected by the calling program upon return from the routine.

```
JSR   PRODOS
BCS   ERROR
```

SEC is also sometimes used to force a branch. For example:

```
SEC
BCS   ADDRESS      ; (ALWAYS)
```

SED: Set Decimal Mode

Description

SED sets the 65816 to the Binary Coded Decimal (BCD) mode, in preparation for an ADC or SBC operation.

Flags & Registers Affected

N	V	-	B	D	I	Z	C
				•			

Acc	X	Y	Mem

Addressing Modes Available

	Common	Hex
Mode	Syntax	Coding
Implied Only	SED	F8

Uses

BCD math is used to encode decimal data in a flexible number of bytes. In this mode, each four bits (nibble) of a byte represent one digit of a base ten number. Although not discussed in this book, here is a brief example of a BCD addition operation:

```
ENTRY   SED                 ; SET DEC MODE
        CLC                 ; PREPARE FOR ADDITION
        LDA   #$25          ; %00101001 = #25
        ADC   #$18          ; %00011000 = #18
        STA   RSLT          ; RSLT = %01000011 = #43
        CLD                 ; CLR DEC MODE
DONE    RTS
```

SEI: Set Interrupt Disable

Description

SEI is used to disable the interrupt response to an IRQ (a maskable interrupt). This does not disable the response to an NMI (Non-Maskable Interrupt) or RESET.

Flags & Registers Affected

N	V	-	B	D	I	Z	C
					•		

Acc	X	Y	Mem

Addressing Modes Available

	Common	Hex
Mode	**Syntax**	**Coding**
Implied Only	SEI	78

Uses

SEI is automatically set whenever an interrupt occurs so that no further interrupts can disturb the system while it is going through the $FFFE,FFFF vector path. ProDOS typically does a SEI/CLI operation when entering and exiting from the routines that read and write data on the disk, so interrupts do not interfere with the highly timing-dependent disk read/write routines. (See PHP also.)

SEP: Set Bits in Status Register

Description

This sets bits in the Status Register according to which bits are set in the operand. If the *e* bit is 1 (emulation), bit 4 (break flag) and bit 5 (unused) are ignored. If e = 0 (native), then bits 4 and 5 condition the *m* and *x* bits, respectively.

Flags & Registers Affected

N	V	-	B	D	I	Z	C
•		*	*			•	

Acc	X	Y	Mem

m *x* only if in native mode, e = 0

Addressing Modes Available

Mode	Common Syntax	Hex Coding
Immediate	SEP $FF	E2 FF

Uses

Although this can be used to condition any of the bits in the Status Register, SEP is used most often in the native mode to set the *m* and/or *x* bits to enable 8-bit operations for the Accumulator and memory locations and/or the index registers (X and Y).

```
SEP  $30          ; M AND X = 1 (8 BITS BOTH)
SEP  $20          ; M = 1, X UNAFFECTED
SEP  $10          ; X = 1, M UNAFFECTED
SEP  $00          ; NOTHING IS AFFECTED
```

In the *Merlin* assembler, the assembler will automatically adjust its internal register size assumptions for future instructions (like LDA, LDX, and so on) that follow a particular REP or SEP instruction. However, if the *m*- and *x*-bit status within a code segment is ambiguous or inconsistent with the current internal settings, the directive MX may be used.

```
MX   %11          ; M = 1, X = 1
MX   %01          ; M = 0, X = 1
```

In the *APW* assembler, each occurrence of REP or SEP *must* be accompanied with the appropriate LONGA ON/OFF and/or LONGI ON/OFF directive.

STA: Store Accumulator

Description

Stores the contents of the Accumulator into the specified memory location. The contents of the Accumulator are not changed, nor are any of the status register flags. One byte is stored if m = 1 (8-bit mode); two bytes are stored if m = 0 (16-bit mode).

Flags & Registers Affected (none)

N	V	-	B	D	I	Z	C

Acc	X	Y	Mem
			•

Addressing Modes Available

Mode	Common Syntax	Hex Coding
Absolute	STA $FFff	8D ff FF
Absolute Long	STA $00FFff	8F ff FF 00
Direct Page	STA $FF	85 FF
Direct Page Indirect	STA ($FF)	92 FF
Direct Page Indirect Long	STA [$FF]	87 FF
Absolute Indexed,X	STA $FFff,X	9D ff FF
Absolute Long Indexed,X	STA $00FFff,X	9F ff FF 00
Absolute Indexed,Y	STA $FFff,Y	99 ff FF
Direct Page Indexed,X	STA $FF,X	95 FF
Direct Page Indexed Indirect,X	STA ($FF,X)	81 FF
Direct Page Indirect Indexed,Y	STA ($FF),Y	91 FF
Direct Page Indirect Long Indexed,Y	STA [$FF],Y	97 FF
Stack Relative	STA $FF,S	83 FF
Stack Relative Indirect Indexed,Y	STA ($FF,S),Y	93 FF

Uses

STA is another highly used instruction, being used at the end of many operations to put the final result into a memory location.

In general, the LDA/STA combination is used to transfer bytes from one location to another.

STP: Stop Processor

Description

This brings the whole system to a nearly permanent halt by stopping the microprocessor's clock input. RESET is the only way to resume operation.

Flags & Registers Affected (none)

N	V	-	B	D	I	Z	C

Acc	X	Y	Mem

Addressing Modes Available

	Common	Hex
Mode	**Syntax**	**Coding**
Implied Only	STP	DB

Uses

STP is really designed for other hardware devices that may use the 65816 microprocessor. When the clock input is stopped, the power consumption of the 65816 drops almost to zero. In the case of the Apple IIGS, this really doesn't save much because of all those other peripheral cards, the video circuitry, the power supply itself, the monitor sitting on top of the computer, and so on.

STX: Store the X Register

Description

Stores the contents of the X Register in the specified memory location. The X Register is unchanged and none of the status register flags are affected. One byte is stored if x = 1 (8-bit register); two bytes (a word) are stored if x = 0 (16-bit registers).

Flags & Registers Affected (none)

N	V	-	B	D	I	Z	C

Acc	X	Y	Mem
			•

Addressing Modes Available

	Common	Hex
Mode	**Syntax**	**Coding**
Absolute	STX $FFff	8E ff FF
Direct Page	STX $FF	86 FF
Direct Page Indexed,Y	STX $FF,Y	96 FF

Uses

STX is another alternative to using LDA/STA to transfer data. In some instances, the Accumulator will already hold a value you wish to preserve while you transfer another byte or word. The X Register is also used by the Monitor GETLN routine to return the length of the input string.

STY: Store the Y Register

Description

STY stores the contents of the Y Register in the specified memory location. The Y Register is unchanged, and none of the status register flags are affected. One byte is stored if x = 1 (8-bit register), two bytes (a word) if x = 0 (16-bit registers).

Flags & Registers Affected (none)

N	V	-	B	D	I	Z	C	Acc	X	Y	Mem
											•

Addressing Modes Available

	Common	Hex
Mode	Syntax	Coding
Absolute	STY $FFff	8C ff FF
Direct Page	STY $FF	84 FF
Direct Page Indexed,X	STY $FF,X	94 FF

Uses

STY is used to store the value of the Y Register, usually from within string or data scanning loops. For example, here is a routine which returns the position of the first control character in a block of data.

```
ENTRY  LDY  #$00       ; ZERO COUNTER
LOOP   LDA  DATA,Y     ; GET CHARACTER
       BEQ  NOTF       ; CHAR = 0 = END OF STRING
       CMP  #$20       ; 'SPC'
       BCS  NXT        ; CHR > CTRL'S
FOUND  STY  POS        ; SAVE Y-REG
DONE   RTS

NXT    INY             ; Y = Y + 1
       BNE  LOOP       ; TILL Y=0 AGAIN.
       BRA  DONE       ; BRANCH ALWAYS

NOTF   LDY  #$FF       ; FLAG NOTFOUND
       BRA  FOUND      ; BRANCH ALWAYS
```

STZ: Store Zero in Memory

Description

STZ stores a one-byte (m = 1) or two-byte (m = 0) zero value in the memory location indicated by the operand.

Flags & Registers Affected (none)

N	V	-	B	D	I	Z	C

Acc	X	Y	Mem
			•

Addressing Modes Available

Mode	Common Syntax	Hex Coding
Absolute	STZ $FFff	9C ff FF
Direct Page	STZ $FF	64 FF
Absolute Indexed,X	STZ $FFff,X	9E ff FF
Direct Page Indexed,X	STZ $FF,X	74 FF

Uses

STZ is a convenient alternative to using LDA/STA to zero a memory location. In some instances, the Accumulator will already hold a value you wish to preserve while you zero out another byte or word.

```
LDA   #$00
STA   MEM
```

is replaced by

```
STZ   MEM
```

TAX: Transfer Accumulator to X Register

Description

Puts contents of Accumulator into the X Register. Doesn't affect the Accumulator.

Flags & Registers Affected

N	V	-	B	D	I	Z	C
•						•	

Acc	X	Y	Mem
	•		

Addressing Modes Available

Mode	Common Syntax	Hex Coding
Implied Only	TAX	AA

The actual data transferred depends significantly on the condition of the *e*, *m*, and *x* bits at the moment of transfer:

e = 1 = Emulation

m	x	Accumulator		X Register
1 (8)	1 (8)	$FFff	→	$00ff

In emulation mode, both the Accumulator and the X Register are one byte in size. Although the Accumulator has a hidden B portion (the high-order byte), this is not transferred to the X Register because, in the 8-bit mode, the high-order byte of the X Register is always forced to zero. Thus, the result in the X Register is always $00ff, regardless of the high-order byte of the Accumulator.

e = 0 = Native

m	x	Accumulator		X Register
0 (16)	0 (16)	$FFff	→	$FFff

Transfer as expected.

m	x	Accumulator		X Register
0 (16)	1 (8)	$FFff	→	$00ff

The high-order byte of the X Register is always zero in the 8-bit mode.

m	x	Accumulator		X Register
1 (8)	0 (16)	$FFff	→	$FFff

Although the Accumulator is in the 8-bit mode, *both* bytes are transferred (A and B portions) if the X Register is in the 16-bit mode. *This is a common source of program bugs.* If the Accumulator is in the 8-bit mode, it is possible that the Accumulator is still carrying along some value (not necessarily zero) from millions of previous instructions in the hidden B register. You should never assume the B register in the Accumulator is zero unless you have explicitly set it that way.

m	**x**	**Accumulator**		**X Register**
1 (8)	1 (8)	$FFff	→	$00ff

This is equivalent to the e = 1 (emulation mode) transfer.

Uses

Most simply, TAX is used for transferring data in the manner which it implies.

TAY: Transfer Accumulator to Y Register

Description

Puts contents of Accumulator into the Y Register. Does not effect the Accumulator. See TAX for a discussion of the impact of the condition of the *e*, *m*, and *x* bits.

Flags & Registers Affected

N	V	-	B	D	I	Z	C
•						•	

Acc	X	Y	Mem
		•	

Addressing Modes Available

	Common	**Hex**
Mode	**Syntax**	**Coding**
Implied Only	TAY	A8

Uses

TAY is used for transferring data from the Accumulator to the Y Register.

TCD: Transfer Accumulator to Direct-Page Register

Description

Transfers a 16-bit value from the Accumulator and sets the direct-page register to that value, regardless of the condition of the *e*, *m*, or *x* bits.

Flags & Registers Affected

N	V	-	B	D	I	Z	C
•						•	

Acc	X	Y	Mem

Addressing Modes Available

Mode	Common Syntax	Hex Coding
Implied Only	TCD	5B

Uses

This is used to set the current direct-page value from a value stored in the Accumulator. This could be because a subroutine in your application wishes to use a different direct page then the rest of the application, or because your subroutine has been called by another program with its own direct page elsewhere. An example of this is the UPDATE routine used in a program that uses the Window Manager.

In general, the procedure for saving and restoring the direct-page register would look like this:

```
PHD              ; SAVE CURRENT DIRECT PAGE
LDA   MYDP       ; DP ADDRESS FOR OUR ROUTINE
TCD              ; SET DP = MYDP
NOP              ; MORE PROGRAM HERE . . .
PLD              ; RESTORE DIRECT PAGE TO ORIGINAL
RTS              ; BACK TO WHEREVER
```

TCS: Transfer Accumulator to Stack

Description

This puts the contents of the Accumulator into the stack pointer. None of the status register flags are affected, nor is the Accumulator itself changed. How many bytes are transferred depends on the condition of the *e* and *x* bits.

Flags & Registers Affected (none)

N	V	-	B	D	I	Z	C

Acc	X	Y	Mem

Addressing Modes Available

Mode	Common Syntax	Hex Coding
Implied Only	TCS	1B

If the processor is in the native mode (e = 0), then 16 bits are transferred from the Accumulator to the Stack Pointer regardless of the condition of the *m* bit. If the e = 1 (emulation mode), then only the lower byte (A) of the Accumulator is transferred to the Stack Pointer, because the high-order byte of the Stack Pointer is locked to $01 (page $100).

Uses

This provides a way of directly setting the stack pointer.

TDC: Transfer Direct Page Register to Accumulator

Description

Transfers the 16-bit value in the direct page register to the Accumulator, regardless of the condition of the *e*, *m*, or *x* bits.

Flags & Registers Affected

N	V	-	B	D	I	Z	C
•						•	

Acc	X	Y	Mem
•			

Addressing Modes Available

Mode	Common Syntax	Hex Coding
Implied Only	TDC	7B

Uses

This is used to determine, and optionally to save, the current direct-page value. This could be because a subroutine in your application wishes to use a different direct page then the rest of the application, or because your subroutine has been called by another program with its own direct page elsewhere. An example of this is the UPDATE routine used in a program that uses the Window Manager.

In general, the procedure for saving and restoring the direct-page register using TDC would look like this:

```
TDC                   ; PUT CURRENT DIRECT PAGE IN ACC.
PHA                   ; SAVE CURRENT DIRECT PAGE
LDA   MYDP            ; DP ADDRESS FOR OUR ROUTINE
TCD                   ; SET DP = MYDP
NOP                   ; MORE PROGRAM HERE . . .
PLD                   ; RESTORE DIRECT PAGE TO ORIGINAL
RTS                   ; BACK TO WHEREVER
```

TRB: Test and Reset (Clear) Memory Bits

Description

Clears bits in memory corresponding to each bit set in the Accumulator. Also conditions the Z flag depending on the result in the same way as the BIT instruction. That is, Z will be clear (BNE will work) if any of the tested bits were set before being cleared. Whether the operation involves a byte or a word depends on the status of the *e* and *m* bits.

Flags & Registers Affected

N	V	-	B	D	I	Z	C
						•	

Acc	X	Y	Mem
			•

Addressing Modes Available

Mode	Common Syntax	Hex Coding
Absolute	TRB $FFff	1C ff FF
Direct Page	TRB $FF	14 FF

Uses

TRB is an alternative to using the AND instruction to force zeros in given bit positions. It has the advantage of combining the function of the BIT instruction in telling you whether any of the bits you just cleared were set beforehand. Use an operand with only one bit set for cases where you want to test and clear a specific bit. (See also TSB.) Operates on one byte if m = 1, two bytes if m = 0.

```
LDA  #$80        ; %10000000
TRB  MEM         ; CLEAR BIT 7
BNE  SET         ; BIT SET BEFOREHAND
```

TSB: Test and Set Memory Bits

Description

Sets bits in memory corresponding to each bit set in the Accumulator. Also conditions the Z flag depending on the result in the same way as the BIT instruction. That is, Z will be set (BEQ will work) only if all of the tested bits were clear before being set. Operates on one byte if m = 1, on two bytes if m = 0.

Flags & Registers Affected

N	V	-	B	D	I	Z	C
						•	

Acc	X	Y	Mem
			•

Addressing Modes Available

Mode	Common Syntax	Hex Coding
Absolute	TSB $FFff	0C ff FF
Direct Page	TSB $FF	04 FF

Uses

TSB is an alternative to using the ORA instruction to force 1's in given bit positions. It has the advantage of combining the function of the BIT instruction in telling you whether any of the bits you just set were clear beforehand. Use an operand with only one bit set for cases where you want to test and set a specific bit. (See also TRB.)

```
LDA  #$80        ; %10000000
TSB  MEM         ; SET BIT 7
BEQ  CLR         ; BIT CLEAR BEFOREHAND
```

TSC: Transfer Stack Pointer to Accumulator

Description

This puts the 16-bit contents of the Stack Pointer into the Accumulator, regardless of the condition of the *e* or *m* bits. The N (sign) and Z (zero) flags are conditioned. The stack pointer is unchanged. When e = 1 (emulation), the high-order byte of the Accumulator will always be set to $01, since that is the high byte of the Stack Pointer in the emulation mode (page $100).

Flags & Registers Affected

N	V	-	B	D	I	Z	C
•						•	

Acc	X	Y	Mem
•			

Addressing Modes Available

Mode	Common Syntax	Hex Coding
Implied Only	TSC	3B

Uses

TSC is used in examining the value of the stack pointer at a particular moment. (See also TSX.)

TSX: Transfer Stack Pointer to X Register

Description

This puts the contents of the Stack Pointer into the X Register. The N (sign) and Z (zero) flags are conditioned. The stack pointer is unchanged. If x = 0, two bytes are transferred, otherwise only the low-order byte of the Stack Pointer will be used.

Flags & Registers Affected

N	V	-	B	D	I	Z	C
●							●

Acc	X	Y	Mem
	●		

Addressing Modes Available

Mode	Common Syntax	Hex Coding
Implied Only	TSX	BA

Uses

The most obvious use of TSX is in preserving the value of the stack pointer at a particular moment.

Another use for TSX is in retrieving data from the stack without having to do a PLA instruction. Although stack relative addressing can be used to access data on the stack, TSX can be used to retrieve information that is officially lost at that point. This lets you retrieve data that is lower in memory than the current stack pointer, and which would be overwritten by the next PHA instruction.

One example of this is in using a JSR to a known RTS in the Monitor for no other purpose than to be able to immediately retrieve the otherwise lost return address. This is done so that position-independent code has a way of finding out where it's currently located. Although there is really not room here for an in-depth explanation, here's the routine that uses a JSR to a known RTS, and then examines the stack to determine where in memory it is currently executing.

```
ENTRY  PHP           ; SAVE INTERRUPT STATUS
       SEI           ; SET INTERRUPT DISABLE
       JSR  RETURN   ; $FF58
       TSX           ; GET STACK POINTER
       LDA  STACK,X  ; $100,X
       STA  PTR+1    ; SAVE HIGH BYTE OF RETURN ADDRESS
       DEX           ; MOVE TO NEXT POSITION
       LDA  STACK,X  ; GET LOW BYTE OF RETURN ADDRESS
       STA  PTR      ; (PTR) = ENTRY+2.
       PLP           ; RESTORE INTERRUPT STATUS
DONE   RTS
```

This technique was originally developed for the 6502 microprocessor, and code similar to this is used on peripheral cards that must determine which slot they're assigned to. On the Apple IIGS with the 65816 microprocessor, this is not really needed because the PER instruction will put an address on the stack without the worry of illegal stack use, or conflict with interrupts. (See PER.)

Caution: Most Step and Trace utilities will not properly trace code like this because of the somewhat illegal use of the stack. Strictly speaking, good programming principles dictate that once data is officially off the stack, it is counted as being effectively lost. This is especially true in the case of interrupts, where an interrupt in the middle of the dummy JSR, RTS, and retrieval process could produce a completely invalid result in PTR,PTR+1. That is why our routine temporarily disables interrupts while it examines the dead area of the stack.

TXA: Transfer X Register to Accumulator

Description

This puts the contents of the X Register into the Accumulator, and thus conditions the status register just as if a LDA instruction had been executed. The X Register is unaffected by the operation. (See also TAX.)

Flags & Registers Affected

N	V	-	B	D	I	Z	C
•						•	

Acc	X	Y	Mem
•			

Addressing Modes Available

Mode	Common Syntax	Hex Coding
Implied Only	TXA	8A

The actual data transferred depends significantly on the condition of the *e*, *m*, and *x* bits at the moment of transfer:

e = 1 = Emulation

m	*x*	X Register		Accumulator
1 (8)	1 (8)	$00ff	→	$FFff

In emulation mode, both the Accumulator and the X Register are one byte in size. However, the Accumulator has a hidden B portion (the high-order byte), that is not overwritten by the X Register because it is in the 8-bit mode. Thus, the result in the Accumulator still contains the high-order byte, regardless of the high-order byte of zero in the X Register.

e = 0 = Native

m	*x*	X Register		Accumulator
0 (16)	0 (16)	$FFff	→	$FFff

Transfer as expected.

m	*x*	X Register		Accumulator
0 (16)	1 (8)	$xxff	→	$FFff

The high-order byte of Accumulator (B) is *not* overwritten by the high-order byte of the X Register.

m	*x*	X Register		Accumulator
1 (8)	0 (16)	$00ff	→	$00ff

Because the Accumulator is in the 16-bit mode, both bytes of the X Register are transferred even though the X Register is in the 8-bit mode. *This is a common source of program bugs.* Although you may have had some value in the B portion of the Accumulator, it will be overwritten by TXA even if x = 1 (8-bit mode).

m	*x*	**X Register**		**Accumulator**
1 (8)	1 (8)	$00ff	→	$FFff

This is equivalent to the e = 1 (emulation mode) transfer. The B portion of the Accumulator retains its value.

Uses

TXA provides a way of retrieving the value in the X Register for appropriate processing by the program. In the case of string-related routines, this is often the length of the string just entered or scanned. The Accumulator can then go about the things it does so well in terms of putting the value into the most useful part of memory. Notice that there are more addressing modes available to the STA command, not to mention the overall powers granted the Accumulator in terms of logical operators and so forth.

TXS: Transfer X Register to Stack Pointer

Description

This puts the contents of the X Register into the Stack Pointer. None of the status register flags are affected, nor is the X-Register itself changed. If e = 1 (emulation), then only the low-order byte of the X Register is transferred, since the stack is fixed to page 1 ($100-$1FF). If e = 0 (native) and x = 0 (16-bit registers), then both bytes of the X Register are used. If e = 0 and x = 1 (8-bit register), then the low-order byte of the X Register is transferred, and the high-order byte is forced to zero. This puts the stack in page zero of bank zero.

Flags & Registers Affected (none)

N	V	-	B	D	I	Z	C

Acc	X	Y	Mem

Addressing Modes Available

	Common	Hex
Mode	Syntax	Coding
Implied Only	TXS	9A

Uses

This provides a way of directly setting the stack pointer.

TXY: Transfer X Register to Y Register

Description

This puts the contents of the X Register into the Y Register, and conditions the status register just as if a LDY instruction had been executed. The X Register is unaffected by the operation. One byte is transferred if x = 1; two bytes are transferred if x = 0.

Flags & Registers Affected

N	V	-	B	D	I	Z	C
•						•	

Acc	X	Y	Mem
		•	

Addressing Modes Available

	Common	Hex
Mode	**Syntax**	**Coding**
Implied Only	TXY	9B

Uses

TXY provides a way of transferring the contents of the X Register to the Y Register. This could either be because you want to temporarily store the contents of the X Register while you use it for something else, or because you want to use the index in the X Register in an addressing mode only supported by the Y Register. For example:

```
        LDX   #$00         ; INITIALIZE COUNTER
LOOP    LDA   BUFF,X       ; GET CHARACTER FROM ABSOLUTE ADDR.
        TXY                ; SET Y = X
        STA   (PTR),Y      ; STORE USING INDIRECT ADDRESSING
        INX
        CPX   LEN          ; LENGTH OF STRING YET?
        BCC   LOOP         ; NOPE
DONE    RTS
```

TYA: Transfer Y Register to Accumulator

Description

This puts the contents of the Y Register into the Accumulator, thus conditioning the status register as if an LDA instruction had been executed. The Y Register is unaffected by the operation. The actual data transferred depends on the condition of the *e*, *m*, and *x* bits. See the discusson of TAX for detailed examples.

Flags & Registers Affected

N	V	-	B	D	I	Z	C
•						•	

Acc	X	Y	Mem
•			

Addressing Modes Available

Mode	Common Syntax	Hex Coding
Implied Only	TYA	98

Uses

TYA provides a way of retrieving the value in the Y Register for appropriate processing by the program. This comes in handy when scanning a data block, and information as to certain locations is to be processed. As mentioned under TXA, the Accumulator has far greater flexibility than the Y Register in terms of addressing modes, logical operators available, and so on.

TYX: Transfer Y Register to X Register

Description

This puts the contents of the Y Register into the X Register, and conditions the status register just as if a LDX instruction had been executed. The Y Register is unaffected by the operation. One byte is transferred if x = 1, and two bytes are transferred if x = 0.

Flags & Registers Affected

N	V	-	B	D	I	Z	C
•						•	

Acc	X	Y	Mem
	•		

Addressing Modes Available

Mode	Common Syntax	Hex Coding
Implied Only	TYX	BB

Uses

TYX provides a way of transferring the contents of the Y Register to the X Register. This could either be because you want to temporarily store the contents of the Y Register while you use it for something else, or because you want to use the index in the Y Register in an addressing mode only supported by the X Register. For example:

```
        LDY  #$00        ; INITIALIZE COUNTER
LOOP    LDA  (PTR),Y     ; GET CHARACTER USING INDIRECT
        TYX              ; SET X = Y
        STA  BUFF,X      ; STORE USING ABSOLUTE WITH INDEX
        INY
        CPY  LEN         ; LENGTH OF STRING YET?
        BCC  LOOP        ; NOPE
DONE    RTS
```

WAI: Wait for Interrupt

Description

This brings current program execution to a stop until the next interrupt or RESET occurs.

Flags & Registers Affected (none)

N	V	-	B	D	I	Z	C

Acc	X	Y	Mem

Addressing Modes Available

	Common	Hex
Mode	**Syntax**	**Coding**
Implied Only	WAI	CB

Uses

WAI is designed for use with other hardware devices that may use the 65816 microprocessor, or for peripheral cards or specialized devices on the Apple IIGS that require synchronized interrupts. While the processor is waiting, the power consumption of the 65816 is reduced (though not as low as for the STP instruction). The WAI instruction can also be used to cause the microprocessor to respond nearly instantly to an interrupt event. Ordinarily, if an interrupt occurs while an instruction is executed, several cycles of the microprocessor may elapse while that instruction is completed before the interrupt is processed. The WAI instruction allows hardware designers to insure that the microprocessor will respond instantly to an interrupt.

WDM: William D. Mensch, Jr.

Description

This instruction is included as a bridge to a possible, though not yet implemented, expanded instruction set. The characters WDM are the initials of the designer of the 65816, William D. Mensch, Jr., of the Western Design Center, Inc. WDM is a minimum two-byte instruction. Bytes following the initial opcode are subject to future definition, and may involve one or more additional bytes.

Flags & Registers Affected

N	V	-	B	D	I	Z	C	Acc	X	Y	Mem
?	?	?	?	?	?	?	?	?	?	?	?

Addressing Modes Available

Mode	Common Syntax	Hex Coding
Implied Only:	WDM ??	42 ??

XBA: Exchange B and A Accumulators

Description

This swaps the A and B portions of the Accumulator, regardless of the condition of the *e* or *m* bits. B is the high-order byte; A, the low-order. The resulting condition of the N and Z flags depends on the contents of the A portion of the Accumulator result. N is set (BMI) if bit 7 is set, Z is set (BEQ) if the A Accumulator is zero.

Flags & Registers Affected

N	V	-	B	D	I	Z	C
•						•	

Acc	X	Y	Mem
•			

Addressing Modes Available

Mode	Common Syntax	Hex Coding
Implied Only	XBA	EB

Uses

XBA can be used to swap the hidden B Accumulator in the 8-bit mode with the A Accumulator. It can also be used to swap the low- and high-order bytes in the 16-bit mode (same operation, different interpretation).

Although it's not particularly more efficient than just adding $100 with the ADC instruction, here's a way to increment the high-order byte of an address in the Accumulator:

```
LDA   MEM       ; GET VALUE FROM MEMORY
XBA             ; PUT HIGH BYTE IN "A"
INC             ; ADD 1
XBA             ; NET: ACC = ACC + $100
STA   MEM       ; SAVE RESULT
```

This is equivalent to

```
CLC             ; PREPARE FOR ADDITION
LDA   MEM       ; GET VALUE FROM MEMORY
ADC   #$100     ; ADD $100
STA   MEM       ; SAVE RESULT
```

XCE: Exchange Carry and Emulation Bits

Description

This swaps the contents of the Carry flag with the emulation bit. If the Carry is clear, the result is e = 0, and the microprocessor is put into the native mode (16 bits enabled, but not yet selected). If the Carry is set, the result is e = 1, and the microprocessor is put in the emulation mode (8 bits only for Accumulator, index registers, and memory operations).

Flags & Registers Affected

N	V	-	B	D	I	Z	C
		•	•				•
		m	*x*				

Acc	X	Y	Mem
	•	•	

If *e* is cleared (native), then *m* and *x* are set to 1 (8 bit). If *e* is set (emulation), *m* and *x* disappear in function, and are replaced by the Break flag for bit 4 and by an unused bit for bit 5.

Addressing Modes Available

Mode	Common Syntax	Hex Coding
Implied Only	XCE	FB

Uses

XCE is the only way to switch the microprocessor from the native to emulation mode, and vice versa. Here's a review of the action in each direction.

Native to Emulation

```
        SEC
        XCE                 ; e = 1 = EMULATION
```

Other Effects:

m = 1	Accumulator/Memory operations locked to 8 bits. Accumulator continues to hold both A and B portions intact.
x = 1	Index Register size locked to 8 bits. The high-order bytes of X and Y are set to zero.
Stack	The stack is set to page one ($1xx), bank zero, and is limited to one page in size ($100 to $1FF).

Direct Page,
Program Bank,
Data Bank

The Direct Page, Program Bank, and Data Bank registers do not explictly change. Although ProDOS 8 and other Apple II software may expect the Direct Page, Program Bank, and Data Bank values to be $0000, it is up to the application to make sure this is the case if any of these have been reset by the application, and a switch is made to emulation for the purpose of executing a Monitor routine, Applesoft BASIC program, and so forth.

Emulation to Native

```
        CLC
        XCE                 ; e = 0 = NATIVE
```

Other Effects:

m = 1

Accumulator/Memory operations default to 8 bits. Accumulator continues to hold both A and B portions intact. Data size may then be changed with REP or SEP instructions at will.

x = 1

Index Register size defaults to 8 bits. The high-order bytes of X and Y are set to zero. Register size may then be changed with REP or SEP instructions at will.

Stack

The stack is left set to page one ($1xx), bank zero, and but is no longer limited to one page in size. Program may then use TCS or any other relevant instruction to change the stack location as desired to anywhere in bank 0.

Direct Page,
Program Bank,
Data Bank

The Direct Page, Program Bank and Data Bank Registers do not explictly change. Although ProDOS 8 and other Apple II software may have set the Direct Page, Program Bank, and Data Bank values to be $0000, the application may change these as desired. ProDOS 16 automatically sets the Program Bank Register when an application is loaded and run, and assigns $400 bytes somewhere in bank 0 for the Direct Page ($100 bytes) and the Stack ($300 bytes). Under ProDOS 16, the program must set its own Data Bank Register as needed.

Appendix B

The Apple IIGS Monitor

Early chapters in this book introduced the Apple IIGS Monitor and some of the commands that make life easier for the assembly language programmer. This appendix provides a quick reference guide for some of the additional and useful commands in the Monitor not discussed in the main body of the book.

The Monitor is entered by typing CALL–151 from Applesoft BASIC. The mini-assembler is started by typing the exclamation mark (!) and is described in Chapter 3. You can exit the mini-assembler by typing Return alone on a line. You can return to Applesoft BASIC from the monitor by typing Control-C or by pressing Q (for Quit).

The following sections organize the Monitor commands by function. Assume that each *sample instruction* is terminated by pressing Return.

Memory Operations

Sample Instruction	**Description**
02/	Set current examination bank to $02.
1234	Display contents of location $1234.
1234.5678	Display hex and ASCII values from memory in the range.
$1234–$5678.	
{Return}	Return alone displays the next 8 or 16 bytes starting at the current address depending on whether the screen is in 40 or 80 columns.
02/1234.5678	Sets current examination bank to $02, and dumps contents of $1234 through $5678 in bank $02.
1234: 56	Stores $56 in location $1234 in the current examination bank.
02/1234: 56	Stores $56 in location $1234 in bank $02. Note: The bank byte may be included in any of the following memory instructions as you wish.
Control-X (No C/R)	Terminates a memory dump in progress.
1234: "A"	Stores the ASCII value ($41 or $C1) for the letter *A* in location $1234. Whether the high bit is set or not depends on the status of the filter value.
FF = F	Change filter value for ASCII characters to $FF for high bit on.
7F = F	Change filter value for ASCII characters to $7F for high bit off.

1234: 01 02 03	Store the values $01, $02, $03 in locations $1234, $1235, and $1236.
1234: "TEST"	Store the ASCII values for the characters T-E-S-T in locations $1234, $1235, $1236, and $1237, with the high bit conditioned by the filter value.
1234: 'ABCD'	Store the ASCII values for the characters in the *reverse order* that they appear on the line. Thus the characters D-C-B-A would be stored starting at location $1234. This is called *flip ASCII*.
0<1234.5679Z	Fills memory locations $1234 through $5678 with 0.
800<1234.5678M	Moves memory from $1234 to $5678 to location $800+.
800<1234.5678V	Compares each byte in the range of $1234 to $5678 to the corresponding byte starting at $800. Any bytes that do not match are reported.
"A"<1234.5678P	Search for the ASCII characters from $1234 to $5678.
25<1234.5678P	Search for the value $25 in memory in the range of $1234 to $5678.
"ABCD"<1234.5678P	Search for the pattern of ASCII characters ABCD in the memory in the range of $1234 to $5678.
25 7F 3E<1234.5678P	Search for the pattern of hex bytes 25 7F 3E in memory in the range of $1234 to $5678.

Number Conversions

Sample Instruction	Description
1234=	Convert $1234 to decimal.
=1234	Convert 1234 (decimal) to hex.

Program Execution and Register Display

Sample Instruction	Description
Control-E	Display contents of registers. These registers are set when a BRK is encountered, or they may be set by the user.
Control-N	Returns *e*, *m*, and *x* bits to Native mode (0).
Control-R	Returns registers and flags to default Monitor configuration.
300G	Run a program in bank 0 (only). All registers are set using the stored values in the register display before the Go is executed. The routine should end with an RTS for control to return to the Monitor.
02/0300X	Execute a program in any bank. All registers are set using the stored values in the register display before the Go is executed. The routine should end with an RTL for control to return to the Monitor.

The following commands change the registers and flags in the stored register and flag display:

1234=A	Set Accumulator to $1234.
1234=X	Set X Register to $1234.
1234=Y	Set Y Register to $1234.
1234=D	Set Direct-Page Register to $1234.
12=B	Set Data Bank to bank $12.
12=K	Set Program Bank to bank $12.
1234=S	Set Stack Pointer to $1234.
12=P	Set Status Register to $12.
12=M	Set machine state for the next Go or eXecute command to $12.
12=Q	Set Quagmire state for next Go or eXecute command to $12. Quagmire bits are defined as follows:

Bit 7 = 1	High speed mode.
Bit 6 = 1	Stop Language Card, I/O shadowing.
Bit 5 = 1	Must always be zero.
Bit 4 = 1	Stop bank 1 hi-res shadowing.
Bit 3 = 1	Stop super hi-res shadowing.
Bit 2 = 1	Stop hi-res page 2 shadowing.
Bit 1 = 1	Stop hi-res page 1 shadowing.
Bit 0 = 1	Stop text page 1 shadowing.

0 = m	Set *m* bit to 0 (or 1).
0 = e	Set *e* bit to 0 (or 1).
0 = x	Set *x* bit to 0 (or 1). (See Control-N and Control-R.)
0 = L	Change language card RAM to first bank.
1 = L	Change language card RAM to second bank.

Appendix C

ProDOS 16 File Dump Utility

This program, Program C-1, demonstrates how a ProDOS 16 application opens, reads, and closes a file. In addition, the routine handles ProDOS errors by printing an error code and gives the user a chance to try again.

Support of text input and output on the Apple IIGS is very limited. Apple really doesn't want people to write programs that use the text display, so very little effort went into the text tools.

In particular, although there is a ReadString command in the text tools that will input a line of text from the keyboard, it does not support any editing functions such as the backspace or delete key, so is nearly useless. This sample program demonstrates how a very simple editing routine is built by handling the left- and right-arrow keys and Delete. ReadChar could have been used for getting a character from the keyboard, but there is a dilemma in how to handle control characters vs. normal text. You want to echo normal characters to the screen, but not control characters. ReadChar doesn't distinguish between these in its echo parameter. In addition, a pause function is included that will start and stop the text output with a keypress.

For these reasons, the program deals directly with the keyboard register, $C000 for input, but it uses various text tools for output. Since the primary purpose of this program is to illustrate ProDOS 16 file techniques, I will leave it as an exercise for you to improve upon the input routine.

Program C-1. P16 File Dump

```
*********************************************
*    P16 FILE DUMP DEMO PROGRAM             *
*           MERLIN ASSEMBLER                *
*********************************************

           MX    %00                ; TELL MERLIN WE'RE IN 16 BITS
           REL
           DSK   FDUMP.SYS16.L

           LST   OFF                ; DON'T PRINT MACRO LISTING
           USE   UTIL.MACS          ; USE MACRO LIBRARY
           LST   ON                 ; LISTING BACK "ON"
```

```
                                       EXP    OFF              ; DON'T EXPAND MACROS

               =E100A8      PRODOS     EQU    $E100A8          ; STD. PRODOS 16 ENTRY
               =C000        KYBD       EQU    $00C000
               =C010        STROBE     EQU    $00C010

008000: 4B                  STARTUP    PHK                     ; NOTE THAT TEXT TOOLS AND THE
008001: AB                             PLB                     ; MATH TOOLS DO NOT NEED TO BE
                                                               ; STARTED UP.

008002: E2 30               SETRES     SEP    $30              ; 8-BIT MODE
008004: A9 5C                          LDA    #$5C             ; JML (JMP LONG)
008006: 8F F8 03 00                    STAL   $3F8             ; CTRL-Y VECTOR
00800A: C2 30                          REP    $30              ; 16-BIT MODE
00800C: A9 A8 83                       LDA    #RESUME
00800F: 8F F9 03 00                    STAL   $3F9             ; $3F9,3FA
008013: A9 00 00                       LDA    #^RESUME
008016: 8F FB 03 00                    STAL   $3FB             ; $3FB,3FC

                            PROMPT     PushLong #MSSG1         ; POINTER TO STRING TO PRINT
                                       ToolCall $200C          ; WriteCString

00802B: A9 8D 00            GETPATH    LDA    #$8D             ; GET PATHNAME
00802E: 8D 7E 83                       STA    INBUF
008031: 9C 7C 82                       STZ    LEN              ; LENGTH = 0

                            INPUT      PushLong #INBUF         ; PRINT EXISTING PATHNAME
                                       ToolCall $200C          ; WriteCString

                            GETCHAR    PushWord #$0000         ; SPACE FOR RESULT
                                       PushWord #$0000         ; NO ECHO
                                       ToolCall $220C          ; ReadChar
008056: 68                             PLA                     ; RETRIEVE CHARACTER

008057: 29 FF 00            :1         AND    #$00FF           ; CLEAR HIGH BYTE
00805A: C9 FF 00                       CMP    #$FF             ; DELETE CHAR?
00805D: F0 0F  =806E                   BEQ    EDIT

00805F: C9 A0 00                       CMP    #$A0             ; IS IT A CTRL CHAR?
008062: B0 1D  =8081                   BCS    ECHO             ; NOPE

008064: C9 8D 00            CTRL       CMP    #$8D             ; RETURN = DONE?
008067: F0 26  =808F                   BEQ    GOTPATH

008069: C9 88 00                       CMP    #$88             ; BACKSPACE?
00806C: D0 C6  =8034                   BNE    INPUT            ; IGNORE, BACK FOR MORE

00806E: AD 7C 82            EDIT       LDA    LEN              ; GET LEN CHAR
008071: F0 C1  =8034                   BEQ    INPUT            ; IGNORE
008073: AA                             TAX                     ; KEEP OLD LEN IN X-REG
008074: 3A                             DEC                     ; SUBTRACT 1
008075: 8D 7C 82                       STA    LEN              ; LEN = LEN 1
```

```
008078: A9 00 00                  LDA   #$00
00807B: 9D 7E 83                  STA   INBUF,X          ; PUT ZERO AT END
                                                         ; (DELETES OLD NTH CHAR).
00807E: 4C 34 80                  JMP   INPUT            ; GO GET SOME MORE

008081: 48               ECHO     PHA                    ; SAVE CHARACTER
008082: EE 7C 82                  INC   LEN              ; ADD 1 TO LENGTH
008085: AE 7C 82                  LDX   LEN              ; PUT IN XREG
008088: 68                        PLA                    ; RETRIEVE CHARACTER
008089: 9D 7E 83                  STA   INBUF,X          ; ADD TO STRING
                                                         ; AUTO '0' AT END! (HIGH BYTE)
00808C: 4C 34 80                  JMP   INPUT            ; GO GET SOME MORE

00808F: AE 7C 82         GOTPATH  LDX   LEN              ; GET LENGTH OF INPUT

008092: E0 04 00         CHK1     CPX   #$04             ; 4 = LEN "QUIT"
008095: D0 13 =80AA               BNE   FIX              ; IT'S NOT "QUIT"

008097: AD 7F 83         CHK2     LDA   INBUF+1          ; 1ST & 2ND CHARS OF INPUT
00809A: CD 23 82                  CMP   WORD             ; "QUIT"?
00809D: D0 0B =80AA               BNE   FIX              ; NOPE
00809F: AD 81 83                  LDA   INBUF+3          ; 3RD & 4TH CHARS
0080A2: CD 25 82                  CMP   WORD+2
0080A5: D0 03 =80AA               BNE   FIX              ; NOPE

0080A7: 4C 79 81                  JMP   QUIT             ; STR$ = "QUIT"

0080AA: AD 7C 82         FIX      LDA   LEN
0080AD: E2 30                     SEP   $30              ; 8-BIT MODE
0080AF: 8D 7E 83                  STA   INBUF            ; CHANGE TO PRODOS STR$
0080B2: C2 30                     REP   $30              ; BACK TO 16 BITS

                         CLRSCRN  PushWord #$008C        ; HOME & CLEAR SCREEN
                                  ToolCall $180C         ; WriteChar

0080C2: 22 A8 00 E1      OPEN     JSL   PRODOS
0080C6: 10 00                     DA    $10              ; OPEN COMMAND
0080C8: EE 81 00 00               ADRL  OPENBLK          ; OPEN CMD TABLE
0080CC: 90 03 =80D1               BCC   OPEN2            ; NO ERROR

0080CE: 4C 85 81                  JMP   ERROR            ; PRODOS ERROR MESSAGE

0080D1: AD EE 81         OPEN2    LDA   OPENBLK          ; GET REFERENCE NUMBER
0080D4: 8D F8 81                  STA   READBLK          ; STORE REF NUMBER

0080D7: 22 A8 00 E1      READ     JSL   PRODOS
0080DB: 12 00                     DA    $12              ; READ COMMAND
0080DD: F8 81 00 00               ADRL  READBLK          ; READ CMD TABLE
0080E1: 90 08 =80EB               BCC   PRINT            ; NO ERROR . . .

0080E3: C9 4C 00                  CMP   #$4C             ; ERROR = END OF FILE?
0080E6: F0 5C =8144               BEQ   CLOSE            ; YEP!
```

```
0080E8: 4C 85 81                 JMP   ERROR          ; PRODOS ERROR MSSG

0080EB: A2 01 00         PRINT   LDX   #$01           ; 1ST CHAR OF BUFFER

0080EE: AF 00 C0 00      PRLOOP  LDAL  KYBD           ; CHECK FOR A PAUSE KEY
0080F2: 29 FF 00                 AND   #$00FF         ; CLEAR HIGH BYTE
0080F5: C9 80 00                 CMP   #$80           ; KEYPRESS?
0080F8: 90 14    =810E           BCC   PRCHAR         ; NOPE
0080FA: 8F 10 C0 00              STAL  STROBE         ; CLEAR KEYBOARD

0080FE: AF 00 C0 00      PAUSE   LDAL  KYBD
008102: 29 FF 00                 AND   #$00FF
008105: C9 80 00                 CMP   #$80
008108: 90 F4    =80FE           BCC   PAUSE          ; WAIT FOR KEYPRESS
00810A: 8F 10 C0 00              STAL  STROBE

00810E: BD 7E 82         PRCHAR  LDA   BUFFER,X
008111: 29 FF 00                 AND   #$00FF         ; CLEAR HIGH BYTE OF ACC.
008114: DA                       PHX                  ; SAVE OUR XPOSITION
008115: 48                       PHA                  ; SAVE THE CHAR FOR LATER

008116: 48                       PHA                  ; PUSH THE CHARACTER
                                 ToolCall $180C       ; WriteChar

008122: 68               NXTCHAR PLA                  ; GET CHAR JUST PRINTED
008123: 29 7F 00                 AND   #$007F         ; CLEAR HIGH BIT
008126: C9 0D 00                 CMP   #$000D         ; WAS IT A RETURN?
008129: D0 0E    =8139           BNE   :2             ; NO, CONTINUE PRINTING
                                 PushWord #$008A      ; LINE FEED
                                 ToolCall $180C       ; WriteChar

008139: FA               :2      PLX                  ; RETRIEVE X VALUE
00813A: E8                       INX                  ; NEXT CHAR IN BUFFER
00813B: EC 02 82                 CPX   NUMREAD        ; ALL CHARS PRINTED YET?
00813E: 90 AE    =80EE           BCC   PRLOOP         ; NOPE
008140: F0 AC    =80EE           BEQ   PRLOOP         ; THIS WILL BE THE LAST ONE
008142: B0 93    =80D7           BCS   READ           ; GET ANOTHER BATCH

008144: 22 A8 00 E1      CLOSE   JSL   PRODOS
008148: 14 00                    DA    $14            ; CLOSE COMMAND
00814A: F8 81 00 00              ADRL  READBLK        ; SAME TABLE AS 'READ'
00814E: 90 03    =8153           BCC   DONE           ; NO ERRORS
008150: 4C 85 81                 JMP   ERROR          ; PRODOS ERROR MSSG

                         DONE    PushLong #MSSG3      ; END OF FILE MSSG.
                                 ToolCall $200C       ; WriteCString

                         RDKEY2  PushWord #$0000      ; SPACE FOR RESULT
                                 PushWord #$0000      ; ECHO FLAG = NO ECHO
                                 ToolCall $220C       ; ReadChar

008175: 68                       PLA                  ; RETRIEVE CHARACTER
```

```
008176: 4C 1A 80               JMP   PROMPT            ; TRY AGAIN

008179: 22 A8 00 E1   QUIT     JSL   PRODOS            ; DO QUIT CALL
00817D: 29 00                  DA    $29               ; QUIT CALL COMMAND VALUE
00817F: E8 81 00 00            ADRL  QUITBLK           ; ADDRESS OF PARM TABLE
008183: 00 00                  BRK   $00               ; SHOULD NEVER GET HERE...

008185: 8D 75 82      ERROR    STA   ERRCODE
                               PushLong #MSSG2         ; ADDRESS OF MSSG TEXT
                               ToolCall $200C          ; WriteCString

008199: AD 75 82      PRCODE   LDA   ERRCODE           ; RETRIEVE ERROR CODE
00819C: 48                     PHA                     ; PUT IT ON STACK
                               PushLong #HEXSTR+1      ; STRING DATA BUFFER
                               PushWord #4             ; MAX LENGTH OF OUTPUT STRING.
                               ToolCall $220B          ; Int2Hex

                      :1       PushLong #HEXSTR        ; POINTER TO STRING DATA
                               ToolCall $1C0C          ; WriteCString

                      PRERR2   PushLong #MSSG2A        ; ADDRESS OF MSSG TEXT
                               ToolCall $200C          ; WriteCString

                      ERDONE   PushWord #$0000         ; SPACE FOR RESULT
                               PushWord #$0000         ; ECHO FLAG = NO ECHO
                               ToolCall $220C          ; ReadChar
                                                       ; WAIT FOR KEYPRESS
0081E4: 68                     PLA                     ; RETRIEVE CHAR.

0081E5: 4C 1A 80               JMP   PROMPT            ; TRY AGAIN IF ERROR


0081E8: 00 00 00 00   QUITBLK  ADRL  $0000             ; NO PATHNMAME
0081EC: 00 00                  DA    $0000             ; STD. QUIT

0081EE: 00 00         OPENBLK  DA    $0000             ; FILE REFERENCE NUMBER
0081F0: 7E 83 00 00            ADRL  INBUF             ; POINTER TO PATHNAME
0081F4: 00 00 00 00            ADRL  $0000             ; HANDLE TO PRODOS BUFFER

0081F8: 00 00         READBLK  DA    $0000             ; FILE REFERENCE NUMBER
0081FA: 7F 82 00 00            ADRL  BUFFER+1          ; POINTER TO DATA BUFFER
0081FE: FF 00 00 00            ADRL  255               ; 255 CHARACTERS TO READ
008202: 00 00 00 00   NUMREAD  ADRL  $0000             ; NUMBER OF CHARS READ

                               TR    ON                ; DON'T PRINT ALL THE CHARS

008206: 8C            MSSG1    HEX   8C                ; HOME & CLEAR SCREEN
008207: D0 CC C5 C1            ASC   "PLEASE ENTER PATHNAME: "
00821E: A8 CF D2 A0            ASC   "(OR '"
008223: D1 D5 C9 D4   WORD     ASC   "QUIT"
008227: A7 A9 A0 8D            ASC   "') ",8D,8A,00

```

```
00822D: 8D  8A          221 MSSG2     HEX   8D,8A               ; PRINT RETURN, LF FIRST
00822F: D0  D2  CF  C4  222           ASC   “PRODOS ERROR $“,00
00823E: 8D  8A          223 MSSG2A    HEX   8D,8A               ; ANOTHER CARRIAGE RETURN, LF
008240: D0  D2  C5  D3  224           ASC   “PRESS A KEY TO TRY AGAIN“,00
                        225
008259: 8D  8A          226 MSSG3     HEX   8D,8A               ; PRINT RETURN, LF FIRST . . .
00825B: D0  D2  C5  D3  227           ASC   “PRESS A KEY FOR NEXT FILE“,00
                        228
008275: 00  00          229 ERRCODE   DA    $0000
                        230
008277: 04  B0  B0  B0  231 HEXSTR    STR   “0000”
                        232
00827C: 00  00          233 LEN       DA    $0000               ; LENGTH OF STRING IN INBUF
                        234
00827E: 00  00  00  00  235 BUFFER    DS    $100                ; DATA BUFFER FOR US
                        236
00837E: 8D  00          237 INBUF     HEX   8D,00               ; BEG. STRING AT LEFT
008380: 00  00  00  00  238           DS    40                  ; ROOM FOR 40 CHARS
                        239
                        240 ************************************************
                        241
0083A8: 4B              242 RESUME    PHK
0083A9: AB              243           PLB                       ; SET OUR DATA BANK
0083AA: 18              244           CLC
0083AB: FB              245           XCE                       ; SET NATIVE MODE
0083AC: C2  30          246           REP   $30                 ; 16-BIT MODE
0083AE: 4C  79  81      247           JMP   QUIT                ; TRY TO QUIT
                        248
0083B1: 94              249 CHKSUM    CHK                       ; CHECKSUM FOR VERIFICATION

--End Merlin-16 assembly, 946 bytes, errors: 0
```

Appendix D

Suggested Reading

The Apple IIGS is such an involved and extended system that no one book can hope to cover more than just a portion of the information that is available on the machine. The following list is provided to help you in selecting additional references that will be helpful in programming the Apple IIGS.

Apple Computer Co., Inc. *Apple IIe Technical Reference Manual.* Reading, MA: Addison-Wesley Publishing Co., Inc.

———. *Apple IIGS Firmware Reference*. Reading, MA: Addison-Wesley Publishing Co., Inc.

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———. *Graphics and Sound for the Apple IIGS* . Greensboro, NC: COMPUTE! Publications, Inc.

Sather, Jim. *Understanding the Apple IIe*. New York, NY: Brady Communications Co., Inc.

Wagner, Roger. *Assembly Lines: The Book, Volume II*. Santee, CA: Roger Wagner Publishing, Inc.

Worth, Don and Pieter Lechner. *Beneath Apple ProDOS*. New York, NY: Brady Communications Co., Inc.

Appendix E

ASCII Character Chart

This chart shows some of the possible forms of a byte value in memory. The first three columns show the hex value and its decimal and binary equivalents. This can be handy when conversions are needed. The next three columns show the same value with the high bit set.

The ASCII character column shows the character assigned to the two values (high bit clear and set). For control characters, the standard ASCII abbreviation is also given, along with a notation for those characters that have some particular significance on the Apple IIGS.

Note that for control characters, the ˆ symbol is used. Thus a Control-A would be indicated ˆA.

Hex	Dec	Binary	Hex	Dec	Binary	ASCII Character		
$00	0	0000 0000	$80	128	1000 0000	ˆ@	NUL	Null
$01	1	0000 0001	$81	129	1000 0001	ˆA	SOH	
$02	2	0000 0010	$82	130	1000 0010	ˆB	STX	
$03	3	0000 0011	$83	131	1000 0011	ˆC	ETX	
$04	4	0000 0100	$84	132	1000 0100	ˆD	EOT	
$05	5	0000 0101	$85	133	1000 0101	ˆE	ENQ	
$06	6	0000 0110	$86	134	1000 0110	ˆF	ACK	
$07	7	0000 0111	$87	135	1000 0111	ˆG	BEL	Bell
$08	8	0000 1000	$88	136	1000 1000	ˆH	BS	Backspace
$09	9	0000 1001	$89	137	1000 1001	ˆI	HT	TAB
$0A	10	0000 1010	$8A	138	1000 1010	ˆJ	LF	Linefeed
$0B	11	0000 1011	$8B	139	1000 1011	ˆK	VT	Up arrow
$0C	12	0000 1100	$8C	140	1000 1100	ˆL	FF	Formfeed
$0D	13	0000 1101	$8D	141	1000 1101	ˆM	CR	Return
$0E	14	0000 1110	$8E	142	1000 1110	ˆN	SO	
$0F	15	0000 1111	$8F	143	1000 1111	ˆO	SI	
$10	16	0001 0000	$90	144	1001 0000	ˆP	DLE	
$11	17	0001 0001	$91	145	1001 0001	ˆQ	DC1	XON
$12	18	0001 0010	$92	146	1001 0010	ˆR	DC2	
$13	19	0001 0011	$93	147	1001 0011	ˆS	DC3	XOFF
$14	20	0001 0100	$94	148	1001 0100	ˆT	DC4	

Hex	Dec	Binary	Hex	Dec	Binary	ASCII Character		
$15	21	0001 0101	$95	149	1001 0101	^U	NAK	Right arrow
$16	22	0001 0110	$96	150	1001 0110	^V	SYN	
$17	23	0001 0111	$97	151	1001 0111	^W	ETB	
$18	24	0001 1000	$98	152	1001 1000	^X	CAN	Cancel line
$19	25	0001 1001	$99	153	1001 1001	^Y	EM	
$1A	26	0001 1010	$9A	154	1001 1010	^Z	SUB	
$1B	27	0001 1011	$9B	155	1001 1011	^[	ESC	Escape
$1C	28	0001 1100	$9C	156	1001 1100	^\	FS	
$1D	29	0001 1101	$9D	157	1001 1101	^]	GS	
$1E	30	0001 1110	$9E	158	1001 1110	^^	RS	
$1F	31	0001 1111	$9F	159	1001 1111	^_	US	
$20	32	0010 0000	$A0	160	1010 0000	space		
$21	33	0010 0001	$A1	161	1010 0001	!		
$22	34	0010 0010	$A2	162	1010 0010	”		
$23	35	0010 0011	$A3	163	1010 0011	#		
$24	36	0010 0100	$A4	164	1010 0100	$		
$25	37	0010 0101	$A5	165	1010 0101	%		
$26	38	0010 0110	$A6	166	1010 0110	&		
$27	39	0010 0111	$A7	167	1010 0111	’		
$28	40	0010 1000	$A8	168	1010 1000	(		
$29	41	0010 1001	$A9	169	1010 1001	)		
$2A	42	0010 1010	$AA	170	1010 1010	*		
$2B	43	0010 1011	$AB	171	1010 1011	+		
$2C	44	0010 1100	$AC	172	1010 1100	,		
$2D	45	0010 1101	$AD	173	1010 1101	-		
$2E	46	0010 1110	$AE	174	1010 1110	.		
$2F	47	0010 1111	$AF	175	1010 1111	/		
$30	48	0011 0000	$B0	176	1011 0000	0		
$31	49	0011 0001	$B1	177	1011 0001	1		
$32	50	0011 0010	$B2	178	1011 0010	2		
$33	51	0011 0011	$B3	179	1011 0011	3		
$34	52	0011 0100	$B4	180	1011 0100	4		
$35	53	0011 0101	$B5	181	1011 0101	5		
$36	54	0011 0110	$B6	182	1011 0110	6		
$37	55	0011 0111	$B7	183	1011 0111	7		
$38	56	0011 1000	$B8	184	1011 1000	8		

Hex	Dec	Binary	Hex	Dec	Binary	ASCII Character
$39	57	0011 1001	$B9	185	1011 1001	9
$3A	58	0011 1010	$BA	186	1011 1010	:
$3B	59	0011 1011	$BB	187	1011 1011	;
$3C	60	0011 1100	$BC	188	1011 1100	<
$3D	61	0011 1101	$BD	189	1011 1101	=
$3E	62	0011 1110	$BE	190	1011 1110	>
$3F	63	0011 1111	$BF	191	1011 1111	?
$40	64	0100 0000	$C0	192	1100 0000	@
$41	65	0100 0001	$C1	193	1100 0001	A
$42	66	0100 0010	$C2	194	1100 0010	B
$43	67	0100 0011	$C3	195	1100 0011	C
$44	68	0100 0100	$C4	196	1100 0100	D
$45	69	0100 0101	$C5	197	1100 0101	E
$46	70	0100 0110	$C6	198	1100 0110	F
$47	71	0100 0111	$C7	199	1100 0111	G
$48	72	0100 1000	$C8	200	1100 1000	H
$49	73	0100 1001	$C9	201	1100 1001	I
$4A	74	0100 1010	$CA	202	1100 1010	J
$4B	75	0100 1011	$CB	203	1100 1011	K
$4C	76	0100 1100	$CC	204	1100 1100	L
$4D	77	0100 1101	$CD	205	1100 1101	M
$4E	78	0100 1110	$CE	206	1100 1110	N
$4F	79	0100 1111	$CF	207	1100 1111	O
$50	80	0101 0000	$D0	208	1101 0000	P
$51	81	0101 0001	$D1	209	1101 0001	Q
$52	82	0101 0010	$D2	210	1101 0010	R
$53	83	0101 0011	$D3	211	1101 0011	S
$54	84	0101 0100	$D4	212	1101 0100	T
$55	85	0101 0101	$D5	213	1101 0101	U
$56	86	0101 0110	$D6	214	1101 0110	V
$57	87	0101 0111	$D7	215	1101 0111	W
$58	88	0101 1000	$D8	216	1101 1000	X
$59	89	0101 1001	$D9	217	1101 1001	Y
$5A	90	0101 1010	$DA	218	1101 1010	Z
$5B	91	0101 1011	$DB	219	1101 1011	[
$5C	92	0101 1100	$DC	220	1101 1100	\
$5D	93	0101 1101	$DD	221	1101 1101	]
$5E	94	0101 1110	$DE	222	1101 1110	^
$5F	95	0101 1111	$DF	223	1101 1111	_
$60	96	0110 0000	$E0	224	1110 0000	‘
$61	97	0110 0001	$E1	225	1110 0001	a

Hex	Dec	Binary	Hex	Dec	Binary	ASCII Character
$62	98	0110 0010	$E2	226	1110 0010	b
$63	99	0110 0011	$E3	227	1110 0011	c
$64	100	0110 0100	$E4	228	1110 0100	d
$65	101	0110 0101	$E5	229	1110 0101	e
$66	102	0110 0110	$E6	230	1110 0110	f
$67	103	0110 0111	$E7	231	1110 0111	g
$68	104	0110 1000	$E8	232	1110 1000	h
$69	105	0110 1001	$E9	233	1110 1001	i
$6A	106	0110 1010	$EA	234	1110 1010	j
$6B	107	0110 1011	$EB	235	1110 1011	k
$6C	108	0110 1100	$EC	236	1110 1100	l
$6D	109	0110 1101	$ED	237	1110 1101	m
$6E	110	0110 1110	$EE	238	1110 1110	n
$6F	111	0110 1111	$EF	239	1110 1111	o
$70	112	0111 0000	$F0	240	1111 0000	p
$71	113	0111 0001	$F1	241	1111 0001	q
$72	114	0111 0010	$F2	242	1111 0010	r
$73	115	0111 0011	$F3	243	1111 0011	s
$74	116	0111 0100	$F4	244	1111 0100	t
$75	117	0111 0101	$F5	245	1111 0101	u
$76	118	0111 0110	$F6	246	1111 0110	v
$77	119	0111 0111	$F7	247	1111 0111	w
$78	120	0111 1000	$F8	248	1111 1000	x
$79	121	0111 1001	$F9	249	1111 1001	y
$7A	122	0111 1010	$FA	250	1111 1010	z
$7B	123	0111 1011	$FB	251	1111 1011	{
$7C	124	0111 1100	$FC	252	1111 1100	|
$7D	125	0111 1101	$FD	253	1111 1101	}
$7E	126	0111 1110	$FE	254	1111 1110	~
$7F	127	0111 1111	$FF	255	1111 1111	Delete

Index

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Errata:
Apple IIGS Machine Language for Beginners

by Roger Wagner
(revised 8/29/90 - ECM)

Page 19: Line 290 of the program should read:

```
290 POKE 49186,OS: POKE 49204,OB: REM RESTORE SCREEN
```

Pages 61, 67: The Main Menu of Merlin 16 displays **F: Full Screen Editor**, not "E: Editor, command mode."

Page 67: Paragraph 3: After a successful assembly, it is *not* necessary to type Q to Quit, as Merlin automatically returns to the Main Menu.

Page 69: Assembler Directives, paragraph 2: When a source file is loaded, Merlin 16 automatically goes to the editor, so pressing a command key is *not* necessary.

Page 93: The KEEP and ORG line positions should be interchanged so that ORG comes before the KEEP directive. In the program itself, the instruction to load the Accumulator with the letter "A" should read:

```
          LDA  #$C1        ; LETTER "A"
```

Page 94: The output listing for Program 5-6 is incorrect, and is more similar to, although not identical to, the output when assembling Program 5-7.

Chapter 6: APW users should note that when entering the example programs, the listings shown assume the 8 bit mode of the 65816. When using the APW assembler, you will have to remember to include the directives LONGA OFF and LONGI OFF at the beginning of your source listings. LONGI OFF tells the APW assembler to use the 8 bit mode for 'Index' register operations such as LDX, STY, etc.

Page 115: In the listing at the bottom of the page, the CMP instruction should be CMP #$FFFF. This compares the Accumulator to the immediate value of $FFFF, *not* the memory location $FFFF.

Page 133: Setting and clearing the Carry, paragraph 2: "If you want to **clear** the Emulation bit to **0** (sometimes called..."

Above the last paragraph, the instructions should read:

```
SEP  #$20    ; %00100000 binary
REP  #$30    ; %00110000 binary
```

In the last paragraph, the text should read "...SEP #**$20** sets bit **5**, the *m* bit, to 1, thus setting the Accumulator ..." In the next sentence, the text should read "... REP #$30..."

Page 134: In the third paragraph, the last sentence should end: "... the 65816, i.e., the letter "A" followed by an inverse "@". Note that this program should be tested in the 40-column display mode."

Page 138: **REP and SEP: The Monitor vs. Merlin:** In Merlin 16, the instructions REP and SEP do not required the pound-sign ("#"). Thus, both REP #$20 and REP $20 are acceptable forms of the instructions. The dollar-sign ("$") *is* required to tell the assembler that the number is in hexadecimal notation. When using the Monitor to List (disassemble), however, you'll notice that the dollar-sign is not displayed. This is because the Monitor assumes all numbers shown (or entered in the Mini-Assembler) are in hex.

Page 146: "This gives the correct two-byte result of **$0310**, and is equivalent to..."

Page 152: Paragraph 4: Complementary angles are those two angles whose sum is **90 degrees**, not 180 degrees. Sigh...

Page 170: The two "ORA Value:" lines should read "**EOR Value**". The result of the second EOR operation for Example #2 is $83 = **1000 0011.**

Page 182: In Figure 10-2, the LDA instruction should appear in the form:

```
LDA  [$80],Y
```

Page 213: Between lines 16 and 17 of Program 11-1, the bytes for addresses $00030A-$00031F are data generated by the assembler for the ASC data on line 16, and should not be confused as text to be added by the reader. These bytes will not be tabbed as shown in the book into the assembler fields, but rather, will appear normally in the data area to the left during the assembly.

Page 214: Between lines 36 and 37 in Program 11-1, you should insert the instruction **CLC** in preparation for the addition operation. This will change the length of the assembled file to 93 bytes.

Page 230: Insert a line with the instruction **INY** just before the label LOOP in program 12-1.

Page 237: Second paragraph from the bottom, the reference to line 36 should instead refer to line **42.**

Page 251: The last paragraph should be ignored since all Merlin listings in the book using BRK $00, and thus give the same object file length and listing appearance as the APW assembler.

Page 259: Last paragraph, regarding local labels in Merlin: Local labels can be any label following a colon (example :LOOP), in addition to :1 through :9.

Page 261: The program example should use **AND #$DF**, not ORA #$DF.

Page 262: Paragraph 5: Reference to lines 69 through 74 should be **79 through 84**; reference to lines 69, 70 should be **79,80.**

Last paragraph: "..., (DS followed by a \) which...", *not* "...followed by a Z...". The very last line should read **DS** \, not DSZ.

Page 263: Paragraph 2, reference to "lines 76-83" should be **91-98.** "Lines 90-96" should be **100-106.**

Page 267: The label on line 147 should be **PARMTBL2;** the label on line 152 should be **PARMTBL3.**

Page 268: The byte displayed for location $00213E should be **$D0**, not $80. Line 175 should be **DS **, a Merlin command that defines a dummy block sufficient to fill to the next page boundary in memory. Line 158 was omitted from the listing, and should read:

```
 158        TR  ON          ; DON'T PRINT ALL HEX BYTES
```

Line 173 (the checksum) should have a value of **$F6**, with the changes made above.

Pages 266, 267: Although the program will work as listed, the error handling on lines 89 and 106 is not really correct. When an error occurs during the reading of a ProDOS file, the file should be closed as part of the error-handling routine. Therefore, a better design would be for the JSR ERROR on line 89 to be followed by a JSR RDKEY and a JMP CLOSE, similar to the lines **72-74** above. Short of writing an entire routine to ask the user to re-insert disks, etc., an error in trying to close the file (line 106) can be handled with a JSR RDKEY and JMP BEGIN, as is done on lines 72-74.

Page 275: Because of an early change to ProDOS 16, the listings shown in the book that access the keyboard and strobe locations no longer work unless they are done using long addressing. These programs will work with version 1.1 of ProDOS 16, but all later versions of ProDOS will require a change to the programs. In paragraph 3, the LDA KYBD should be **LDAL KYBD.**

Page 276: Lines 12-14 of Program 14-1 should be:

```
12  KYBD    EQU  $E0C000      ; KEYBOARD SOFTSWITCH
13  STROBE  EQU  $E0C010      ; KEYBOARD STROBE
14  SCREEN  EQU  $E00400      ; LINE 1 ON SCREEN
```

Line 27 of Program 14-1 should be **LDAL KYBD**. Because the BIT instruction does not have a long addressing form, line 31 should be replaced with **STAL STROBE**. If you get a Fatal System Error $110A when trying to run this program, it means you are using the original version of ProDOS 16 (v. 1.1). Merlin 16 defaults to the later versions, so to solve your problem you need only re-boot and try the program again with version 1.2 or later of ProDOS 16.

Page 277: The byte value displayed for the checksum (line 47) will be **$0A** after the changes above.

Page 278: Because the program listing shown is in the 8-bit mode, only a single INX instruction is needed in the LOOP part of the program. The comment after the first INX should read "NEXT CHAR".

Page 279: Lines 16-18 of Program 14-2 should be:

```
12  KYBD    EQU  $E0C000      ; KEYBOARD SOFTSWITCH
13  STROBE  EQU  $E0C010      ; KEYBOARD STROBE
14  SCREEN  EQU  $E00400      ; LINE 1 ON SCREEN
```

Line 31 should read **LDAL KYBD**; line 35 should be **STAL STROBE.**

Page 280: The checksum value in line 101 will be **$CC** after you make the changes above.

Page 281: Make sure that when entering the text for the Linker command file shown, that you have the opcodes TYPE, LINK, etc. in the opcode column, and not the label column. It is also *not* necessary to run the Linker.GS as indicated in the manual, since all versions of Merlin.16 default to loading the Linker.GS when it starts up.

Page 282: The instructions here are directed to assembling and linking program 14-1, the P16.SYSTEM program. The first paragraph after step 5 should read "To do the quick link, first load the P16.SYSTEM source file, and then immediately type NEW from the Command Box. Then type LINK with no specified pathname in the **Command Box** (O). Merlin will use the last name (P16.SYSTEM) as a source file and will automatically assemble and link the file. The final object file generated by the link..."

Pages 305-306: The descriptions of Bit 3 and Bit 4 of the shadow register are reversed. Bit 3 controls the Super Hi-Res area, and Bit 4 controls Auxmem.

Page 315: The labels COUT, HOME, KYBD, and STROBE on lines 7-10 are not used in the program, and as such are not needed in the program.

Page 316: Line 55 should read **BRA BOX**. The label on line 57 should be **SHUTDOWN**. The checksum for this listing will then be **$46**.

Page 317: Calling Tools from ProDOS 16: The reference to lines 29 and 32 in the second paragraph of the text should read **lines 29 through 32**.

Page 321: The label on line 54 should be **SHUTDOWN**.

Page 325: The example macro for _TLStartUp should read:

```
_TLStartUp  MAC
            LDX #$0201
            JSL $E10000
            EOM
```

In the interest of standardization, the Merlin 16 GS Tool Macro Library *does* use the underscore at the beginning of each tool name, contrary to the indication of the book.

Page 327: The third line of the PushWord macro should be:

```
            PEA   ]1
```

Page 328: Contrary to the second paragraph from the bottom, the macros in listing 16-5 are *not* expanded since the listing does use the Merlin 16 LST OFF and EXP OFF directives.

Page 329: Line 30 should read **LDA #^RESUME.**

Page 345: The Command Value for MMStartUp should be **$0202**, not $0102.

Page 347: Second paragraph of "Using the Memory Manager:" You do not *have* to set your RAM disk to 800K to hold all the pictures created. Only about 144K is really needed. It will also take 144K of system (non-RAM disk) memory to store all the pictures, so you will need at least 512K of expansion RAM for program 17-1 to work. Program 17-1 does not set the ProDOS prefix, so you will have to put the program file on /RAM5 (or wherever) with the pictures to be loaded.

Page 348: Line 9 of Program 17-1 should not have an asterisk (which makes the line a comment). Rather DSK should appear in the opcode column with MM.DEMO.P8 as the operand. Lines 25-28 are missing from the listing, and appear as follows:

```
25          LST  OFF              ; DON'T PRINT MACROS
26          USE  UTIL.MACS        ; USE MACRO.LIBRARY
27          LST  ON               ; LISTING BACK "ON"
28          EXP  OFF              ; DON'T EXPAND MACROS
```

Page 349: MMSTART on line 49 should begin with a **PushWord #$0000**, with the ToolCall $0202 on the next line. This will involve inserting a new line into the listing.

Page 354: The checksum on line 318 will be **$0B** after the changes above.

Page 355: In the first paragraph of text, the references to HGR should be **HGR2**. At the bottom of the page, the diagram for MMStartUp should have shown the requirement of pushing a word onto the stack as space for the result prior to doing the call.

Page 359: The Command Value for MTStartUp should be **$0103**; the value for MTShutDown should be **$0303.**

Page 361: The byte range indicated for the Minute value should be **0-59**, not 9-59.

Page 363: The opcodes **SEC** and **DEX** on lines 74 and 81 should be indented to the opcode column in the listing.

Page 376: The fourth paragraph text reference to the Color Value column should refer to **Master Value.**

Page 381: The comment on line 119 should read "CLEAR HIGH **BYTE**"

Page 392: The end of the second paragraph should inlude: "(Add enough spaces to the end of each message so that the single quote mark is directly below the letter "L" in the word "TABLE" on line 323.)

Page 395: On line 104, the semi-colon is *not* the beginning of a comment. The line should read:

```
MSSG2     STR  'Press keys; use "Q" to Quit'
```

The comment on line 134 should read "QUIT" KEY (HI BIT CLR)?

Page 396, 397: Note that for lines 200 and 204, there should be 2 spaces after each 0000. On page 397, there should be 4 spaces after Event: and 6 spaces after Type:

Page 399: The label on line 323 should be EVENTMSSG. Be sure to add enough spaces to each of the messages on lines 325-340 so that there are 16 characters *including* the 00 at the end. When entered properly, the closing quote for each message will line up with the "L" in "TABLE" on line 323.

Page 417, 418: Insert the instruction **TAX** (to transfer the value of the Acc. to the X-register) between the instructions ASL and JSR (MENTBL,X) on both pages.

Page 420: At the bottom of the page, the hexadecimal values for the characters in the Event Mgr. demo should be **$11, $12, $13** and **$14**.

Page 423: The last line on the page should refer to **NewMenu** in place of NewHandle.

Page 432: The RTS on line 215 should be in the opcode column, *not* the label column.

Page 436: Lines 420 and 421: the Z should be the \ character. On line 414, the comment should read "PUT WINDOW AT FRONT ($FFFF = -1)".

Page 438: Merlin 16 uses Open-Apple-**Y** to select to the end of the listing, not Open-Apple-Q.

Page 439: In the second paragraph, the first sentence should end "... called SPECIAL, which consisted of nothing more than an **RTS.**"

Page 441: On the lines with XMSG and YMSG, there should be 4 spaces after the 1st 0000, and 2 spaces after the 2nd 0000.

Page 452: In the source listing, the third line from the bottom should have a second **INY** instruction added, so that there are two INY's. (needed to increment two bytes forward).

Page 452, 453: The ERASE routine has a bug in it. The DOCSETUP routine calls ERASE in order to erase the window. The ERASE routine fills the memory occupied by the window region with color #14 and then adds the rectangle to the current update region (causing the system to redraw it during the next call to TaskMaster). This works fine when ERASE is picked from the menu because the window has already been created... however, when DOCSETUP calls ERASE, the window has not been created yet, causing the GetPortRect and InvalidRect calls to lead to unexpected results (a.k.a. system crashes).

In order to fix this bug, change the label ERASE to ERASE2, and the JSR ERASE in DOCSETUP to JSR ERASE2. Finally, move the four lines above the RTS at the top of page 453 (PushLong #WINRECT, ToolCall $2004, PushLong #WINRECT, ToolCall $3A0E) *above* the new label ERASE2 and place the label ERASE on the first PushLong statement.

The final chunk of code should look like this:

```
********************************

ERASE   PushLong  #WINRECT        ; POINTER TO WINDOW RECTANGLE
        ToolCall  $2004           ; GetPortRect
                                  ; MAKE WINRECT = WINDOW

        PushLong  #WINRECT        ; THE WINDOW RECTANGLE
        ToolCall  $3A0E           ; InvalidRect
                                  ; FORCE TASKMASTER TO UPDATE

ERASE2  PushLong  PICHNDL
        ToolCall  $2002           ; HLock
                                  ; MAKE SURE IT DOESN'T MOVE

        LDA       [PICHNDL]       ; LONG INDIRECT LOAD
        STA       PTR             ; GET THE MEM ADDRESS
        LDY       #$02
        LDA       [PICHNDL],Y
        STA       PTR+2           ; (PTR) = ADDR. OF PICTURE

CLR     LDA       #$EEEE          ; CLEAR BLOCK OF MEMORY TO COLOR #14
        LDY       #$0000          ; BEG. OF BLOCK
```

```
:1      STA       [PTR],Y
        INY
        INY
        CPY       #32000          ; DONE YET?
        BCC       :1              ; NOPE

UNLOCK  PushLong  PICHNDL
        ToolCall  $2202           ; HUnlock

        RTS

*********************************
```

Page 454: The tool calls SetPenSize and SetSolidPenPat work with the current port. In order to change the pen size and color in the drawing window, we must set make that window's GrafPort current. So, before the line with the label SETPEN, insert these two lines:

```
     PushLong  WPTR       ; SET PORT TO OUR WINDOW
     ToolCall  $1B04      ; SetPort
```

Page 466: With the changes above, the checksum for the new sketcher program will be **$96**, not $05.

Page 485: The hex byte for the BCC opcode should be **$90**, not $6D.

Page 497: The Addressing Modes examples for BRL should be:

	Common	**Hex**
Mode	**Syntax**	**Coding**
Relative Only	`BRL LABEL`	**82 FF FF**
	`BRL $FFFF`	**82 ff ff**

Page 518: In the example program segment, there should be a **TAX** instruction after the ASL and before the JMP (CMDTBL,X).

Page 520: In the example program segment, there should be a **TAX** instruction after the ASL and before the JMP (CMDTBL,X).

Page 525: In the odd/even example program segment, EVEN and ODD are reversed. It should read BCS ODD and BCC EVEN.

Page 526: In accordance with the expressed preference of Apple Computer, the assembler syntax for the MVN and MVP instructions should be revised to reflect the requirement for a complete label as the operand for these instructions. Although the instruction itself only encodes the source and destination bank bytes, the assembler requires that the complete address be used. There is also an error in the hex code shown for the MVP instruction. Thus, the Addressing Mode Available chart should appear as follows:

	Common	**Hex**
Mode	**Syntax**	**Coding**
Implied Only	MVN **LABEL1, LABEL2**	54 00 FF
	MVP **LABEL1, LABEL2**	**44** 00 FF

and the last line of the program segment on page 527 should read as:

```
            MVN SRCE,DEST    ; SOURCE AND DEST. ADDRESSES
```

Page 530: ORA can also be used to convert upper case letters to lower case:

```
ENTRY      LDA  CHAR       ; GET CHARACTER
           CMP  #$C1       ; "A" - ASSUMES HIGH BIT ASCII
           BCC  DONE       ; LESS THAN "A"
           CMP  #$E0       ; 1ST LOWER CASE LETTER
           BCS  DONE       ; GREATER OR EQUAL
XVERT      ORA  #$20       ; SET BIT 5: UC -> LC
           STA  CHAR       ; PUT CHAR BACK
DONE       RTS
```

Page 531: The Addressing Modes examples for PEA should be:

	Common	**Hex**
Mode	**Syntax**	**Coding**
Immediate Only	PEA **$FFff**	F4 **ff FF**

Page 533: The Addressing Modes examples for PEI should be:

	Common	**Hex**
Mode	**Syntax**	**Coding**
Indirect Only	PEI **($ff)**	D4 **ff**

Page 534: The Addressing Modes examples for PER should be:

	Common	**Hex**
Mode	**Syntax**	**Coding**
Relative Only	PER **$FFff**	62 **xx XX**

The first line of the PER example should read:

```
8000: 62 03 00          PER  LABEL    ; XVRTED TO 3 BY ASSEMBLER
```

In addition, the first paragraph after the example should read "The microprocessor will take the relative offset of **3** (the operand of the PER instruction), add this to the program counter for the next instruction ($8003), and push the result (**$8006**) on the stack."

Page 553: RTI is equivalent to:

```
PLP
RTS (or RTL)
```

in that the status register is restored from the stack, and a return (RTS or RTL, depending on the processor status) is done using the address remaining on the stack.

Page 590: The correct syntax for the Pattern Search command is as follows:

```
\"A"\<1234.5678P
\25\<1234.5678P
\"ABCD"\<1234.5678P
\25 7F 3E\<1234.5678P
```