Programming the Apple IIgs™
in C and Assembly Language

Mark Andrews
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Programming the Apple IIgs™
in C and Assembly Language

Mark Andrews
with
Michael Halpin

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Introduction

The Apple IIgs is two computers in one, and this book is about both of them. It’s also about the two most powerful programming languages for the Apple IIgs: assembly language and C.

Apple calls the IIgs a two-in-one computer because it runs most software written for earlier Apple IIs, yet offers today’s computer user a host of brand new Macintosh-like features—plus full color—at an Apple II price.

This book is a two-in-one book, twice over; it teaches you how to program the IIgs in both of its operating modes—8-bit emulation mode and 16-bit native mode—and it teaches you to do that in two languages—assembly language and C.

If you want to learn to program both of the computers built into the IIgs—in C, assembly language, or both—this is the book you are looking for.

In plain English, and with the help of many, many figures and tables, this book introduces you to the IIgs from the ground up: how it’s laid out, how its microprocessor works, and how it is different from—and similar to—other computers in the Apple II family. After that ground has been covered, you learn how to start programming the Apple IIgs in assembly language and C.

What This Book Can Do for You

If you’ve written programs in BASIC, Pascal, or any other programming language, this book is all you need to start programming the Apple IIgs in assembly language. If you’re an experienced assembly language programmer, you can learn how to expand your knowledge to include all the new and special features of the Apple IIgs. If you’re primarily a C programmer, you can learn how to deal with all the IIgs’s new features in programs written in C.
This book is also an asset to assembly language programmers who would like to start saving time by including C routines in their programs and to C programmers who would like to streamline and speed up portions of their programs by learning some assembly language. If either of these possibilities appeals to you, you'll be happy to learn that the software development system used to write the programs in this book, the Apple Programmer's Workshop (APW), makes it easy to combine routines written in assembly language and C—and this book teaches you how.

What You Can Find in These Pages

As you read this book, and type and run the many example programs, you may notice that

- Unlike many books on C and assembly language programming, it is written in English, not computerese, and is designed for people who want to learn to program, not just for professional programmers and engineers (though some of them will find it useful, too).

- It includes a complete course on how to use the Apple IIgs Toolbox, a set of built-in assembly language subroutines that distinguish the IIgs from all previous Apple IIIs. The Toolbox is what provides the IIgs with such spectacular graphics features as windows, pull-down menus, icons, and mouse-controlled commands. This book teaches you how to use most of the tools in the Toolbox, in both C and assembly language.

- It is packed with what almost every computer book could use more of: type-and-run programs that do far more than illustrate the points being discussed. They are designed to put the IIgs through its paces as you learn how it works. When you finish this book, these programs form a useful library of commonly used Apple IIgs routines.

What You Can Learn

By the time you finish this book, you'll also know how to

- Program the Apple IIgs's 65C816 chip in assembly language, in both its 8-bit emulation mode and its 16-bit native mode. Part 1 covers the fundamentals of Apple IIgs programming. Most of the programs in this segment are written in emulation mode. In part 2, you can pull out all the stops and learn how to program the IIgs in its full 16-bit native mode.
What You Need

To use this book, you need an Apple IIgs with at least two 3.5-inch disk drives, a monochrome or color monitor, and at least 512K of extra memory. A hard disk, a 1-megabyte RAM disk, and at least another 512K of extra memory are highly recommended.

As you advance in your knowledge of IIgs programming, a few books besides this one might come in handy. Two works that every serious IIgs programmer should own are the Apple IIgs Toolbox Reference and the Apple IIgs ProDOS 16 Reference, both written at Apple and published by Addison-Wesley. The Apple IIgs Toolbox Reference is a particularly important work because it explains exactly how to use every tool in the IIgs Toolbox in programs written in both assembly language and C.

Three other books that are required reading for IIgs programmers are the Apple IIgs Programmer's Workshop Reference, the Apple IIgs Programmer's Workshop Assembler Reference, and the Apple IIgs Programmer's Workshop C Reference, which were also written at Apple and published by Addison-Wesley. Many other books that you might find useful or interesting are listed in the Bibliography.

Ready, Set, Go!

If you've read this far, it's a safe bet that you're at least a little bit interested in learning how to program the Apple IIgs in C, assembly language, or both. There's no better time to begin than right now. So turn the page and start from the top—with chapter 1.
Acknowledgments

Many thanks to Eagle I. Berns, Steve Glass, Loretta Barnard, Kevin Armstrong, Brent Olson, David D. Good, Greg Borovsky, Eric Ford, Anil Gurssahani, Ray Hughes, Brian Hurley, Dennis Kudo, and Alireza Latifi, all of Apple. Without their help and patience, this book could not have been written.

To Swami Muktananda
PART 1

Fundamentals of Apple IIgs Programming
What do you get when you cross an Apple Macintosh with an Apple II? When hardware engineers at Apple Computer attempted that feat, they came up with the Apple IIgs—a remarkable new personal computer that offers Macintosh-like features at an Apple II price, with super high-resolution graphics and spectacular sound thrown in as part of the bargain.

An Apple II—Plus!

The specifications of the Apple IIgs are not quite the same as those of the Apple Macintosh. For example, the IIgs uses a 65C816 microprocessor, but Macintosh computers are built around chips of the 68000 family. Also, the IIgs has a different type of screen display. The IIgs generates a color video display with a screen resolution of either 320-by-200 pixels or 640-by-200 pixels, depending on the graphics mode. The Macintosh Plus and the Mac SE produce black-and-white displays that measure 512-by-342 pixels. Table 1–1 lists the most important specifications of the Apple IIgs.

There are other differences between the IIgs and the Macintosh. One difference, immediately apparent to a potential computer purchaser, is that a Mac, even a low-end model, is considerably more expensive than a IIgs.
<table>
<thead>
<tr>
<th>Feature</th>
<th>Specifications</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPU</td>
<td>65C816</td>
<td>16-bit microprocessor with 24-bit (16 MHz) addressing capability. 6502 and 65C02 compatible.</td>
</tr>
<tr>
<td>Operating speeds</td>
<td>2.8 MHz and I MHz</td>
<td>Selectable dual operating speeds provide compatibility with earlier Apple IIs.</td>
</tr>
<tr>
<td>Memory capacity</td>
<td>256K RAM, 128K ROM</td>
<td>RAM expandable to 8.25 megabytes. One megabyte of memory available for ROM expansion.</td>
</tr>
<tr>
<td>Desktop user interface</td>
<td>Mouse, windows, pull-down menus</td>
<td>Macintosh-like programming and user environment.</td>
</tr>
<tr>
<td>Mouse</td>
<td>Two button</td>
<td>Connects with IIgs by ADB (Apple Desktop Bus) cable.</td>
</tr>
<tr>
<td>Toolbox</td>
<td>In RAM and ROM</td>
<td>Toolbox contains more than 800 prewritten routines that can be used in application programs.</td>
</tr>
<tr>
<td>Keyboard</td>
<td>78 keys</td>
<td>Detached keyboard has built-in numeric keypad and can be used to type in foreign languages.</td>
</tr>
<tr>
<td>Monitor outputs</td>
<td>RGB and NTST</td>
<td>Can be used with analog RGB monitor, composite monitor, or TV (with modulator adaptor).</td>
</tr>
<tr>
<td>Text modes</td>
<td>40 column and 80 column</td>
<td>Text modes measure 40 columns by 24 lines and 80 columns by 24 lines. Border, foreground colors, and background colors are user-selectable.</td>
</tr>
<tr>
<td>Graphics modes</td>
<td>Apple II modes and super high-resolution mode</td>
<td>All Apple IIc and Ile graphics modes, plus super high-resolution mode.</td>
</tr>
<tr>
<td>Resolution</td>
<td>320-by-200 pixels, 640-by-200 pixels</td>
<td>Two screen resolutions offered in super high-resolution mode.</td>
</tr>
<tr>
<td>Colors</td>
<td>4,096</td>
<td>4,096-color palette available in super high-resolution mode; 16 or more colors can be displayed simultaneously.</td>
</tr>
<tr>
<td>Sound</td>
<td>32-oscillator synthesizer</td>
<td>Ensoniq synthesizer supports 15 independent voices. Sound chip includes 64K of dedicated RAM for storing sound patterns.</td>
</tr>
<tr>
<td>Enhanced monitor</td>
<td>Built into ROM</td>
<td>Handles 24-bit addresses. Includes mini-assembler and I/O routines. Can perform hex math.</td>
</tr>
<tr>
<td>BASIC</td>
<td>Applesoft</td>
<td>Enhanced BASIC interpreter built into ROM.</td>
</tr>
<tr>
<td>Control panel</td>
<td>Built-in desk accessory</td>
<td>Can be used to set display parameters, slot and port use, operating speed, RAMdisk, and disk drives.</td>
</tr>
<tr>
<td>Clock</td>
<td>Built in</td>
<td>Provides time and date.</td>
</tr>
<tr>
<td>Serial ports</td>
<td>Two built-in serial ports</td>
<td>Support modems, printers, and AppleTalk. Serial card can also be installed.</td>
</tr>
<tr>
<td>AppleTalk</td>
<td>Uses one serial port</td>
<td>AppleTalk can be used with either serial port. No peripheral card required.</td>
</tr>
<tr>
<td>Disk port</td>
<td>Disk I/O port uses custom IC</td>
<td>Up to six disk drives can be supported by built-in port, or plug-in cards, or both.</td>
</tr>
</tbody>
</table>
Another difference, not quite so obvious but as important from a programmer’s point of view, is that the Mac and the IIGS don’t “speak” the same machine language. The Mac has a 32-bit microprocessor designed to be programmed in 68000 assembly language. The main microprocessor in the IIGS, the 65C816, is a 16-bit successor to the 8-bit 6502 and 65C02 chips in older Apple IIs. (The difference between an 8-bit chip and a 16-bit chip is covered in chapter 5.) Furthermore, the memory of the Macintosh is laid out as one continuous bank, but the memory map of the IIGS is broken into 64K banks, like the memory map of an Apple IIc or an expanded Apple IIE. The memory architecture of the Apple IIGS is covered in chapter 4.

Because of the Apple IIGS’s 6502-family microprocessor, color display, IIc and IIE compatibility, and Apple II heritage, it is actually related more closely to earlier members of the Apple II than to the Mac (although it is something of a Mac lookalike). Nonetheless, the IIGS is much more than just a souped-up Apple II.

“Like Janus, the god of doorways,” one Apple spokesman explained, “the IIGS looks in two directions.” First, he pointed out, the computer looks toward the future: “With its many high-performance features—such as its improved color display, advanced sound system, 16-bit processor, and larger memory, it makes it possible for more powerful programs to be designed.” But, he emphasized, it also “looks back on the past. Because it also has the features of earlier members of the Apple II family, it can run most of the vast library of software that was written for its predecessors, such as the Apple IIc and the Apple IIE.”

The IIGS, in its forward-looking stance, is a new breed of Apple II, operated in a Macintosh-like desktop environment—complete with a super high-resolution screen, icons, pull-down menus, desk accessories, and a mouse. To make life easier for the programmer who wants to use these new features, the IIGS comes with a fully equipped Toolbox—an enormous library of prewritten routines that are easily incorporated into user-written programs. With the Toolbox, programmers working in high-level languages such as C,
assembly language, Pascal, and even BASIC can make use of windows, menus, icons, and the rest of the IIGS desktop environment without writing the code from scratch. With the help of the Toolbox, it is easier to write sophisticated, eye-catching programs for the IIGS than it is to write simpler programs for earlier Apple IIs.

The main features of the IIGS Toolbox are described in detail in part 2, which begins with chapter 7. Important tools in the Toolbox are covered individually, beginning in chapter 7.

**Memory Magic**

Of all the remarkable features of the IIGS, the one probably most welcome to programmers is the IIGS’s prodigious memory capacity. The computer comes with 256K of RAM and 128K of ROM—a far bigger supply of memory than the 128K of RAM and 32K of ROM built into its most recent predecessor, the Apple IIc. You can expand the generous amount of RAM supplied with the IIGS to as much as 8.25 megabytes with the simple addition of a plug-in card.

The huge memory capacity of the IIGS is made possible by the addressing capabilities of its 65C816 microprocessor. As you will see in chapter 4, the 65C816 has 24-bit addressing capability, giving it a total memory space of 16 megabytes. Of this total, 8.25 megabytes are available for RAM expansion and 1 megabyte is available for ROM expansion.

The memory of the IIGS is mapped out in detail in chapter 4. In chapter 6, which is devoted to the addressing modes of the IIGS, you’ll see how the IIGS addresses memory.

**24-Bit Addressing**

The Apple IIGS as an Apple II

Because the IIGS is compatible with earlier Apple IIs, its memory layout can be used in two ways: in a mode that emulates earlier Apple IIs or in a mode that takes full advantage of the computer’s memory capacity. When the IIGS is in Apple II emulation mode, only 128K of memory is used, and that 128K is laid out like the main and auxiliary memory banks of a IIc or IIe. Figure 1–1 is a map that shows how the memory of the Apple IIGS is organized when it is operated in Apple II emulation mode.

The IIGS in Native Mode

When the IIGS is in native mode, another 128K of RAM and a full 128K of ROM are added, along with whatever additional memory is installed. All this added memory is available for use in application programs, except for a few areas in low memory claimed by ROM addresses, operating system RAM, sound and video RAM, and system I/O memory. Figure 1–2 is a map that shows the memory architecture of a IIGS system running in 16-bit native mode.

The Memory Manager

One new feature of the IIGS is that all memory-related operations can be handled by a special tool called the Memory Manager. The Memory Manager is active when the IIGS is booted and, from that moment on, is in complete control of the computer’s memory. It can allocate, deallocate, and compact
1—Introducing the IIGS

Figure 1–1
Memory map of the IIGS in IIC/Ile emulation mode

Figure 1–2
Memory map of the IIGS in 16-bit native mode
memory while application programs are running, taking most of the burden of memory management off the programmer. The memory architecture of the IIgs and the role of the Memory Manager are discussed in more detail in chapter 4.

**Faster than a Speeding Apple II**

In addition to a larger memory capacity, the IIgs runs faster than earlier members of the Apple II family. The IIgs’s 65C816 processor operates at 2.8 MHz, almost three times as fast as the 1 MHz speed of the 6502 and 65C02 chips in the IIe and IIc. But the 65C816 can also be set to run at the same speed as a 6502 or 65C02. Because of this dual-speed capability, the IIgs can run most of the vast library of software for earlier Apples. You can experiment with operating speeds. Many programs designed for earlier Apples can be run on a IIgs at either the 1 MHz speed they were designed for or the IIgs’s native clock speed of 2.8 MHz. This can add new challenges to arcade-style games designed for earlier Apples. On a IIgs, some games can be accelerated to almost three times their speed on earlier Apple IIs.

Besides the 65C816 chip’s faster speed and expanded memory addressing capability, it has a bigger and more powerful set of internal registers. Its accumulator, X register, and Y register are expanded from 8 bits to 16 bits. It also has three new registers: an 8-bit data bank register, an 8-bit program bank register, and a 16-bit direct page register. Other features of the 65C816 include 11 new addressing modes and 36 new assembly language instructions, for a total of 24 addressing modes and a total vocabulary of 91 assembly language mnemonics. These new features are examined in chapter 5.

**GS: Graphics and Sound**

The IIgs has many other special features. Two attributes are so important that the computer was named after them: the g in IIgs stands for *graphics* and the s stands for *sound*. So let’s pause for a closer look at the graphics capabilities of the IIgs and a brief glance at the IIgs world of sound.

**IIgs Graphics**

The IIgs can handle both text modes and all three graphics modes of its most recent predecessors, the IIc and the IIe. Like the IIc and the IIe, the IIgs has two text modes. It can produce a 40-column, 24-line text screen, which is displayed on an ordinary television screen, or an 80-column, 24-line text screen, which requires a high-resolution color or monochrome monitor. The IIgs’s three graphics modes are like those in the IIc and the IIe: a low-resolution mode, a high-resolution mode, and a double high-resolution graphics mode with a 16-color palette and a screen display 560 dots wide by 192 dots high.

But these three graphics modes—designed for earlier Apples and built into the IIgs primarily for compatibility—are not the modes for which the Apple IIgs is named. Besides the three graphics modes in the IIc and the expanded IIe, the IIgs has two new graphics modes called super high-
resolution modes. One of these, 320 mode, has a screen display that measures 320 dots wide by 200 dots high. The other, 640 mode, has a 640-by-200 dot display. In super high-resolution graphics mode, a palette of 4,096 colors is available, and up to 16 colors—or even more, with interrupts—can be displayed simultaneously.

Both of the graphics modes native to the IIgs are produced by a large-scale integrated (LSI) video chip called the video graphics controller, or VGC. The VGC can generate 4,096 colors and, with video interrupts, can simultaneously display up to 256 colors on the screen. Without using interrupts or other special techniques, the VGC can display up to 16 colors at a time in 320 mode and up to 6 colors at a time (including black and white) in 640 mode. With a color-interleaving system called dithering, a 640-mode screen, like a 320-mode screen, can display up to 16 colors at a time. More details about IIgs graphics—and a collection of type-and-run graphics programs—are presented in chapter 8.

IIgs Sound

In addition to spectacular graphics, the IIgs has sensational sound. Computer critics have raved that the IIgs has the finest sound system of any computer in its class.

The IIgs owes its sonic superiority to a 15-voice, 32-oscillator integrated circuit called the digital oscillator chip, or DOC. The DOC is manufactured by Ensoniq and used in their line of professional sound synthesizers. The chip has 64K of independent RAM and can generate waveforms from digital samples stored on a disk and loaded into its memory. So it can produce multivoice music and other kinds of complex sounds without tying up the IIgs's main microprocessor.

The IIgs sound system includes another custom chip called a general logic unit, or GLU. The GLU chip is a system interface with the DOC. This enables the IIgs to produce sound in two ways: with its DOC chip or with a simple, switch-controlled circuit that produces notes, tones, and beeps in the manner of earlier Apple IIs.

The IIgs sound system, like most of the computer's other new features, is designed to be programmed with the help of the IIgs Toolbox. The sound-producing capabilities of the Apple IIgs are described in more detail in chapter 13.

A Closer Look at the Toolbox

In the earliest models of the IIgs, parts of the Toolbox were built into ROM and parts were included on a system disk. In later models, as the design of the Toolbox became more solid, tools originally included on the system disk were moved into ROM. From a programmer's point of view, it ordinarily doesn't matter whether a given IIgs tool is built into ROM or provided on a system disk and loaded into RAM when needed (except that tools in ROM load and work faster). That's because the Toolbox includes a special tool-finding and tool-loading program called the Tool Locator. The Tool Locator
can automatically find any tool—in ROM or RAM—and then load that tool into memory.

After a tool is found and loaded by the Tool Locator, it can be incorporated into an application program by calling an assembly language macro—if the program is written in assembly language. C programs call Toolbox functions using standard C calling functions.

The Apple IIgs Programmer’s Workshop (APW), the software package used to write and assemble the assembly language programs in this book, comes with a library of macros that make it easy to include Toolbox macros in application programs. There’s more about macros in chapters 3 and 7. The APW C compiler, which was used to write and compile the C programs in this book, has an interface library that allows Toolbox functions to be incorporated into C programs. There’s more about that in chapter 3.

The APW assembler is introduced in chapter 2, and the APW C compiler makes its first appearance in chapter 3. Most of the assembly language programs in part 2 contain calls to APW Toolbox macros. Most of the C programs use Toolbox functions in the APW C interface library.

Opening the Toolbox

The Apple IIgs Toolbox contains a large assortment of useful prewritten routines. Five of these tools are of primary importance. Apple refers to them as the “Big Five.” These five major tools are

- The Tool Locator. Details about the Tool Locator are presented in chapters 3 and 7.
- The Memory Manager. The Memory Manager is covered in more detail in chapter 7.
- QuickDraw II, which handles graphics and drawing routines. QuickDraw II, modeled after the QuickDraw tool set for the Apple Macintosh Toolbox, is examined in chapter 8.
- The Event Manager, which handles mouse operations and determines what the IIgs does in response to various moving and clicking operations that involve the mouse. The Event Manager is covered in chapter 7.
- The Miscellaneous Tool Set, which—despite its unimportant-sounding name—is vital to the operation of the IIgs. The Miscellaneous Tool Set handles low-level mouse operations, firmware interrupt operations, access to the RAM that is backed up by the built-in battery, reading and setting the computer’s built-in clock, and many other important functions. The Miscellaneous Tool Set contains so many different kinds of tools that it is not covered in a chapter of its own, but is referred to as required in part 2.

The other tools in the IIgs Toolbox are
• The Menu Manager, which is used to create and control pull-down menus. The Menu Manager is the subject of chapter 7.

• The Window Manager, which takes care of the document and picture windows displayed by application programs. With the help of the Window Manager, you can place multiple windows on the screen. You can also scroll, shrink, expand, and drag windows, and place windows in front of and behind other windows on the screen. You get a close look at the Window Manager in chapter 10.

• The Dialog Manager, which handles alert dialogs—text windows that warn of impending danger—and boxes that let you choose functions by activating controls (such as scroll bars and pushbuttons) displayed on the screen. The Dialog Manager is examined in chapter 11.

• The Control Manager, which handles scroll bars, buttons, and all other kinds of onscreen controls used by tools such as the Window Manager and the Dialog Manager.

• The Font Manager, which controls the selection, loading, styling, displaying, and printing of character fonts.

• The LineEdit Tool Set, which handles keyboard text input when the IIgs is in super high-resolution graphics mode.

• The Text Tool Set, which handles keyboard text input when the IIgs is in 40-column or 80-column text mode. The Text Tool Set is introduced in chapter 3.

• The Scrap Manager, which manages cut-and-paste operations.

• The Standard File Operations Tool Set, which works with ProDOS 16 to create dialog windows that load and save disk files. The Standard File Operations Tool Set and ProDOS 16 are covered in chapter 12.

• The List Manager, which handles lists displayed on the screen when the IIgs is in super high-resolution display mode. The List Manager is used by higher-level tool sets such as the Standard File Tool Set and the Font Manager. It is also available for use by application programs.

• The Print Manager, which interfaces the IIgs to a variety of printers, including dot-matrix graphics printers such as the ImageWriter and laser printers such as the LaserWriter.

• QuickDraw Auxiliary, which adds some tools—and more graphics power—to QuickDraw II.

• The Integer Math Tool Set, which can make life easier for the designer of mathematically oriented programs. With the help of the Integer Math Tool Set, a program can easily handle mathematical operations ranging from simple integer addition to complex trigonometric functions.
The Standard Apple Numerics Environment (SANE), which includes a library of more advanced arithmetic and mathematic operations.

The Sound Tool Set, which controls both the old-fashioned switch-style sound system of the IIGs and the computer’s newer supersophisticated digital oscillator chip (DOC) sound synthesizer. Instructions for programming the Sound Tool Set, and some type-and-run routines that put it through its paces, are presented in chapter 13.

The Desk Manager, which controls the operation of desk accessories—mini-applications that can be run at any time without interfering with application programs.

The Scheduler, which delays the activation of desk accessories and other applications until the resources they need are available.

The Apple Desktop Bus (ADB), a tool for connecting input devices such as the keyboard, the mouse, graphics tablets, and game controllers to the Apple IIGs.

The disk operating system used by the IIGs is ProDOS 16. ProDOS 16 is a 16-bit descendent of ProDOS 8, the IIc and IIe operating system. The IIGs can run programs written under ProDOS 8, ProDOS 16, and even Apple DOS, the operating system that preceded ProDOS 8. To help programmers use ProDOS effectively, the IIGs Toolbox includes a Standard File Manager, which is covered in chapter 12.

What Happens When You Turn It On

When you turn on the IIGs and boot the system disk, the first thing you see depends upon how much memory your IIGs has. If it has 512K of memory or more, you’ll see the IIGs Finder—a screen patterned after the opening screen of the Apple Macintosh, but displayed in full color. If your IIGs has less than 512K of memory, the startup screen will be a Program Launcher—a plainer looking display that does not have all the features of the Finder, but does allow you to select and run programs with a mouse. If you have 512K of memory and still see a Launcher display, your system disk is not a Finder disk, which now comes with every Apple IIGs, but a Launcher disk, which was packed with the first IIGs computers and is now outdated. Early IIGs disks were missing some tools, had bugs in others, and thus won’t work with some of the programs in this book. So, if you have a Launcher disk instead of a Finder disk, please see your Apple dealer. Figure 1–3 is an illustration of the Finder disk’s screen display. On the opening screen of the Finder disk, the Apple IIGs displays icons, or small pictures, representing various components in the system. On the Finder screen, each 3.5-inch disk in a disk drive is represented by an icon that looks like a 3.5-inch disk. If your system includes a hard disk, a RAM card, or a hard disk drive, those are represented by icons too.
From the IIgs Finder disk, you can load, or launch, any executable program stored on a disk. For example, you can use the Launcher to load the APW assembler-editor system, the APW C compiler, or programs you have created using the APW system.

**The User Environment**

Much has been written and said about the new era in personal computing that began with the introduction of the Apple Macintosh. By offering the personal computer user a new type of user environment—featuring such innovations as windows, pull-down menus, icons, and the mouse—the Apple Macintosh started such a revolution in desktop computing that even IBM was finally forced to incorporate Mac-like features in its personal computer line.

The secret behind the success of the Macintosh—and the IIgs—is *event-driven programming*. In the pre-Macintosh era, computers were designed to operate under a system called *sequential programming*. If pre-Mac computers were difficult to understand and easy to hate, it was largely because of the sequential design of their programs. When a program is written in a sequential fashion, it presents the user with an onscreen prompt and expects the user to type in something. If the user types in a response that the computer considers acceptable, the computer goes to another part of the program it is running—
that is, into another mode. At that point, the user might be presented with another menu, forcing a choice that puts the program into still another mode.

To get from one kind of operation to another, the user of a sequentially designed program usually has to move up or down through a hierarchy of menus, often having to pass through one mode to get to another. This approach puts the computer in charge of the user and often makes the user feel subservient, intimidated, and even angry at the machine.

Event-driven programming, in the hands of a skilled programmer, can reverse this scenario and make the computer the servant of the user. The main characteristic of an event-driven program is that it is modeless. When an event-driven program is executed, the computer can do just about anything the program allows at just about any time, without the user having to switch modes or move through a hierarchy of menus.

The IIgs—with its pull-down menus, windows, and icons—is very much at home with modeless, event-driven programs. In a typical IIgs program, you are first presented with a menu. With the help of a mouse, you can then select a menu option. If you make a mistake while running an event-driven program, the program (if it is well-written) courteously indicates the mistake and suggests an alternate approach. This style of programming makes you the master and the computer the servant—which, of course, is the way things ought to be.

So it is not difficult to see why computers programmed in the old-fashioned sequential style have been the targets of so much wrath and why event-driven computers like the Mac have become so popular—among program designers and users. All the programs in part 2 are event-driven programs, and more about event-driven programming is presented in chapter 9.

To support event-driven programming, a computer needs a host of features that were unavailable in the computers of yesteryear. The IIgs, like the Macintosh, has all the features needed to make event-driven programming possible: windows, pull-down menus, icons, dialog windows that enable the user to communicate with the computer, and the mouse. Because of these features, the "feel" of the IIgs is similar to the feel of the Mac—although a few features of the venerable Apple II line have also been thrown in so that the computer's Apple II heritage is not forgotten.

The goal of this book is to help you learn to program the IIgs in the way it was meant to be programmed—using its mouse-controlled, event-driven, user environment. You'll do that using both assembly language, which is fast but not easy to master, and C, which is a little slower (though still light-years ahead of BASIC) but considerably easier to learn and quite a bit easier to manage.

In this chapter, you looked at the Apple IIgs, some of its principal features, and its most important programming tool, the IIgs Toolbox. In chapter 2, you start programming the IIgs in assembly language. In chapter 3, you start writing some C programs.
CHAPTER 2

Programming the IIgs in Assembly Language

*Using the APW Assembler*

If you've written assembly language programs for an Apple II, but haven't done any assembly language programming for the Apple IIgs, you're in for a big surprise. Programs written for the IIgs run faster, offer more sophisticated graphics and sound capabilities, and—best of all, from a programmer's point of view—can use more than 800 prewritten routines built into the Apple IIgs Toolbox. Some of the tools in the IIgs Toolbox are built into ROM and others are loaded into RAM when you boot the computer's system disk. But they're all available for use at any time in application programs.

**The APW Assembler-Editor**

The Apple IIgs Programmer's Workshop (APW), which was used to write most of the assembly language programs in this book, comes with a library of macros that make it quite easy to use the IIgs Toolbox in user-written programs. APW was created by the Byte Works Inc., a small company in Albuquerque, New Mexico, and is marketed by Apple. It is the first assembler-editor package offered solely for the Apple IIgs, and it is designed with all the IIgs's advanced features in mind.
The APW Package

Apple calls the APW package "a development environment for the Apple IIgs computer." It contains

- A shell that enables the IIgs programmer to run programs and use many useful file management and utility functions.
- An editor that can be used to write assembly language programs, C programs, executable shell files (exec files), and text files.
- An assembler that converts, or assembles, assembly language programs into machine language programs.
- A linker that converts machine code files produced by the APW assembler or C compiler into load files—files the IIgs system loader can load into memory. Briefly, here’s how the linker works. When a program is written using the APW assembler or the APW C compiler, it is stored in memory in a format called object module format, or OMF. Before an OMF file can be executed, however, it must be linked, or converted into a format that the system loader can load into memory. The process of converting OMF files into linked files, or loadable and executable files, is the job of the APW linker. To create a linked file, the linker resolves external references (references in one program segment to routines or data in another). The linker then creates relocation dictionaries that the system loader uses to relocate code as needed when it is loaded into memory.
- A generous selection of utility programs that perform many functions. These programs format disks, copy files and disks, catalog disk directories, assemble and link assembly language programs, disassemble machine code and display it as source code, display the contents of memory, and much more. (It is beyond the scope of this book to examine the APW system’s utility programs in detail.)
- An optional C compiler that converts, or compiles, C programs into executable machine language programs.
- An optional debugger that helps programmers correct assembly language programs.

A Warning

Before we go into any more detail about the APW development system, it should be pointed out that the version of the system available at this writing may not be exactly the same as the one you’re using. The APW development system evolved from the ORCA/M assembler, which was designed long before the advent of the Apple IIgs, and the evolution of the APW system is still continuing. When this book was written, APW was a text-oriented system that did not use the sophisticated graphics or event-driven programming capabilities of the Apple IIgs. By the time you read this, APW may have evolved into a super high-resolution program with windows, pull-down menus, and mouse controls. If that’s the kind of APW system you have, some of the information in the following paragraphs won’t apply because
Using the APW Shell

When you use the APW system to write an assembly language program, the system’s shell provides the interface that allows you to execute APW commands and programs. When you are writing a program, for example, you can activate the APW editor and assembler by typing shell commands. You can also use the shell to perform such tasks as copying files, deleting files, and listing directories. More ways to use the shell as an assembly language programming tool are described in the *Apple IIgs Programmer's Workshop Assembler Reference*, written by the folks at Apple and published by Addison-Wesley.

Getting Started

There’s no such thing as a standard IIgs configuration, and APW systems can also be different (a system designed for assembly language programmers will include a machine language assembler, one intended for C programmers will include a C compiler, and still other systems could include both an assembler and a C compiler).

Ordinarily, an APW system designed for assembly language programming will include two disks: one labeled /APW and the other labeled /APWU (for APW utilities). A C-based package will generally include one disk labeled /APW and one labeled /APWC.

In this chapter, we devote our attention primarily to APW systems designed around the APW assembler. Specific tips on installing and operating C-based systems are provided in chapter 3.

To simplify the installation of the APW development system, the designers of the system have placed a utility program called INSTALL on the APW disk. For owners of hard disks, a utility called HDINSTALL is provided.

It's easy to install an APW package on an Apple IIgs system. First, you should back up your original APW disks and put them in a safe spot. Then, if you are using a floppy disk system, place the copy of your /APW disk in one drive and a blank formatted disk in another. If you have a hard disk system, you can use APW's HDINSTALL program to install APW on your hard disk.

If you have a floppy disk system, you can install APW by simply booting APW from your master disk copy and typing a command like this following APW’s # prompt:

```
install /apw /[name of your disk]
```

If all has gone well, the APW system will install itself on your blank formatted disk. When installation of your /APW disk is complete, you should see a prompt on the screen telling you that it is now time to install your /APWU disk. You can then remove the /APW disk, insert your /APWU disk, and type the command install /APWU. Your disks will start to spin again, and when everything is finished, you will have an installed copy of APW, complete on a single disk.

APW’s HDINSTALL program works in a similar way, except that the program is installed in a hard disk directory instead of on an individual floppy.
What the APW System Contains

When you have the APW system installed on a disk—either hard or floppy—an catalog of the system will reveal that it contains the following files:

- A directory titled SYSTEM. This directory contains the APW program and text editor, which you will use to write your source code programs; a LOGIN file, which takes over when APW is booted and can configure APW to your individual Apple IIgs system; a SYSHELP file, which you can use to obtain information about any shell command by simply typing the word HELP followed by the actual command; and a few other files used by the APW system.

- A LANGUAGES directory, which includes the APW assembler (or, if you have a C-based system, your C compiler). The LANGUAGES directory also includes a file called LINKED that is used link object code programs after they have been assembled.

- A LIBRARIES file, which contains a subdirectory called AINCLUDE. In the AINCLUDE directory, you will find a collection of files divided into two categories. About half the files begin with the prefix E16, and the other half start with the prefix M16.

  The files that begin with M16 are APW macros: short, prewritten assembly language source files that you can incorporate easily into application programs. The files that begin with E16 are equate listings: source code files that define constants often used in Apple IIgs programs. After you learn how to use the equate files in the AINCLUDE library, they can be very useful in assembly language programs.

- In a C-based APW system, C libraries are also included in the LIBRARIES directory.

- A UTILITIES directory, which contains many important APW utilities. These include MACGEN, which is used to include APW macros in application programs; MAKKLIB, which can be used to convert application programs into libraries so that they can be accessed more rapidly; and DEBUG, which can be used to run APW’s optional assembly language debugger.

- APW.SYS16, the main APW program.

Using the APW System

After you set up the APW system, you can boot it by itself, from your IIgs finder disk, or from a hard disk, depending upon your preference and the configuration of your IIgs system. No matter how you launch APW, the first thing you’ll see after APW goes into action is a screen heading that looks something like this:
A few lines below this display is a number sign prompt followed by a cursor:

#-

When this prompt appears on the screen, APW is installed and operating, and the computer is in the APW shell’s command line mode. If you’re using a pair of 3.5-inch drives and don’t have a hard disk drive, you may have to do a little prefix changing; that is, you may have to direct APW to read your data disk by using the APW shell’s prefix command. The prefix command can be followed by a full or partial pathname, like this:

prefix /MYVOLUME

or by a device number with a period in front of it, like this:

prefix .D2

More details on the use of the prefix command are in the Apple IIgs Programmer’s Workshop Reference, the Apple IIgs Programmer’s Workshop Assembler Reference, and the Apple IIgs ProDOS 16 Reference (all were prepared by Apple and published by Addison-Wesley).

The APW Editor

After APW is up and running, and the prefix of your data disk is set, it’s easy to activate the APW editor. Just tell APW you want to edit a file and enter the name of the file. For example, type this line following APW’s # prompt (don’t type the prompt, just the two words that follow it):

#edit ZIP.SRC

This line tells APW you want to start editing a file named ZIP.SRC. Although the SRC suffix is not required, it is often used to distinguish source code files (assembly language programs) from object code files (machine language programs). The convention in this book is to give source code programs the SRC suffix and to assign no suffix to machine language programs.

When you type a command line using the format edit filename, APW looks on your data disk for a file with the name you have provided. If it can find one, it displays the file on the screen so you can edit it. If there is no file on the disk with that name, APW goes into editor mode and presents
a blank screen—blank, that is, except for a ruler line at the bottom. Then you can write a new program that will have the filename you have chosen.

This is a good time to install and load APW and type the command line edit ZIP.SRC, if you haven't done so already. Then you'll be ready to type, assemble, and execute the ZIP.SRC program, which appears in listing 2-1. If you're familiar with the adventures of a certain pinhead cartoon character, you'll understand how the program got its name.

Listing 2-1
ZIP.SRC program

* 
* ZIP.SRC
* A program that asks an important question
* 
KEEP ZIP
LIST ON

Zippy START
phk ; make program bank
plb ; and data bank the same

pea testmsg|-16 ; push msg bank on stack
pea testmsg ; push msg address on stack

ldx #$200C ; put tool no. in x reg
jsl $E10000 ; long jump to tool dispatcher
rtl ; long return

testmsg dc c'Are we programming yet?',h'OO'

END

The ZIP.SRC program is written in the Apple IIgs's 16-bit native mode. It doesn't use the Memory Manager or some of the other advanced features of the IIgs, but it is a native mode program.

In a few moments you'll examine the ZIP.SRC program line by line. First, though, let's take a close look at the APW editor, so you can see how it works and how it is used in assembly language programming.

If you've programmed an Apple II or another microcomputer using other kinds of assembly language editors, one of the first things you may notice about the ZIP.SRC program is that it has no line numbers. The APW editor doesn't need them. Line numbers date back to the days of line-oriented editors, when programs were corrected a line at a time and lines were referred to by their line numbers. The APW editor doesn't have any use for line numbers because it is a screen-oriented editor, with a cursor that you move with arrow keys and cut-and-paste functions, which allow large blocks of text—not just
individual lines—to be copied, deleted, and moved. The APW editor operates similar to a full-featured word processor and is a remarkably sophisticated program editing system.

**No Origin Directive**

If you’re an old hand at Apple II assembly language programming, another odd fact you may notice about listing 2–1 is that it has no origin directive. Almost every program ever written for a pre-OS Apple II begins with an origin directive, usually abbreviated ORG, that tells the assembler (and the programmer) where to load the program into memory. The APW assembler has an ORG directive and can use it to assemble programs designed to run in the Apple IIgs’s 8-bit emulation mode. But Apple strongly advises that you not use the origin directive in programs written in native mode. When you write a native mode program for the IIgs, Apple suggests that you let the Memory Manager make all decisions about where to place programs in memory. If you ignore that advice and insist on placing programs in specific locations by using origin directives, you may interfere with the Memory Manager’s operations and clobber other programs resident in memory.

**Control Commands**

Before you start typing the ZIP.SRC program, you may want to practice typing on the empty screen that appears before you now. As noted, you can use the arrow keys to move the cursor around the screen. You can also move the cursor using the spacebar, the Delete key, the Tab key, and the Return key, just as you would with a word processor.

To move the cursor more than one line up or down at a time, or to move it right or left more than one word at a time, hold down the key on your keyboard while you press an arrow key. Pressing Right arrow or Left arrow moves the cursor right or left a word at a time. Pressing Up arrow or Down arrow moves the cursor to the top or bottom of your screen.

You can move the cursor to the beginning of a line by typing and to the end of a line by typing . -1 moves the cursor to the top of a file, -9 moves the cursor to the bottom of a file, and -2 through -8 move the cursor to various points in-between.

Typing Control-T or deletes a line of text; typing Control-Z or restores it. Control-W or deletes a word. Control-Z or restores the last word deleted, if what you last deleted is a word and not a line.

To delete a block of text, press Control-X or and then use the arrow keys to highlight the block you want to delete. When the block is highlighted, you can delete it by pressing the Return key. Then you can move the cursor to another place in your program—or even to a program on another disk—and place the deleted block there by simply pressing Control-V or V.

You can copy a block to another position or to another program by following the same procedure, but substituting Control-C or C-C for the Control-X or X that you use when you want a block deleted. Other control commands recognized by the APW editor are listed in table 2–1.
<table>
<thead>
<tr>
<th>Function</th>
<th>Command</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beep the speaker</td>
<td>Control-G</td>
</tr>
<tr>
<td>Beginning of line</td>
<td>^..</td>
</tr>
<tr>
<td></td>
<td>^..&lt;</td>
</tr>
<tr>
<td>Bottom of screen/Page down</td>
<td>Control-^J</td>
</tr>
<tr>
<td></td>
<td>Down arrow</td>
</tr>
<tr>
<td>Change</td>
<td>See <em>Search and replace</em></td>
</tr>
<tr>
<td>Clear</td>
<td>See <em>Delete</em></td>
</tr>
<tr>
<td>Copy</td>
<td>Control-C</td>
</tr>
<tr>
<td></td>
<td>^C</td>
</tr>
<tr>
<td>Cursor down</td>
<td>Control-J</td>
</tr>
<tr>
<td></td>
<td>Down arrow</td>
</tr>
<tr>
<td>Cursor left</td>
<td>Control-H</td>
</tr>
<tr>
<td></td>
<td>Left arrow</td>
</tr>
<tr>
<td>Cursor right</td>
<td>Control-U</td>
</tr>
<tr>
<td></td>
<td>Right arrow</td>
</tr>
<tr>
<td>Cursor up</td>
<td>Control-K</td>
</tr>
<tr>
<td></td>
<td>Up arrow</td>
</tr>
<tr>
<td>Cut</td>
<td>Control-X</td>
</tr>
<tr>
<td></td>
<td>^X</td>
</tr>
<tr>
<td>Define macros</td>
<td>^Esc</td>
</tr>
<tr>
<td>Delete</td>
<td>^Delete</td>
</tr>
<tr>
<td>Delete character</td>
<td>Control-F</td>
</tr>
<tr>
<td></td>
<td>^F</td>
</tr>
<tr>
<td>Delete character left</td>
<td>Delete</td>
</tr>
<tr>
<td></td>
<td>Control-D</td>
</tr>
<tr>
<td>Delete line</td>
<td>Control-T</td>
</tr>
<tr>
<td></td>
<td>^T</td>
</tr>
<tr>
<td>Delete to end of line</td>
<td>Control-Y</td>
</tr>
<tr>
<td></td>
<td>^Y</td>
</tr>
<tr>
<td>Delete word</td>
<td>Control-W</td>
</tr>
<tr>
<td></td>
<td>^W</td>
</tr>
<tr>
<td>End of line</td>
<td>^..</td>
</tr>
<tr>
<td></td>
<td>^-&gt;</td>
</tr>
<tr>
<td>End macro definition</td>
<td>Option-Esc</td>
</tr>
<tr>
<td>Enter escape mode</td>
<td>See <em>Turn on escape mode</em></td>
</tr>
<tr>
<td>Execute macro</td>
<td>Option-letter key</td>
</tr>
<tr>
<td>Find</td>
<td>See <em>Search</em></td>
</tr>
<tr>
<td>Insert line</td>
<td>Control-B</td>
</tr>
<tr>
<td></td>
<td>^B</td>
</tr>
<tr>
<td>Insert space</td>
<td>^spacebar</td>
</tr>
<tr>
<td>Paste</td>
<td>Control-V</td>
</tr>
<tr>
<td></td>
<td>^V</td>
</tr>
<tr>
<td>Quit</td>
<td>Control-Q</td>
</tr>
<tr>
<td></td>
<td>^Q</td>
</tr>
<tr>
<td>Quit macro definitions</td>
<td>Option</td>
</tr>
</tbody>
</table>
### Table 2-1 (cont.)

<table>
<thead>
<tr>
<th>Function</th>
<th>Command</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remove blanks</td>
<td>Control-R</td>
</tr>
<tr>
<td>Repeat count</td>
<td>1 to 32,767</td>
</tr>
<tr>
<td>Return</td>
<td>Return</td>
</tr>
<tr>
<td>Screen moves</td>
<td>0-1 to 0-9</td>
</tr>
<tr>
<td>Scroll down one line</td>
<td>Control-P</td>
</tr>
<tr>
<td>Scroll up one line</td>
<td>Control-O</td>
</tr>
<tr>
<td>Search down</td>
<td>0-L</td>
</tr>
<tr>
<td>Search up</td>
<td>0-K</td>
</tr>
<tr>
<td>Search and replace down</td>
<td>0-J</td>
</tr>
<tr>
<td>Search and replace up</td>
<td>0-H</td>
</tr>
<tr>
<td>Set and clear tabs</td>
<td>0-Tab</td>
</tr>
<tr>
<td>Start of line</td>
<td>0-., 0-&lt;</td>
</tr>
<tr>
<td>Tab</td>
<td>Tab</td>
</tr>
<tr>
<td>Tab left</td>
<td>Control-A</td>
</tr>
<tr>
<td>Toggle auto indent mode</td>
<td>0-Return</td>
</tr>
<tr>
<td>Toggle escape mode</td>
<td>Esc</td>
</tr>
<tr>
<td>Toggle insert mode</td>
<td>Control-E</td>
</tr>
<tr>
<td>Toggle select mode</td>
<td>Control-0-X</td>
</tr>
<tr>
<td>Toggle wrap mode</td>
<td>Control-0-W</td>
</tr>
<tr>
<td>Top of screen/Page up</td>
<td>0-Up arrow</td>
</tr>
<tr>
<td>Turn on escape mode</td>
<td>Control-0-</td>
</tr>
</tbody>
</table>
KEEP ZIP

Now what does that mean?

Assembler Directives

In source code written using the APW assembler-editor system, statements called *assembler directives* are often placed in the headings of programs, before the first lines of executable code. The line KEEP ZIP is such a directive. When the ZIP.SRC program is assembled, the KEEP ZIP directive tells the assembler to save the machine language version of the program as a file named ZIP. Because the source code version of the program is titled ZIP.SRC, there is no conflict between these two filenames.

The next line of the program:

LIST ON

is also an assembler directive. It is there because the APW assembler will not generate a listing when a program is assembled unless you tell it to. The LIST ON directive tells the assembler to produce a listing.

Program Segments

The next line of the program:

Zippy START

is made up of two parts: a label and an assembler directive. The label is Zippy and the directive is START. We'll look at the START directive first.

The APW assembler, unlike most assemblers designed for small computers, generates programs divided into modules called *program segments*. The division of programs into segments greatly facilitates the writing of well-designed modular programs. Thanks to the use of program segments, a long complex program written with the APW system can consist of one small segment, or main loop, that calls other segments as needed. Furthermore, each segment can include a set of local variables used only in that segment—and the program can use a set of global variables recognized by every segment in the program.

Because local variables in an APW program have no effect outside the segments in which they appear, local variables in one segment can have the same names as local variables in another segment, without conflict. Even if a local variable is given the same name as a global variable, it will not cause a conflict; APW simply uses the local variable and ignores the global one.

Now turn your attention again to the line:

Zippy START

As pointed out, this line consists of two parts: the label Zippy and the directive START. It marks the beginning of a program segment named Zippy and, in this case, also marks the beginning of the ZIP.SRC program. The
segment ends, as all APW program segments do, with the END directive. Because the ZIP.SRC program is only one segment long, the END directive also marks the end of the program.

In programs written using the APW assembler-editor system, every program segment begins with a line that includes START or a similar directive (DATA is used to begin data segments, for example), and every program ends with the END directive. When a START or DATA directive begins a segment, the directive must be preceded by a label that provides the segment’s name.

The next two lines in the ZIP.SRC program are the first lines that contain executable code. They are

```
phk           ; make program bank
plb           ; and data bank the same
```

The abbreviations phk and plb are assembly language instructions, or mnemonics. The words that follow the semicolons in the right-hand column are comments, which are used like REM statements in BASIC programs. They are ignored by the APW assembler, but can provide valuable information to the next person who reads and tries to make sense of a program. (And that person could be you, because even people who write programs often find it difficult to figure out what they were trying to do after the ink on a program is dry.)

In programs written using the APW assembler, comments are usually preceded by semicolons, asterisks, or exclamation points. Asterisks and exclamation points are often used to identify remarks that take up a whole line. Semicolons must be used to set off comments that appear in the right-hand column of an APW source code program.

Now back to the program in progress. The mnemonics phk and plb are often encountered in the initialization sections of IIgs assembly language programs. They set up two internal registers in the 65C816—the data bank register and the program bank register—so that both registers point to the same bank of memory. We won’t cover the memory architecture of the IIgs until chapter 4, and the internal registers of the 65C816 aren’t introduced until chapter 5. For now, it’s sufficient to note that placing data used by a program and the program itself in the same memory bank simplifies matters greatly for the 65C816 processor when the program is assembled and run.

The phk and plb mnemonics belong to a category of instructions called stack operations because they manipulate a special area of memory called the stack. In assembly language jargon, a stack is an area of memory in which data is stored temporarily in the order last-in, first-out, abbreviated LIFO. A stack is sometimes compared with a spring-mounted stack of plates in a cafeteria. When a plate is placed on top of the stack, it covers up the plate that was previously on top, and it must be removed before the next plate can again be accessed.

In 65C816 assembly language, the phk instruction means push the program bank register on the stack, and the plb instruction means pull the
data bank register off the stack. When you use these two instructions together, they transfer the contents of the program bank register into the data bank register, using the stack as a temporary storage area for the data being transferred. This roundabout procedure is used because there is no 65C816 instruction for accomplishing the transfer more directly. More details about the stack—and about the phk and plb mnemonics—are presented in chapters 5 and 6.

Now let’s move on to the next two lines of the ZIP.SRC program:

```
pea testmsg|1-16     ; push msg bank on stack
pea testmsg       ; push msg address on stack
```

The pea mnemonic, like the phk and plb instructions, is a stack operation. It means push effective address. In the ZIP.SRC program, it pushes the address of a text message onto the stack so that the message can be displayed on the screen. The address being pushed on the stack is the starting address of a string called testmsg. That string appears, along with an identifying label, in the last line of the program:

```
testmsg # dc c'Are we programming yet?','h'00'
```

The rather cryptic formatting of this line is discussed in a few moments, when we get to the end of the program. First, though, look again at the two lines that push the address of testmsg onto the stack.

In chapter 5, you’ll see why the pea instruction has to be used twice to push the address of the testmsg string onto the stack. Briefly, though, this is the reason. Because the 65C816 is a 16-bit chip, it can perform manipulations on pieces of data up to 16 bits long. But because it has a 24-bit data bus, it can access addresses that are up to 24 bits long. So it takes two operations to push an address onto the stack: one to push the 8-bit bank number of the address and another to push the 16-bit remainder of the address. When a 24-bit address is pushed on the stack in this way, it must be pulled off the stack in a similar fashion, but in reverse order. If you don’t quite understand this, don’t worry. Stack operations are covered in more detail in chapter 6.

**Operands**

Now you’re ready to take a look at the operands used by the pea mnemonic in these same two lines:

```
pea testmsg|1-16     ; push msg bank on stack
pea testmsg       ; push msg address on stack
```

As you have seen, the testmsg operand is a label that identifies a text string. In the ZIP.SRC program, testmsg|1-16 means the first 16 bits of the address of the testmsg string. For reasons that become clearer in chapters 4 and 5, the first 16 bits of the address of the testmsg string hold the bank number of the address. So, in the ZIP.SRC program, the statement pea testmsg|1-16 pushes the bank number of the address in ques-
tion onto the stack. Then the statement `pea testmsg` pushes the rest of the address.

The next two lines print the string labeled `testmsg` on the screen:

```assembly
ldx #$200C            ; put tool no. in x reg
jsl $E10000           ; long jump to tool dispatcher
```

To understand what these two lines do, you need to know something about how the Apple IIgs Toolbox works. The Toolbox isn't examined until chapter 7, but it wouldn't hurt to point out now that each tool in the Toolbox has a 2-byte identification number, and a program can call any tool in memory by using its identification number.

In the ZIP.SRC program, a utility called the `tool dispatcher` calls a tool with the identification number $200C. Tool number $200C, as you can verify by looking at the list of IIgs tools presented in appendix B, is a tool called `WriteCString`. The `WriteCString` call is part of the Text Tool Set. It can be used to print a C-style string (a string ending in $00) on a text output device such as a printer or a monitor screen.

Using the Tool Dispatcher

The ZIP.SRC program uses the tool dispatcher to make the `WriteCString` call, which prints the string labeled `testmsg` on the screen. More information about tool calls is provided in chapter 7. For the moment, it's sufficient to note that the following steps must be taken to call a tool using the tool dispatcher:

1. Certain parameters (in this case the address of the string to be printed) must be pushed on the stack.
2. The identification number of the tool to be called must be placed in the 65C816's X register. (More information about the X register and the 65C816's other internal registers is presented in chapter 5.) In the ZIP.SRC program, the statement used to load `WriteCString`'s ID number into the X register is `ldx #$200C`.
3. The tool dispatcher must be called with the statement `jsl $E10000`, which means `jump to a subroutine located at memory address $E10000`. The `jsl` mnemonic, which stands for `jump to subroutine—long`, is often used in Apple IIgs programs to access subroutines that lie across bank boundaries.

The last line of executable code in the ZIP.SRC program is

```assembly
rtl                    ; long return
```

The `rtl` mnemonic, which stands for `return from subroutine—long`, is used at the end of a subroutine (or the end of a program) that is called from across bank boundaries. This instruction is examined in greater detail in chapter 5.
Now we have come to the line

```assembly
testmsg # dc c'Are we programming yet?', h'00'
```

In this line, `testmsg` is a label that identifies the string that follows. The abbreviation `dc`, which comes next in the line, stands for *define constant* and means, obviously, a constant is being defined. The abbreviation `c`, which comes next, means a character string follows.

The text that follows `c` and is enclosed in single quotation marks is the string printed on the screen when you run the program. After the string is a comma, then the abbreviation `h`, which tells the assembler that the next value it encounters is a hexadecimal number.

The hex number that follows `h` is also enclosed in single quotation marks. The number is $00$, the conventional terminator for C-style strings.

The last word in listing 2–1 is, appropriately enough

```assembly
END
```

This ends the program segment labeled *Zippy* and also ends the *ZIP.SRC* program.

### The APW Editor’s Menu

When you finish typing the *ZIP.SRC* program, you can leave the APW editor by typing Control-Q. Your program disappears from the screen and is replaced by the APW editor’s menu. By picking menu choice S, you can save the *ZIP.SRC* program under the filename you chose when you entered the editor (this filename appears at the top of the menu). Or, by selecting menu choice N, you can save it under a different name. After you save the program, you can choose menu selections to load another file, return to the editor (and to the program you just finished editing), or exit from the editor.

### Assembling the *ZIP.SRC* Program

When you have typed the *ZIP.SRC* program and have made sure that it contains no mistakes, return to the APW shell by selecting menu choice E. You can then assemble and link your program by typing
ASML ZIP.SRC

You can then run it by typing:

ZIP

When the ZIP.SRC program prints its important question on the screen, you can answer it with a resounding yes!
If you want to learn how to program the Apple IIgs in C, this is the chapter you’ve been waiting for. Even if you are interested only in assembly language, it is strongly suggested that you read this chapter because it contains valuable information about the APW system that you won’t find elsewhere in this book.

It’s important to note, however, that this chapter does not teach you C programming from the ground up. If that’s what you need, you’ll have to supplement this book with an introductory text on C programming. (A few are listed in the Bibliography.) But even if you’ve never written a line of C code, you are still invited to type, compile, and run the two sample programs in this chapter.

If you’re an experienced C programmer, you’ll be ready to write C programs for the IIgs when you finish this chapter. If you’re new to C, you’ll get some hands-on experience in writing simple C programs using the Apple Programmer’s Workshop, plus a basic understanding of how things are done in C. If you know a little about C and are interested in learning more, this chapter and the information on C in the rest of this book provide a general understanding of how the language works and how it fits into the Apple IIgs programming environment.
The C Language

Before you start programming in C, we'll present some historical and technical information about the language. The C language was invented by Dennis Ritchie of Bell Laboratories and was originally designed for developing applications and utilities in the UNIX environment. Since then, it has become popular among professional and amateur programmers as a general-purpose language. C programs have been written for virtually every kind of microcomputer, minicomputer, and mainframe computer. Apple recognized C's usefulness and popularity by making it the first high-level language for the Apple IIgs.

C is successful because it offers a balance between the programmer-friendly features of a high-level language and the speed and versatility of assembly language. It is almost (though not quite) as easy to work in as a high-level language such as Pascal. Yet it offers the kind of unrestricted access to the IIgs's memory, operating system, and I/O functions that is otherwise available only in assembly language.

Structure of a C Program

A C program is a collection of functions, or sets of instructions for performing specific tasks. Information to be processed in a C program is passed to a function with a parameter list. A parameter list is a list of values, separated by commas and all contained between parentheses, that follows the function's name. The parameter list doesn't have to contain any parameters. But if there are no parameters, the name of the function must still be followed by a pair of parentheses, like this:

\[\text{function}()\]

Parentheses are not the only punctuation marks you'll find in a C program. C uses the semicolon as a separator between statements in a program and uses braces to group statements into blocks.

Any C expression that has a value can be used as a parameter in a parameter list. A C function usually returns a value as its result. So a function itself can be used as a parameter or as an argument to another function.

The value returned by a function does not have to be used by the program in which the function appears. A function can also perform other actions called side effects. Many C functions are used only for their side effects.

Important Features

C provides several ways to make decisions, perform looping operations, and assign and store data. In addition, a number of preprocessor (or compiler) directives facilitate the development of large programs and provide easy access to commonly used code and definitions. APW C also supports enumerated types, and assignments and comparisons between structured variables of the
same type. If you’re an experienced C programmer, you’ll understand this. If not, these and other features of APW C are explored in the programs in this chapter and the rest of this book.

C in the APW Environment

The Apple Programmer’s Workshop (APW), an Apple product, is the development system used to write the C programs in this book. In addition to the standard integer arithmetic offered by most C development systems, the APW system also supports floating-point math. And, along with the standard C libraries—which provide some compatibility with C code developed using other systems—APW C also has a large set of interface libraries to support the Apple IIGS Toolbox. These libraries contain a complete set of function declarations, along with definitions of constants and data structures, that are designed to be used with the IIGS Toolbox. This means you can access the Toolbox directly from C as well as from programs written in assembly language.

Pascal Functions

One noteworthy feature of APW C is that you can define Pascal-style functions. Pascal functions make it possible to use the calling and parameter-passing conventions of Pascal in a C program. Many Toolbox routines were developed using Pascal-style conventions, and APW C’s Pascal function type makes it possible to use them. Pascal functions also allow routines written in Pascal and linked with a C program to be called from C.

A Limitation of APW C

As any C buff will tell you, you can generally do anything in C that you can do in assembly language. In APW C, however, there is a major exception because the 65C816 chip has a “split personality.”

As you saw in previous chapters, the 65C816 has a native (16-bit) mode that takes advantage of 16-bit registers and data paths and a 6502/65C02 emulation (8-bit) mode that emulates earlier members of the 6502 family. Emulation mode enables the IIGs to run most software designed for earlier Apple IIs. It also allows assembly language programmers to create and assemble programs that are compatible with earlier machines.

But APW C is strictly a native mode language; you can’t use it to write programs in 8-bit emulation mode. Even when it’s used to write native mode programs, sometimes its inability to deal with 8-bit machine code is a limitation. In most applications, though, this is not a problem. The APW C compiler also supplies an inline assembler that allows the programmer to insert assembly language code directly into C functions.

When it comes to creating native mode applications for the IIGs—complete with windows, menus, desk accessories, color graphics, and sound—APW C is a powerful and efficient tool.
Installing APW C

If you typed, assembled, and executed the assembly language program in chapter 2, you should have no trouble getting used to the APW C development system. When you work with the C programs, you’ll use the same editor that you used in chapter 2. When you compile and link them, you’ll use similar APW commands.

In a moment, you’ll fire up your APW development system and start writing programs in C. First, though, it must be pointed out that the following instructions apply to a version of APW that may no longer be current by the time you read these words.

As explained in chapter 2, the APW system used to write the programs in this book is a text-based utility that does not make use of the Ilos’s sophisticated graphics interface and event-driven programming capabilities. If APW has been completely overhauled by the time you read this, some of the details in the next few paragraphs may not apply to your APW system. But most of the information that follows should prove helpful, even if APW has been modified.

Adding C to the APW environment is simple if you have a hard disk. Simply start up the APW shell on your hard disk, insert the /APWC floppy in a 3.5-inch disk drive, and type this line following APW’s # prompt:

\[ \text{copy /apwc/languages/ = 5} \]

Then type

\[ \text{copy /apwc/libraries/ = 2} \]

If you don’t have a hard disk, the previous method won’t work because there is not enough room on one 3.5-inch disk for both a C and an assembly language APW package. One way to deal with this problem is to copy one or more of the large directories in the APW system onto another floppy disk or onto a RAM disk. Then set APW’s shell prefixes so they look for the transferred files in their new locations.

You can also set up two stripped-down versions of APW—one for assembly language and one for C—so that you can put a fairly complete assembly language development system on one floppy and a fairly complete C development system on the other. They won’t be on the same disk, however.

If you want to work in both C and assembly language using two floppy disks, here is a relatively painless way to get started:

1. Back up your original APW disks, store them in a safe place, and use your backup copies to conduct the following operations.
2. Start up the computer using a copy of the APW disk. Start APW from your finder disk.
3. Insert a copy of /APWC in your second drive and type the following commands (not the # prompts, just what follows them):

```
copy 2/= /apwc/libraries
delete -c 2/ainclude/=
copy /apwc/languages/= 5
delete -c /apwc/languages/=
delete /apwc/languages
prefix 2 /apwc/libraries
```

These commands set up the APW assembler and compiler on one disk, and the C and assembler support libraries on another.

If you are planning to use this configuration regularly, you can tailor the APW LOGIN file (an exec file that calls APW when the APW disk is booted) so that everything is ready to go as soon as you boot up. To edit the LOGIN file, simply type this line following APW's # prompt:

```
edit 4/login
```

When the editor comes up, add this line to the end of the LOGIN file:

```
prefix 2 /apwc/libraries
```

To save your amended LOGIN file, press Control-Q to leave the editor, then make menu choices S and E. Each time you want to use APW, make sure the modified copy of /APWC is in one of your disk drives when you load APW.SYS16 from the Ilgs finder or (on older system disks) the Ilgs launcher.

After you've used APW C for a while, you may find many files on the /APWC disk you can do without. You may want to create a custom configuration that can save you even more disk space—and time.

As mentioned previously, C programs for the Ilgs are created using the APW editor. They are compiled using commands—such as compile and assemble—that can also be used with the assembler.

To create a C program using the editor, however, you first must set APW's language to C. You can do this by simply typing the following command after APW's # prompt:

```
cc
```

After you use the cc command, any new files you create using the editor are recognized by the APW system as C language source files. APW compiles them using the C compiler when you issue a compile command. If you work mostly in C, you can use the editor to add the cc command to your LOGIN file. The editor then makes all new files C language source files.
Writing a C Program

Now, at last, you’re ready to write a program in C. To begin, start up the editor with a new filename:

```
#edit myprog.c
```

C source files written under APW do not require the .c suffix. But it is a good idea to use the .c suffix because it distinguishes C source files from other kinds of files and makes them easy to spot when you catalog your directory.

When your editor comes up, you can type in a C program like you would type in an assembly language program. Some tips are provided in chapter 2. However, APW C programs, unlike APW assembly language programs, are standard-looking pieces of code. In fact, as long as they use the IIgs’s standard text input and output mode, and don’t require the use of graphics calls in the IIgs Toolbox, they look just like C programs written for any other machine.

For example, type in listing 3–1, the Hello World program found in so many texts on C.

```
Listing 3–1
Hello World program

main()
{
    printf("Hello World!\n")
}
```

When you’ve typed the program, you can leave the editor by pressing Control-Q. Then choose menu selection S to save your work and menu selection E to return to the APW shell’s familiar # prompt.

Next, look at the directory of the current disk to make sure myprog.c was saved as a C language source file. To list the program, type, after APW’s # prompt:

```
cat myprog.c
```

APW shows you a screen display like the one in figure 3–1.

Note that the last item on the second line in figure 3–1, under the heading

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>Blocks</th>
<th>Modified</th>
<th>Created</th>
<th>Access</th>
<th>Subtype</th>
</tr>
</thead>
<tbody>
<tr>
<td>MYPROG</td>
<td>SRC</td>
<td>1</td>
<td>9 Jun 87</td>
<td>9 Jun 87</td>
<td>DNBWR</td>
<td>CC</td>
</tr>
</tbody>
</table>

Figure 3–1
Cataloging a single file
Subtype, is CC. That shows myprog.c has indeed been saved as a C language source file. If there’s something else under Subtype in your disk directory, you probably didn’t use the cc command before you made the new file. In this case, type the following line to change the subtype of myprog.c before compiling it:

change myprog.c cc

Compiling a C Program

After you save a C source file and exit the editor, you can compile the file by typing a line like this:

#compile myprog.c keep=myprog

The compile command in the previous line means exactly the same thing as APW’s assemble command. You can use either one, in C or in assembly language, because the shell looks at the source file’s language to decide whether to invoke the C compiler or the assembler. The keep directive in the command line tells the compiler to create an object file named myprog.root in the current directory. Any valid full or partial pathname can be used as the value of the keep command.

Linking a C Program

When you wrote an assembly language program in chapter 2, you assembled and linked it using the command ASML, which means assemble and link. And when APW received that command, it assembled and linked the program automatically. To create an executable C file, however, you must invoke the linker by specifically using a link command.

Before we link our Hello World program, it might be helpful to explain how the APW linker works. All APW assemblers and compilers, including the APW C compiler, generate object code files that have the same format. This format is called object module format, or OMF. To the linker, it doesn’t matter whether a program was written in C, assembly language, or Pascal. In fact, because all assembled and compiled APW files have the same format, the APW linker can link object files written in any combination of development languages available under APW.

From an object module file created by the APW assembler or C compiler, the linker generates a load file, a file the system loader can load into memory. If necessary, the linker resolves any external references (references to segments of machine code outside the OMF file it is linking) and creates relocation dictionaries that the system loader uses later, at load time, to relocate the load file produced by the linker.

To instruct the linker to link an OMF file and produce a load file, type a command line like this:
There are a few points about this command line that haven’t been explained. But go ahead and type and enter the line, and after you link and run the program, we’ll do the explaining.

Linking a C program can take a while, but when it’s done you’ll see the # prompt in its usual place, waiting for your next command. Then you can run the program you have linked by simply typing

myprog

followed by a carriage return. The greeting “Hello World!” is printed on your screen. The # prompt then appears on the next line, letting you know that myprog has finished executing and you can enter another command.

Now let’s go back for another look at the line you typed to link the myprog program:

link 2/start myprog keep=myprog

To understand what the more cryptic parts of this line mean, it helps to know something about how C programs work.

Part of what makes programs like Hello World so much shorter and easier to write in C than in assembly language is that the compiler takes care of many details. For example, you don’t need to worry about whether to use jsl or jsr when calling a subroutine, what to do with values placed on the stack, how many words to take off the stack, or what addressing mode to use. The compiler knows how to do all this. But it doesn’t know anything about how to start or end a program, or how to read input from the keyboard or print to the screen.

The secret behind the brevity of the Hello World program (it is condensed into one line of code) is the existence of C libraries, which include a number of useful programs. Here’s how a few of them work.

START.ROOT File

If you look in the LIBRARIES subdirectory of your /APWC disk, you’ll see a file called START.ROOT and another file called CLIB. START.ROOT is the object code of an assembly language program on the /APWC disk. Typing start following the link command links the code in START.ROOT to your program.

When you link a C program, it is first linked to START.ROOT. When you execute a C program, the function named main() is called as a subroutine from a machine language program. And START.ROOT is that program. START.ROOT calls main() using the machine language equivalent of a js l instruction. The program then returns to START.ROOT using the machine language equivalent of an r t l instruction, which is placed at the end of main() by the compiler. Details of how the js l and r t l instructions work are in appendix A.

When the START.ROOT program is called, it does whatever is necessary to start up a C program. It also handles any arguments typed on the
command line so that they are accessible through the C input parameters `argc` and `argv`, if applicable. It then carries out the machine language equivalent of the assembly language statement `jsl main()`, which causes the machine code generated by the C program labeled `main()` to be executed.

At the end of the C function `main()` (which, as its name indicates, is always the main function in a C program), START.ROOT encounters the machine language equivalent of an `rtl` instruction—which, as noted, is placed there by the compiler. This instruction returns control to START.ROOT, which then takes care of returning to the shell prompt `#` or, if you launched your program from the finder or the program launcher, to one of those utilities.

**Another Look at Link**

Now let's review the line that you typed to link the Hello World program:

```
link 2/start myprog keep=myprog
```

In this line, the names listed after `link` are pathnames—they can be full or partial pathnames—that tell the linker where to find the object files that make up your program. When C programs are linked, there are always at least two such pathnames in the `link` command line. The linker automatically looks for files with the suffix `ROOT`, so there's no need to include the `ROOT` suffix in your filenames. The `2/` prefix in `2/start` refers to the LIBRARIES subdirectory.

The `keep` directive, as noted, tells the linker where to send its output. Again, you can specify any legal pathname. Typically, an executable file is given the same name as its corresponding source code and object code files. Because executable files, by convention, do not have a suffix, the linker creates a load file called simply `myprog`.

**CLIB File**

Now you're ready to examine CLIB, another important file in the LIBRARIES directory on the /APWC disk. As you've seen, the START.ROOT program takes care of initializing and ending C programs, relieving that burden from the programmer. And, as you may notice when you look at the code for the Hello World program, C also relieves the programmer of such chores as reading inputs from the keyboard and printing characters on the screen. These details, as well as those needed for other kinds of input and output operations, are provided by the CLIB file.

The CLIB file is a special file created by the MAKELIB program. (MAKELIB is in the UTILITIES directory on the /APWC disk.) CLIB is made up of object files containing routines, most of which are written in C, that take care of many common programming actions in a standard manner.

To understand how the CLIB file works, look at how it was used when you compiled the myprog.c program. When the C compiler compiled the program, it didn't know anything about how to print on the screen. It also didn't know anything about CLIB. It created a storage area containing the ASCII codes for the message "Hello World," generated code to put the address of that storage area on the stack, then tried to generate a line of machine language code that would carry out the C statement.
printf('Hello World!\n')

To create a machine language statement that would execute a printf function, the compiler generated an object code statement equivalent to the assembly language statement jsl printf. Then the jsl instruction was converted into a machine language opcode. But the printf instruction remained the same because the compiler didn’t know what it meant. In other words, the compiler treated printf as a symbolic reference.

In assembly language jargon, a symbolic reference is another name for a label that identifies a program segment—that is, a segment of code or data that begins with the start directive. In C, a compiler generates a symbolic reference to identify the location of a function or variable.

The APW linker treats symbolic references in the same way in C and assembly programs. In both, one of the jobs of the APW linker is to resolve symbolic references. When the linker encounters a symbolic reference in a program being linked, it first scans each program listed on the Link command line to see if it contains the reference in question. If it doesn’t find the segment there, it searches for it in any files that appear in the LIBRARIES subdirectory and have the file type LIB.

When the linker linked the Hello World program, there were no other filenames on the Link command line. So, when it encountered the C function printf, it went directly to the LIBRARIES directory and searched for it there.

Finally, in the CLIB file, the linker found what it was looking for: a code segment labeled printf. It added that segment to the executable file it was creating. Then the linker replaced the symbolic reference operand of the jsl printf statement with a value marking the location of the start of the printf routine in relation to the beginning of the load file being created by the linker.

The analysis of the printf function has served as an introduction to a useful set of prewritten C functions called standard C libraries. These libraries, stored in the CLIB file, include more than 40 routines. Most of the routines emulate the behavior of the standard C routines available in UNIX systems. Many of them deal with various aspects of input and output, such as file handling, reading the keyboard, and printing text. In addition to I/O routines, there are mathematic routines, such as sine and cosine functions, and memory allocation routines, such as malloc, calloc, and free. The routines are explained in chapter 5 of the Apple IIgs Programmer’s Workshop C Reference.

CLIB also contains routines that are not called directly from C programs. These provide an interface with the SANE floating-point math routines in the IIgs Toolbox. When you include floating-point arithmetic expressions in your IIgs code, the C compiler generates calls to these SANE interfaces to perform the calculations. Much of the functionality of the standard C libraries can also be achieved by making direct calls to the tools in the Toolbox and to ProDOS. In fact, standard C libraries make extensive use of routines in the Text Tool Set and ProDOS for text I/O and file handling. The standard C
libraries not only simplify your work, they also make it possible to port C source code written for other machines over to the IIgs.

Another Sample Program: The Name Game

Now that you’ve typed and run a very simple C program and understand how to create a C program, you’re ready to write a slightly more complex program. The name of the program is the Name Game. It was written in 1980, in BASIC. Since then it has been translated into five programming languages and has appeared in various forms in more than a dozen books and magazine articles. It will also turn up, in an assembly language version, in chapter 7.

Now you’re ready to type, compile, execute, and analyze the Name Game. Load APW and type this line following the # prompt:

```
edit namegame.c
```

When the editor comes up, you can type in the Name Game program, which appears in listing 3–2.

```
Listing 3–2
Name Game program (C version)
```

```
#include <stdio.h>

main()
{
    char replay = 'Y';
    char name[25];

    while (((replay == 'Y') || (replay == 'y')) { // continue
        putchar(0x8C);
        printf("**** The Name Game ****

            Hello, what's your name?");
        scanf("%24s", name);
        fflush(stdin);

        while (strcmp(name,"George") && strcmp(name,"George") &&
              strcmp(name,"George") { // continue
            printf("\nGo away %s, bring me George!\n\n", name);
            printf("What is your name? ");
            scanf("%24s", name);
            fflush(stdin);
        }

        printf("\nHi George! Try again? (Y/N) ");
        replay = getchar();
    }
```
When you have finished typing and correcting the program, press Control-Q, select S and E to leave the editor, save your work, and return to the shell command line.

**Compiling the Name Game**

You can compile the Name Game by typing the command line

```
#compile namegame.c keep=namegame
```

If you typed in the program exactly as shown in listing 3–2, the compiler generates a screen display that looks like the one in figure 3–2.

Now type a `cat` command, like this:

```
#cat namegame=
```

Your disk directory includes a new file called NAMEGAME.ROOT.

If you made any mistakes in typing the program, the compiler presents a list of error messages. If there are any error messages on the screen, they contain the numbers of the lines in which errors occurred. If the compiler has found errors, enter the editor and compare the lines you typed with the lines in listing 3–2. Then leave the editor, save your changes, and compile the program again.

If you made so many errors that the first one scrolls off the screen (and that’s easy to do, because one error in a C program can cause the compiler to generate many error messages), use the APW shell’s redirection capability to save the compiler’s error messages in a file. Or, if you have a printer hooked up, send them to the printer.

To redirect the compiler’s error messages to a special error file, just type this command:

```
#compile namegame.c keep=namegame >errors
```

Then, to view your file of error messages, you can type

```
#AppLe IIGS APW C Compi
```
#type errors

While APW is printing your error file on the screen, you can stop the display from scrolling by pressing a key. You can resume scrolling by pressing another key.

To redirect your error file to the printer, type

```
#compile namegame.c keep=namegame >.printer
```

Then, if the printer is hooked up and online, you'll get a paper copy of the compiler's output.

Even if you didn't make any errors in typing the Name Game program, you might like to try these exercises in file redirection, just to see how they work. They will come in handy eventually.

## Linking the Program

To link the Name Game, type the command line

```
#link 2/start namegame keep=namegame
```

This line works like the line that linked the Hello World program. It creates a load file called NAMEGAME in the current directory. If the linker displays an error message, you'll have to activate the editor, correct the errors, and compile and link the program again.

If the linker finds any errors in your program, it will probably present a display similar to the one shown in figure 3–3.

The error shown in figure 3–3 was caused by the misspelling of a subroutine's name. In the example, the \f was not included in the function name printf somewhere in the program.

If all goes well and you don't get an error message, you can now run the Name Game by simply typing the command

```
#namegame
```

![Figure 3–3](image)

An error message from the linker
Playing the Name Game

Because the Name Game is a game, please read no further until you play it! Then come back and look at the following play-by-play listing of what should happen when you play the game.

1. The screen clears, and the title **** THE NAME GAME **** appears at the top of the screen.
2. The greeting Hello, what's your name? appears three lines below the title.
3. As you type in your name, the letters you type appear after the ? prompt.
4. If you don’t type George, george, or GEORGE, the computer responds:

   Go away the name you typed in, bring me George!
   What is your name?

5. Steps 3 and 4 repeat until you type George.
6. When you finally give up and type George, the computer responds:

   Hi George! Try again? (Y/N)

7. If you type Y or y, the computer starts the Name Game over again, beginning with step 1. If you type anything else, you return to the shell’s # prompt.

The Art of Debugging

If the program doesn’t work in the manner described, you probably didn’t type it exactly as shown in listing 3–2. Unfortunately, no compiler or linker can spot and report every type of error that can be made in a program. Here are a few types of errors that may not be noticed by the APW system:

- Misspellings.
- Discrepancies in the layout of a screen display.
- The program won’t print Hi George! even if you type in George or keeps playing even after you type N. If one of these problems occurs, press Control-C-Reset (at the same time) to reboot the machine.
- After performing all, part, or none of the steps listed in the play-by-play description, the machine just freezes. You’ll have to reboot for this one, too.

In programs that you write, errors like the last two are usually the hardest to find. In such cases, all you can do is carefully go over your code until you find your error. Then, each time you find an error and track down its cause, it’s a good idea to think for a moment about why the error occurred.

When you start debugging your programs, you’ll have to think in reverse. You’ll need to figure out what kind of mistake was likely to cause a
certain problem before you even know where to look in your source code! This process is called debugging, and it’s an important part of programming—in any language.

How the Name Game Works

If your Name Game program is debugged and running, you’re ready for a line-by-line description of how it works. Let’s start at the top:

```c
#include <stdio.h>
```

The term `#include` is a compiler directive, and the `#include` directive is a standard feature of C. The `#include` directive replaces the line the directive is on with the contents of the named source file. The `<` and `>` around the filename tell the compiler to search for the filename in the `/include` directory.

Macros

The Name Game program needs the contents of the `<stdio.h>` file because they provide definitions for the `putchar` and `getchar` macros. Macros are often found in Apple IIgs programs written in both assembly language and C. When they are included in C programs, they are used like the functions in the CLIB file. In the Name Game program, for example, the `putchar` and `getchar` macros read each character input from the keyboard and print every character displayed on the screen.

Macros, though they may look obscure to the uninitiated, are time-saving and labor-saving aids for assembly language and C programmers. A macro makes it possible to write a complex sequence of code using a single word or a word followed by one or more symbolic variables. When the program is compiled, the macro is replaced by the code it represents.

Macros are often used when the actual code for a frequently performed action is obscure. So they not only save programming time, but also make code more readable. In C programs, macros are more efficient than function calls because the code replacement they require is handled at compile time, and `jsl` and `rtl` instructions are not required. Also, symbolic variables can be used more easily in macros than in subroutines.

Macros do have one disadvantage, however. When a macro is used repeatedly in a program, it uses much more memory than if it were written as a subroutine. A macro is replaced by the sequence of code it calls every time it is used, but a subroutine can be used over and over without using any additional memory.

More information about macros is presented in part 2. For now, all you need to know about macros is that if you didn’t include `<stdio.h>` in the heading of the Name Game program, `putchar` and `getchar` wouldn’t work. The fact that macros are implemented in a slightly different manner than true
function calls is not too important at the moment and is mostly transparent to the programmer.

The Main() Attraction

Now let's move to the next line in the Name Game program:

```c
main()
```

As noted, every C program must have a function called `main()`. For example, in the description of the START.ROOT routine, `main()` is the label the routine jumped to.

To the C compiler, `main()` is just another function definition and is treated the same as any other. When the compiler compiles a `main()` function, it simply generates an OMFI file segment whose start is labeled `main`. To create this segment, it uses all the code between the first and last braces that follow the `main()` declaration. Often, in longer C programs, the `main()` function consists almost entirely of calls to other functions. (A general rule for beginning C programmers is to avoid writing any C function that is too long to fit on the computer screen at one time. If you follow this rule, it reduces your chances of writing convoluted, hard-to-understand “spaghetti code.”)

A Prompt and a Response

Now on to the next line in the Name Game program:

```c
char replay = 'Y';
```

This line is included in the program because you need a place to store the response to the `Try again? (Y/N)` prompt. Because you will store a letter, you declare the `replay` variable to be type `char`. The program ends whenever `replay` is not equal to `'Y'`, so you start out making `replay` equal to `'Y'` to ensure that the game is played the first time through. `'Y'` is a character constant. The single quotes around `'Y'` tell the compiler that it is not the name of a variable. C stores the ASCII value of the letter `'Y'` in the byte of memory it associates with the name `replay`.

Setting Up a String

Now for the line

```c
char name[25];
```

This line is included in the program because you also need a place to store the name the user types in. The statement sets aside 25 bytes to hold the name. The identifier `name` refers to the address of the first byte in the string. The memory area addressed by the identifier `name` is an array of type `char`.

The While Statement

After the `name[]` array is set up, a line is skipped in the program, and this line appears:

```c
while ((replay == 'Y') || (replay == 'Y')){
```
Logical OR Operator

The broad symbol in the while statement is C's logical OR operator. As long as the variable replay is equal to either Y or y, the while statement's condition is true, and the block that follows it is executed.

Both an uppercase Y and a lowercase y are used in the while statement because the C language is case sensitive—that is, it distinguishes between uppercase and lowercase letters. So, in C programs with inputs that are not case sensitive, you often need to write code that forces C to accept either uppercase or lowercase letters as inputs from the keyboard.

The next line in the program:

```c
putchar(0x8c);
```

calls the putchar macro defined in the header file `<stdio.h>`. This line illustrates a fast way to send a single ASCII code to the program's output stream—in this case, the screen. If you wanted to print a single letter on the screen, the argument to putchar (the value inside the parentheses that follow the name of the function) would be the desired letter, enclosed in single quotation marks.

Because the Apple-style ASCII code to clear the screen is not a printable character, but the hexadecimal value $8C$, you can just send the code number itself by omitting the single quotation marks. The 0x preceding the value 8C means 8C is a hexadecimal number. In C, hex constants are indicated by the prefix 0x. So 0x8C represents the same value as $8C$ in assembly language.

The Name of the Name Game

The next line:

```c
printf("***** THE NAME GAME *****\n\n");
```

calls the CLIB routine printf. In this case, the C compiler reserves a space in memory for the characters inside the quotation marks, stores them there with a terminating 0 (null character), and passes the address to the printf routine.

We'll discuss what the printf routine does in a moment. But first,
we’ll describe the 0 that CLIB adds to the characters inside the quotation marks before printf goes into action.

In C, the word string describes an array of characters whose last value is 0. A 0 is called a null character because it does not represent any letter or control character. So 0 is used to mark the end of a string. It tells various C routines that work with strings when they have found the end of a string.

Now you can move to the printf routine. The C compiler interprets another special character—the backslash character (\)—as an escape character. Instead of placing a backslash in the stored string, it treats the character that follows it in a special way. For example, \n following a backslash stands for newline, which in C talk means a carriage return. So the three \n's before the closing quotation marks in the line

```
printf("**** THE NAME GAME  ****\n\n\n");
```

insert three newlines (carriage returns) in the string passed to printf. This means two lines are skipped before the next item is displayed on the screen.

In the next line

```
printf("Hello, what is your name?");
```

you do not include \n because you want the player’s answer to appear on the same line as the question.

### The Scanf Routine

The scanf routine in the statement

```
scanf("%24s",name);
```

is another powerhouse from CLIB. It works like printf, but in reverse. It takes values of text data from the keyboard, echoes them to the screen as they are typed, and stores them in a designated variable or string.

In the scanf routine there are two arguments inside the parentheses, separated by a comma. The first argument, %24s, instructs scanf to read up to 24 characters from the keyboard and place them, in the order they are input, in a string (character array). The second argument, name, is the address of 25 bytes of storage. This tells scanf where to store the character string.

When the user types a carriage return or has input 24 characters, scanf stops accepting characters. If input is ended by a white space character—a space, tab, or newline character—scanf does not add it to the stored string. When input has ended, a 0 is placed at the end of the string of characters that have been typed in, making the array called name a C string. Control then returns to the next statement in the calling routine.

### Counting Characters

In a scanf string like the one in the Name Game program, the % symbol preceding 24 limits the length of the string to 24 characters, plus the terminating 0 that makes it a C string. This is a total of 25 characters, which is the size of the character array name. If you allowed an unlimited number of input characters, scanf would blindly store every character the user enters.
in the area of memory that begins with the first character of the array name. If more than 24 characters were input, the program could eventually crash or overwrite other data stored in memory.

Other values can follow % in a scanf argument to cause the function to read and store data in different ways. You can find more information on this topic in the Apple IIgs Programmer's Workshop C Reference.

The next three lines in the program are

```c
printf("What is your name? ");
scanf("%24s",name);
fflush(stdin);
```

`stdin` is defined in `<stdio.h>`. It represents the standard input stream, which is normally the keyboard. `fflush` is a standard library call that removes any data “queued,” or waiting to be read from or written to. The `scanf` call, which precedes `fflush` in the program, takes in whatever is typed up to, but not including, the first white space character typed. Sometimes, you will be interested in this character. In this case, you are not, so `fflush` disposes it.

If you left the `fflush` call out of the program, the next input request—the `getchar()` call near the end of the program—would accept the pending white space character as its input instead of waiting for the user’s response.

A Loop Within a Loop

Now for the next statement in the Name Game program:

```c
while(strcmp(name,"George")&&strcmp(name,"george")&&strcmp(name,"GEORGE")){
```

You may notice that the `while` loop in this statement is on two lines. This was done simply because the statement is too long to fit on one line. C doesn’t care about extra spaces and carriage returns in source code, as long as they are not within a name or between quotation marks.

Now let’s see what the statement does. Although the program is already inside a `while` loop that recycles the Name Game as many times as users want, you can create another `while` loop that keeps users typing in entries until they decide to go get George (or lie and tell the computer that their name is George).

This loop within a loop introduces another new CLIB routine, `strcmp`. The `strcmp` function compares the C string `name` with the C string `George` and generates a value of 0 if the strings are the same. In C, 0 stands for the logical value false, and any nonzero value stands for true. Our goal is to repeat the `while` loop that asks for George as long as the character array `name` is different from three variations of the name `George`.

Because the result of `strcmp` is nonzero (true) when the string stored in `name` is different from the string stored in `George`, you use the logical
AND operator && to make the comparison. This says: "While name is different from George, AND name is different from george, AND name is different from GEORGE, carry out the following block of code." Otherwise, the program moves to the statement following the closing brace of the block:

printf("\nGo away, %s, bring me George!\n\n", name);

What's new here is that %s, the same term used in the scanf statement, is now used in a printf statement. In this case, it causes printf to print on the screen the string stored in name. This operation is the reverse of the one carried out by scanf, which replaces the contents of name with the string of characters typed at the keyboard. So in this context, you can think of the screen and the keyboard as the input and output sides of the same device.

These are the next two lines in the inner while loop:

printf("What is your name? ");
scanf("%24s", name);

In these two statements, printf prints a line on the screen and scanf places a new string in the variable name. There is nothing new here, but the results are important. The scanf statement provides a new value to be tested by the strcmp routine at the start of the loop. If this operation did not take place, even typing George would not help the poor users. They would have to reboot the machine to get it to stop its dialog.

This brings us to an important point in programming. When you write a while loop, something must eventually happen within the loop to make the condition being tested false and bring the loop to an end.

Now we come to the last statement in the inner while loop:

fflush(stdin);

After the printf and scanf routines are carried out, the fflush routine "flushes" the queue.

The end of the program's inner while loop is marked by a closing brace placed beneath the w that began the loop. This convention makes C code easier to read and understand.

When Your Name Is George

The next line is one you can't get to unless you claim your name is George:

printf("\nHi, George! Try again? (Y/N) ");

At this point, you can decide whether you want to play the game again, though I can't think of why anyone would want to.

This line stores your reply in the variable replay:
replay = getchar();

The `getchar()` macro, which looks and works like an ordinary C function, simply returns the ASCII code for the next character typed at the keyboard. The statement in which it appears also makes it possible to end the program. If you type any character other than Y or y, the condition for the `while` loop near the beginning of the program is not met. As a result, the program passes control to the next statement after this block. But the only thing after the `}` that ends this `while` loop is the `}` that ends `main()`. The compiler places the `rtl` instruction at the end of the generated code, so execution continues with the next statement after `jsl main()` in `START.ROOT`. The result is a return to the shell’s `#` prompt.

Making a Standalone Application

I hope you have now succeeded in getting the Name Game running. If you have, you’re ready to turn it into a standalone application. But before you can do that, you’ll have to tell the IIos that your name is George, so that the Name Game will end and return to the APW shell. Then you can type the command line

`#filetype namegame s16`

This changes the file type of the Name Game from `exe`, a file type which can be executed only under APW, to `s16`, a file type that can be loaded from the IIos finder (or, on older system disks, the IIos launcher).

Now you can astound your friends by letting them play the Name Game. The program may not be impressive enough to put on the market. But with a little imagination—and some fancy graphics tricks you’ll learn in this book—you’ll soon be able to turn it into something more complex and more or less annoying than the original.
The engineers who created the Apple IIgs accomplished a remarkable feat: they stuffed more than 9 megabytes of memory capacity into a computer originally designed to work with 48K of RAM. The secret of how they did it can be summed up in two words: bank switching.

Bank switching is based on the principle that two blocks of memory can share the same address as long as they don’t try to use it at the same time. When a computer uses bank switching, blocks of memory are assigned identical addresses. Special switching facilities are provided so that memory segments that use the same addresses can be switched into and out of the space they share.

In the Apple IIc and the expanded Apple IIe, blocks of memory that use bank switching are controlled by special electronic circuits called soft switches. A soft switch is a microcomputer circuit that can be turned on and off, just like a light switch. You’ll take a closer look at some of the soft switches built into Apple II computers later in this chapter. First, though, let’s pause for a brief look at the memory architecture of microcomputers in general and the Apple IIgs in particular.

**Memory Pages**

The term page is often used in memory mapping. A page is simply a block of 256 bytes of memory, or $100 bytes in hex notation. It is a convenient
unit of memory measurement because the 256 memory addresses in a page can be expressed using the hex values $00$ through $FF$. For example, page 0 on the Apple II memory map is made up of memory addresses $00$ through $FF$, and page 1 includes memory addresses $100$ through $1FF$. The address at which a page number changes—for example, memory address $1FF$, which is the last address on page 1—is known in assembly language as a page boundary.

(Incidentally, in Apple II graphics programming, the word page is also used to describe one screenful of graphics memory. These different uses of the same word should not be confused. You'll encounter graphics pages again later in this chapter.)

**Memory Banks**

Another important unit of memory measurement is a bank. A bank is a group of 256 pages, or a total of 65,536 (64K) banks of memory. The earliest models of the Apple II—the original Apple II and the Apple II + —have just one bank of memory, or a total of 64K. The Apple IIc (and the expanded Apple IIe) have two banks of memory, or 128K. A basic Apple IIgs, without a memory expansion card, has four banks of memory, or 256K. The IIgs's central processor, the 65C816, can address up to 256 banks, or 16 megabytes, of memory (that is, 16,384,000 bytes, or $FA0000$ bytes in hex notation).

Because the 65C816 can address 16 megabytes of memory, the address space of the IIgs also totals 16 megabytes—at least in theory. Actually, however, only 8.25 megabytes of memory are available for RAM expansion, and 1 megabyte is available for ROM expansion. The IIgs also comes with four banks, or 256K, of RAM. Figure 4–1 is a simplified memory map of an unexpanded Apple IIgs, just as it comes out of the box: with 256K of RAM. (A memory map of a fully expanded IIgs is presented in figure 1–2.)

**The Memory Manager**

Until the advent of the IIgs, people who wrote an assembly language program for an Apple II had to decide exactly where in memory their program would be loaded. Then they had to make sure the program would work properly when it was assembled and loaded into the chosen locations. In other words, it was the programmer's responsibility to allocate and manage memory.

With the introduction of the IIgs, this situation changed dramatically. The IIgs, as mentioned in chapter 1, is equipped with an ultrasophisticated programming tool that takes all responsibility for memory management from the programmer. This tool, called the Memory Manager, can allocate blocks of memory, discard blocks of memory when they are no longer needed, and even rearrange blocks of memory so that available RAM space can be used more efficiently. If you use the Memory Manager—and Apple strongly advises that you do—you will never again have to decide where in memory to start a program or a data segment, and you will never again have to juggle
blocks of memory so that they don’t “bump” into each other. All those tasks—and virtually every kind of task that involves memory management—are now jobs for the IIgs Memory Manager.

But the IIgs programmer still needs to know something about the memory architecture of the computer. The IIgs has a lot of firmware (pre-written programs) installed in specific locations in ROM, and it is sometimes helpful to know where they are. It is also helpful to know where screen memory starts and ends, where color tables and other graphics-related data are stored, and where important I/O routines can be found.

Another good reason for understanding the memory architecture of the IIgs is that it is sometimes necessary to place user-written routines in bank 0, so that they can access firmware designed for pre-gs Apple IIs without moving across bank boundaries.

Now that you know why memory sometimes must be managed manually, let’s take a closer look at the Memory Manager. The Memory Manager is built into ROM and goes to work automatically as soon as you turn on the computer. Every time you load an application program, a utility called the system loader (mentioned in chapter 1) calls the Memory Manager and requests memory space for the program. The loader then loads the program into memory at the address returned by the Memory Manager.

After an application program is running, it can summon the Memory Manager and request (or allocate) additional memory. It can also ask the Memory Manager to release (or deallocate) memory when it is no longer needed, and it can query the Memory Manager at any time to find out how much memory is available.
Managing Desk Accessories

The Memory Manager is so meticulous in its record keeping that it always knows which blocks of memory are in use, which programs are using them, and which blocks are free. So when the Memory Manager is active—and it always is—several programs can be present in memory at the same time (coresident), and you can switch back and forth among them at any time. This ability to handle several coresident programs is an important feature of the Memory Manager because it enables the IIgs to use desk accessories. Desk accessories are programs that can be loaded into memory once, then called up and used whenever desired, even while an application is running. Some accessories that can be handled in this way include clocks, calendars, calculators, and note pads.

The Memory Manager also makes it possible for a IIgs to be equipped with any amount of memory ranging from the standard 256K to 8.25 megabytes and for application programs to use the maximum amount of available memory in a way that is transparent to the user (and to the programmer as well).

APW and the Memory Manager

Because the Memory Manager is such an integral part of the IIgs, the APW assembler-editor and the APW C compiler are designed to work closely with the Memory Manager. When you use the APW assembler to write and assemble an assembly language program for the IIgs, you are advised not to assign the program a specific starting point in memory and not to use addressing modes that require literal addresses except when absolutely necessary.

When you follow Apple's guidelines for using the Memory Manager, the APW assembler automatically produces machine code that is relocatable and, therefore, can be handled easily by the Memory Manager. The Memory Manager can handle a relocatable program easily because it can load the program into any block of available RAM, and it can later move the program to another block if needed.

Pointers and Handles

To keep track of the IIgs's memory, the Memory Manager uses two important types of variables: pointers and handles. A pointer is a pair of memory addresses that contain, or point to, a second memory address. In C and assembly language programs, a pointer is a convenient tool for accessing a memory address because the block of memory can be changed by simply altering the addresses stored in the pointer. You examine how pointers work, and how they are used in Apple IIgs programs, in chapter 6. Figure 4-2 gives a rough idea of how a pointer is used in an assembly language program.

When the Memory Manager allocates a block of memory, it usually returns a handle rather than a pointer. A handle is a pair of memory addresses that point to a pointer, which in turn points to still another address. Because of the indirect way in which a handle is used, it is sometimes described as a pointer to a pointer. The use of handles is illustrated in figure 4-3.

The concept of a handle may sound obscure, but the Memory Manager has a good reason for using handles. The machine code produced by the APW assembler is relocatable and can therefore be shuffled around in memory at will by the Memory Manager. But even when a piece of machine code is
relocatable, moving it around in memory can still cause problems. For example, if a program contains a pointer and the code the pointer is supposed to access is moved, the pointer contains an invalid address and will almost certainly crash whatever program is running the next time it is used.

To keep this kind of disaster from occurring, the Memory Manager does not assign a pointer when it allocates a block of memory. Instead, it stores a pointer to the block in a non-relocatable table. The block’s handle is the fixed address to this pointer. In other words, a handle is simply a 4-byte space in which the current address of a block is kept. As the block is moved, this pointer changes, but the correct pointer can always be found in the same place: the handle.

Using this procedure, the Memory Manager can always keep track of any block of code, and blocks of code can always access each other, no matter how many times their addresses change.

**The ILGs Memory Map**

Now that you’ve seen how the Memory Manager works, you are ready to examine the memory map of the ILGs in more detail. Refer back to figure 4–1, the simplified ILGs memory map at the beginning of this chapter.

As you learned in chapter 1, the ILGs’s memory space can be divided into five major segments. Each of these segments can be subdivided into 64K
memory banks. Here is an outline of what each block of memory in the IIgs contains:

- Banks $00 and $01 (memory addresses $000000 through $01FFFF) include both free RAM and system memory. When the IIgs is in Apple IIc/IIe emulation mode, the addresses in these two banks are the only addresses available.

- Banks $02 through $7F (memory addresses $020000 through $7FFFFF) are available for RAM expansion.

- Banks $EO and $El (memory addresses $EO0000 through $E1FFFF) include some free RAM, but are also used for system, input/output (I/O), and display memory.

- Banks $FO through $FD (memory addresses $FO0000 through $FDFFFF) are available for ROM expansion.

- Banks $FE and $FF (memory addresses $FE0000 through $FFFFFF) are used for system firmware.

A more detailed map of the Apple IIgs is presented later in this chapter.
Mapping the IIgs in Emulation Mode

As noted previously in this chapter and in chapter 1, the Apple IIgs can be used in two modes: Apple IIc/IIe emulation mode and native mode (that is, as a fully equipped Apple IIgs). In this section, you’ll see how the memory of the IIgs is apportioned in emulation mode. Then you’ll examine the computer’s memory layout in native mode.

Figure 4-4 is a memory map of the Apple IIgs in Apple IIc/IIe emulation mode. In this mode, the IIgs operates as a 128K computer, and banks $00 and $01 are referred to as main memory and auxiliary memory—the same names they are known by in the Apple IIc and the expanded Apple IIe.

If you’re familiar with Apple IIc or Apple IIe assembly language programming, the map in figure 4-4 will be familiar. If you’re new to Apple II programming, though, a little map reading is in order. So let’s pause for a closer look at what the various blocks of memory in figure 4-4 contain when the IIgs is in emulation mode.

![Memory Map of Apple IIgs in Emulation Mode](image-url)
Fundamentals of IIgs Programming

- Addresses $00 to $FF (page 0). As you will see in chapter 5, memory addresses $00 to $FF, also known as page 0, are an important part of the memory map of any microcomputer. When the operand of an assembly language statement is a page 0 address, the instruction can be carried out faster because a page number does not have to be specified. And, as you shall see in chapter 6, some addressing modes require their operands to be on page 0.

  For now, it's sufficient to note that in an Apple IIc or an expanded Apple IIe, there are two bank-switchable page zeros: one in main memory and one in auxiliary memory. When the IIgs is operated in native mode, any page in bank $00 can be used as page 0—but we'll save further discussion of that point for chapters 5 and 6.

- Addresses $100 to $1FF (stack). The stack is a temporary storage area where values can be tucked away until needed. How the stack works and how it is used are examined in chapter 6.

  In the Apple IIc and the expanded Apple IIe, there are two bank-switchable stacks: one in main memory and one in auxiliary memory. When the IIgs is operated in native mode, the stack, like page 0, can be located anywhere in bank $00. This operation is also covered in chapters 5 and 6.

- Addresses $0200 to $03FF (input buffer, vectors, and link addresses). In bank $00, these addresses are used by the Applesoft input buffer and for certain operating system vectors and link addresses. In bank $01, they are available as free RAM.

- Addresses $0400 to $0BFF (text and low-resolution pages 1 and 2). As noted, the block of memory in which a screen display is stored is sometimes referred to as a page. In the earliest models of the Apple II, there were four such pages: two for text and low-resolution screen displays, and two for high-resolution displays. In the Apple IIc, the expanded Apple IIe, and the Apple IIgs, a second pair of high-resolution graphics pages and a second pair of text and low-resolution graphics pages are provided in auxiliary RAM.

  In all Apple II computers, animated displays can be created by using soft switches to flip between one high-resolution page and another, or between one text or low-resolution display and another. In the Apple IIgs, however, this capability exists only when the computer is in emulation mode, with IIc/IIe-style text or graphics displays. Soft switches are examined at the end of this chapter.

  As figure 4–4 illustrates, text and low-resolution page 1 extends from $0400 to $07FF, and text and low-resolution page 2 extends from $0800 to $0BFF. In application programs that do not use Apple IIc/IIe-style text or low-resolution graphics, both of these blocks of memory can be used as RAM.

- Addresses $0C00 to $1FF (free RAM). In both bank $00 and bank $01, this block of memory is available for use as free RAM.
How Pre-GS Programs Use Memory

When you load a program written for a pre-GS Apple II computer into the Apple IIgs, the IIgs firmware automatically sets up banks $00 and $01 as main and auxiliary memory and configures both banks for Apple IIc/Ile-style operations. The firmware also allocates pages $00 and $01 in bank $00 for use as page 0 and the stack, respectively. (There’s more about page 0 and the stack later in this chapter and in chapter 6.)

When the IIgs configures itself for emulation mode, memory outside banks $00 and $01 is not available for use in programs. But it can be used as a big RAM disk, designated /RAM5.

As you can see by looking at figure 4–4, the largest block of memory in main memory, or bank $00, is labeled main RAM. The largest block in auxiliary memory, or bank $01, is labeled auxiliary RAM. When the IIgs is in emulation mode, main RAM extends from $6000 to $BFFF in bank $00, and auxiliary RAM uses the same block of memory in bank $01. Application programs can use both of these blocks as free RAM.

In the Apple IIgs, just as in earlier Apple IIs, an application can switch
between bank $00 and bank $01 using soft switches—bytes in memory that, like a light switch, can be turned on and off to change memory banks and control IIc-style and IIe-style text and graphics displays.

**Language Card Area**

In the memory addresses that extend from $D000 to $DFFF in both bank $00 and bank $01, there is another block of bank-switchable memory that has come to be known as the language card area of RAM. It got its name when the Pascal language was first introduced for the Apple II and required more memory than what was available. The card added to accommodate Pascal no longer exists—it is now built into the main circuit board of Apple II computers—but this area of memory retains its original name.

Because there are two language card areas—one in bank $00 and one in bank $01—there are actually four banks of useable RAM between memory addresses $D000 and $E000. In bank $00, most of the language card space in both main memory and bank-switched memory is reserved for use by ProDOS (which is covered in chapter 12) and for other needs of the IIgs operating system. In bank $01, the bank-switched portion of the language card area is also reserved for use by system memory, but the portion that does not have to be bank switched is available for use as free RAM.

Now that you've had a good look at the emulation mode memory map of the IIgs, it should be pointed out that the map is misleading in one respect. When the IIgs is running in emulation mode, it does not directly address banks $00 and $01. Instead, all data in banks $00 and $01 is copied into banks $E0 and $E1. It is the copied data that the IIgs reads from and writes to when it is running an emulation program. This process, known as memory shadowing, is carried out because banks $E0 and $E1 are synchronized for use with emulation mode programs, but banks $00 and $01 are not. A fuller description of memory shadowing is presented at the end of this chapter.

As noted, the Apple IIgs has two memory maps; it uses one in emulation mode and the other in native mode. You've just examined the emulation mode memory map, and in a few moments you'll see how the map changes when the IIgs is switched to native mode. Before that, though, it is helpful to explore how the Apple IIgs emulates an Apple IIc.

**Mega II Chip**

As you may remember from chapter 1, the designers of the IIgs faced a double-edged problem. They wanted to build a computer that would not only run programs designed for earlier Apples, but also take full advantage of the increased operating speed and expanded memory addressing capabilities of the 65C816 microprocessor. They came up with an ingenious solution. They created a new integrated chip, the Mega II, to interface the new features of the IIgs with the old features of earlier members of the Apple II family.

The first job for the designers of the Mega II chip was achieving some kind of compatibility between the 2.8 MHz operating speed of the Apple IIgs and the 1 MHz operating speed of earlier Apples. They attained this goal by incorporating the Mega II into the design of the IIgs, as illustrated in figure 4–5.
As figure 4–5 shows, the Mega II chip is connected to

- The Apple IIgs’s ports and slots, which are operated under the control of a 1 MHz chip and are therefore compatible with the ports and slots in earlier Apple IIs.
- A 128K block of RAM called slow RAM, which is built into the IIgs to make it compatible with earlier members of the Apple II family.
- The video chips that generate the IIgs’s text and graphics displays when it is running in IIc/Ile emulation mode.
- The VGC (video graphics controller) chip, which generates the IIgs’s super high-resolution graphics display. Although the VGC chip was designed specifically for the IIgs and is not found in earlier Apple IIs, it operates at a 1 MHz clock speed so that it is synchronized with other video circuitry that is IIc/Ile compatible.

To interface the Mega II module with the 65C816 and the components it controls, Apple engineers designed another special chip called the fast processor interface, or FPI. The FPI, as figure 4–5 shows, is connected not only to the Mega II chip and its 1 MHz components, but also to all the IIgs components that operate at 2.8 MHz. These components include

- A 128K block of fast RAM that is laid out exactly like the 128K of slow RAM controlled by the Mega II
- All the 128K of ROM built into the IIgs
- All expansion RAM that the IIgs owner may install
- The 65C816 processor (which must be switched from 2.8 MHz to 1 MHz before the IIgs can operate in IIc/Ile emulation mode)
Now you're ready to study the concept of memory shadowing, which was briefly mentioned in this chapter. Memory shadowing is a technique the IIgs uses to copy data from banks $00 and $01 into banks $E0 and $E1 so that programs can be run from banks $E0 and $E1 when the computer is in emulation mode. Here, as promised, is an explanation of why memory shadowing is used in the IIgs and how it works.

Because programs written for the Iic and the Ile use memory addresses $0000 through $FFFF, the designers of the IIgs had to build the computer so that Iic and Ile programs could be run in banks $00 and $01. But banks $00 and $01 are also important to the operation of the IIgs in native mode, so they were designed to operate at the native mode speed of 2.8 MHz, not at the emulation mode speed of 1 MHz (the speed at which Iic/Ile programs must be run).

To make the IIgs compatible with programs written for earlier Apple IIs, the creators of the IIgs had to equip it with at least two banks of 1 MHz RAM. They didn't want to slow down banks $00 and $01 just to make them Iic/Ile compatible, so they decided to slow down banks $E0 and $E1—the only other two banks available on a bare-bones IIgs—and make them run at 1 MHz.

Banks $E0 and $E1 also have all the features needed to run Apple Iic/Ile programs. These features include language card mapping in memory addresses $D000 through $DFFF, space for hardware and I/O memory in addresses $C000 through $CFFF, and display buffers used for Iic/Ile-style video displays.

After all these features were incorporated into banks $E0 and $E1, only one problem remained: how to run emulation mode programs designed to be executed from banks $00 and $01 using the clock speed and Iic/Ile features built into banks $E0 and $E1. To solve this problem, the designers of the IIgs used the technique of memory shadowing. Here's how it works.

**The Quagmire State and the Shadow Register**

To find out the current status of the IIgs's shadowing operations, you can read the status of a memory location called the shadow register. The shadow register keeps track of the IIgs's shadowing state, which is also known as the computer's *quagmire state* because shadowing can make memory locations move around like shifting sand. The shadow register, or quagmire register, is at memory address $C035 in bank $E0.

In addition to controlling memory shadowing, the shadow register can also activate or deactivate the I/O and language card areas at addresses $C000 through $DFFF. See table 4–1.

When the shadow register selects shadowing for an area, the IIgs hardware executes any instruction that writes into the selected area in bank $00 or $01 by writing into both the selected area and the same address in bank $00 or bank $01. Then, because the RAM in banks $E0 and $E1 runs at 1 MHz, all code that is shadowed is executed at slow speed.

Shadowing of the I/O and language card spaces is controlled by bit 6 of the shadow register, sometimes referred to as the IOLC (I/O and language
### Table 4–1
The Shadow Register

<table>
<thead>
<tr>
<th>Bit</th>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>Text page 1 shadowing disabled</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>High-res page 1 shadowing disabled</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>High-res page 2 shadowing disabled</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>Super high-res buffer shadowing disabled</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>Shadowing of auxiliary high-res pages disabled</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>Reserved—do not find modify</td>
</tr>
<tr>
<td>6</td>
<td>1</td>
<td>I/O and language card operation disabled</td>
</tr>
<tr>
<td>7</td>
<td></td>
<td>Reserved—do not modify</td>
</tr>
</tbody>
</table>

card) bit. This bit is normally set to 0, which enables I/O in the $CXXX memory addresses and maps the 4K of RAM that ordinarily resides in that space into a second bank of RAM in the $DXXX address range. Figure 4–6 illustrates this operation.

### Shadowing and Interrupts

Some of the interrupt routines used in emulation mode are in ROM in the I/O space of the $C07X address range. For this code to operate, I/O must remain enabled in the $CXXX range of memory in bank $00, and the high 16K of RAM must remain mapped as a language card. In other words, the IOLC bit of the shadow register must be clear. If a program changes the IOLC bit so that it can use RAM in the $CXXX range, the interrupt routines in that area won’t work. So IOLC shadowing must be left on even by programs running in native mode, which otherwise do not use language card mapping.

### Display Shadowing

Programs run on the IIgs can also use display shadowing, which works a little differently than I/O shadowing. When I/O shadowing is used, both reading and writing are slowed to 1 MHz. When only display shadowing is selected, however, the slowdown affects only instructions that write to the shadowed areas. The 65C816 still reads from the display areas of banks $00 and $01 at 2.8 MHz.

When the IIgs loads a program, it automatically sets display shadowing to whatever is appropriate for the program’s operating system: on for DOS 3.3, UCSD Pascal, and ProDOS 8, and off for ProDOS 16 (the operating system used in native mode). An application can turn off shadowing of individual displays by setting individual bits in the shadow register.

More details about memory shadowing and how the shadow register works can be found in the *Apple IIgs Hardware Reference.*
Mapping the IIgs in Native Mode

The memory map used by the IIgs in native mode is considerably different from the one used in emulation mode. The most obvious difference is the native mode map is bigger. It can contain at least 256K of memory and as much as 8.25 megabytes of memory. There are other differences, too. For example, to give native mode programs as much free RAM as possible in banks $00 and $01, the computer’s native mode ROM is in banks $FE and $FF, opening up almost all the memory space in banks $00 and $01 for use as free RAM. System ROM includes Applesoft BASIC, the IIgs monitor, port firmware, and the part of the IIgs Toolbox built into ROM.

Figure 4–7 shows how memory is allocated when the IIgs is in native mode. Programs can occupy most of the space in banks $00 and $01, and all the expansion RAM space in banks $02 through $7F (if expansion RAM is installed). Applications can call the Memory Manager to obtain the memory they need in those areas.

In banks $E0 and $E1, however, there are some blocks of memory that
are not available for use as free RAM, even when the IIgs is in native mode. For example, the I/O space in the $CXXX region and text page 1 are shadowed from memory banks $00 and $01 into banks $E0 and $E1. These areas have to be shadowed for the proper operation of interrupts and peripheral cards, and thus cannot be used as free RAM by application programs.

There are other areas in banks $E0 and $E1, however, that are available for use in application programs. If you decide to use these banks in a program, remember that they are timed to operate as slow RAM—operating at 1 MHz—when they are written to. But they can be read from at the fast speed of 2.8 MHz. If a program merely reads from them, without writing to them, they won't slow the program.

Here is an outline of how the various blocks of memory in banks $E0 and $E1 are used when the IIgs is running in native mode:

- Addresses $0000 to $03FF in bank $E0. Reserved for system use. This block of RAM—used for shadowing page 0, the stack, and other important addresses when the IIgs is in emulation mode—is reserved for future expansion. It is not managed by the Memory Manager, but you can use it by managing it yourself. If you do, though,
your application may not be compatible with future models of the IIgs.

- Addresses $0400 to $07FF in bank $E0 (text page 1). Text page 1 is shadowed into this area even when the IIgs is in native mode. It is not managed by the Memory Manager, but you can use it if you manage it yourself. That could get you into trouble, however, because you never know when something such as a desk accessory might decide to use text page 1 and try to use this segment of memory.

- Addresses $0800 to $OBFF in bank $E0 (text page 2). Text page 2 is not likely to be used by a desk accessory (though it could be), so this region is fairly safe for use by an application program. The Memory Manager doesn’t manage it, though, so once again, beware.

- Addresses $0C00 to $1FFF in bank $E0. Reserved for use by the IIgs system.

- Addresses $2000 to $5FFF in bank $E0 (high-resolution pages 1 and 2). Available for use by application programs that don’t use high-resolution graphics pages 1 and 2. Managed as special memory by the Memory Manager (more about that in chapter 7).

- Addresses $6000 to $BFFF in bank $E0 (free RAM). This 24K chunk of memory is allocated as free RAM and is managed by the Memory Manager.

- Addresses $C000 to $FFFF in bank $E0. Used by the IIgs system. This segment of memory includes I/O space, the language card area, and other addresses used by the IIgs system. It’s off-limits to application programs.

- Addresses $0000 to $03FF in bank $E1. Reserved for system use. Not managed by the Memory Manager. Use at your own risk.

- Addresses $0400 to $0BFF in bank $E1 (alternate text pages 1 and 2). Rarely used and probably safe, but not managed by the Memory Manager.

- Addresses $0C00 to $1FFF in bank $E1. Reserved for use by the IIgs system.

- Addresses $2000 to $5FFF in bank $E1 (alternate high-resolution pages 1 and 2). Available for use by programs that don’t use alternate high-resolution pages 1 and 2. Managed as special memory by the Memory Manager. The special memory designation is covered in chapter 7.

- Addresses $6000 to $BFFF in bank $E1 (super high-resolution display). This is the super high-resolution screen display area of the IIgs. It can be managed as special memory by the Memory Manager. But most programs written for the IIgs use super high-resolution graphics, so using this area of memory as free RAM— even by a program that doesn’t require super high-res graphics—is strongly discouraged.
Soft Switches

If you’re an old hand at Apple II programming, you may be familiar with the concept of soft switches: bytes in memory that perform operations by simply being read from or written to.

If you like to manage Apple II operations using soft switches, you’ll be happy to know that the IIgs has all the soft switches its predecessors have—and an extra register to help you access them conveniently.

The soft switches in the IIgs, like the ones in earlier Apple IIs, reside in the $CXXX block of memory in bank $00. And, like their counterparts, they can be used for bank switching, I/O and graphics operations, and protecting certain blocks of memory by making it possible to read from them but not write to them. Table 4-2 lists some of the most often used soft switches in the Apple IIgs and earlier Apple IIs.

Accessing Soft Switches

There are three ways to manipulate the soft switches in the IIgs:

1. Some soft switches can be toggled on or off with either a read operation, such as lda, or a write operation, such as sta. For example, you can change the setting of the Page2 soft switch at $C055 with a statement such as

\[
\text{sta } \$C055
\]

or a statement like

\[
\text{lda } \$C055
\]

More details of how the Page2 soft switch works are presented in a moment.

2. Some soft switches can be turned on or off with a write operation. For example, you can turn on the RAMWrt switch at $C005 by writing any value to it, using a statement such as

\[
\text{sta } \$C005
\]
### Table 4–2
**Soft Switches**

<table>
<thead>
<tr>
<th>Name</th>
<th>Address</th>
<th>Access</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>80Store</td>
<td>$C000</td>
<td>Write</td>
<td>Off: RAMRd and RAMWrt determine RAM locations</td>
</tr>
<tr>
<td>80Store</td>
<td>$C001</td>
<td>Write</td>
<td>On: Page2 switches between main and auxiliary display pages</td>
</tr>
<tr>
<td>AltZP</td>
<td>$C008</td>
<td>Write</td>
<td>Off: Using main-memory page 0 and stack</td>
</tr>
<tr>
<td>AltZP</td>
<td>$C009</td>
<td>Write</td>
<td>On: Using auxiliary-memory page 0 and stack</td>
</tr>
<tr>
<td>Bank Select</td>
<td>$C080</td>
<td>Two Reads</td>
<td>Read RAM; no write; use $D000 bank 2</td>
</tr>
<tr>
<td>Bank Select</td>
<td>$C081</td>
<td>Two Reads</td>
<td>Read ROM; write RAM; use $D000 bank 2</td>
</tr>
<tr>
<td>Bank Select</td>
<td>$C082</td>
<td>Read</td>
<td>Read ROM; no write; use $D000 bank 2</td>
</tr>
<tr>
<td>Bank Select</td>
<td>$C083</td>
<td>Two Reads</td>
<td>Read and write RAM; use $D000 bank 2</td>
</tr>
<tr>
<td>Bank Select</td>
<td>$C088</td>
<td>Read</td>
<td>Read RAM; no write; use $D000 bank 1</td>
</tr>
<tr>
<td>Bank Select</td>
<td>$C088</td>
<td>Read</td>
<td>Read RAM; no write; use $D000 bank 1</td>
</tr>
<tr>
<td>Bank Select</td>
<td>$C089</td>
<td>Two Reads</td>
<td>Read ROM; write RAM; use $D000 bank 1</td>
</tr>
<tr>
<td>Bank Select</td>
<td>$C08A</td>
<td>Read</td>
<td>Read ROM; no write; use $D000 bank 1</td>
</tr>
<tr>
<td>Bank Select</td>
<td>$C08B</td>
<td>Two Reads</td>
<td>Read and write RAM; use $D000 bank 1</td>
</tr>
<tr>
<td>DHiRes</td>
<td>$C05E</td>
<td>Read/Write</td>
<td>On: If IOUDis is on, turn on double high resolution</td>
</tr>
<tr>
<td>DHiRes</td>
<td>$C05F</td>
<td>Read/Write</td>
<td>Off: If IOUDis is on, turn off double high resolution</td>
</tr>
<tr>
<td>HiRes</td>
<td>$C056</td>
<td>Read</td>
<td>Off: Display text page</td>
</tr>
<tr>
<td>HiRes</td>
<td>$C057</td>
<td>Read</td>
<td>On: Show high-res pages; make Page2 switch between high-res pages</td>
</tr>
<tr>
<td>IOUDis</td>
<td>$C07F</td>
<td>Write</td>
<td>On: Disable IOU access for SC058-SC05F; enable zDHiRes switch access</td>
</tr>
<tr>
<td>IOUDis</td>
<td>$C07F</td>
<td>Write</td>
<td>Off: Enable IOU access for SC058-SC05F; disable DHiRes switch access</td>
</tr>
<tr>
<td>Page2</td>
<td>$C054</td>
<td>Read</td>
<td>Off: Select text page 1 and high-resolution page 1</td>
</tr>
<tr>
<td>Page2</td>
<td>$C055</td>
<td>Read</td>
<td>On: If 80Store off, use main memory displays; if on, use auxiliary displays</td>
</tr>
<tr>
<td>RAMRd</td>
<td>$C002</td>
<td>Write</td>
<td>Off: Read main 48K RAM</td>
</tr>
<tr>
<td>RAMRd</td>
<td>$C013</td>
<td>Write</td>
<td>On: Read auxiliary 48K RAM</td>
</tr>
<tr>
<td>RAMWrt</td>
<td>$C004</td>
<td>Write</td>
<td>Off: Write to main 48K RAM</td>
</tr>
<tr>
<td>RAMWrt</td>
<td>$C005</td>
<td>Write</td>
<td>On: Write to auxiliary 48K RAM</td>
</tr>
<tr>
<td>Rd80Store</td>
<td>$C018</td>
<td>Read bit 7</td>
<td>Bit 7 tells whether 80Store is on (1) or off (0)</td>
</tr>
<tr>
<td>RdAltZP</td>
<td>$C016</td>
<td>Read bit 7</td>
<td>Bit 7 tells whether auxiliary memory (1) or main memory (0) accessed</td>
</tr>
<tr>
<td>RdBnk2</td>
<td>$C011</td>
<td>Read bit 7</td>
<td>Bit 7 tells whether $D000 is bank 2 (1) or bank 1 (0)</td>
</tr>
<tr>
<td>RdDHiRes</td>
<td>$C07F</td>
<td>Read bit 7</td>
<td>Read DHiRes switch (1 = on)</td>
</tr>
</tbody>
</table>
### Table 4–2 (cont.)

<table>
<thead>
<tr>
<th>Name</th>
<th>Address</th>
<th>Access</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>RdHiRes</td>
<td>$C01D</td>
<td>Read bit 7</td>
<td>Bit 7 tells whether high resolution is on (1) or off (0)</td>
</tr>
<tr>
<td>RdiOUDis</td>
<td>$C07E</td>
<td>Read bit 7</td>
<td>Read IOUDis switch (1 = off)</td>
</tr>
<tr>
<td>RdLCRAM</td>
<td>$C012</td>
<td>Read bit 7</td>
<td>Reading RAM (1) or ROM (0)</td>
</tr>
<tr>
<td>RdPage2</td>
<td>$C01C</td>
<td>Read bit 7</td>
<td>Bit 7 tells whether Page2 is on (1) or off (0)</td>
</tr>
<tr>
<td>RdRAMRd</td>
<td>$C013</td>
<td>Read bit 7</td>
<td>Bit 7 tells whether main memory (0) or auxiliary memory (1) is being accessed</td>
</tr>
<tr>
<td>RDRAMWrt</td>
<td>$C014</td>
<td>Read bit 7</td>
<td>Read whether main memory (0) or auxiliary memory (1) is being accessed</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Name</th>
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<th>Function</th>
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<td>80Store</td>
<td>Write</td>
<td>On: Page2 switches between main and auxiliary display pages</td>
</tr>
<tr>
<td>$C002</td>
<td>RAMRd</td>
<td>Write</td>
<td>Off: Read main 48K RAM</td>
</tr>
<tr>
<td>$C004</td>
<td>RAMWrt</td>
<td>Write</td>
<td>Off: Write to main 48K RAM</td>
</tr>
<tr>
<td>$C005</td>
<td>RAMWrt</td>
<td>Write</td>
<td>On: Write to auxiliary 48K RAM</td>
</tr>
<tr>
<td>$C008</td>
<td>AltZP</td>
<td>Write</td>
<td>Off: Using main-memory page 0 and stack</td>
</tr>
<tr>
<td>$C009</td>
<td>AltZP</td>
<td>Write</td>
<td>On: Using auxiliary-memory page 0 and stack</td>
</tr>
<tr>
<td>$C011</td>
<td>RdBnk2</td>
<td>Read bit 7</td>
<td>Bit 7 tells whether $D000 is bank 2 (1) or bank 1 (0)</td>
</tr>
<tr>
<td>$C012</td>
<td>RdLCRAM</td>
<td>Read bit 7</td>
<td>Reading RAM (1) or ROM (0)</td>
</tr>
<tr>
<td>$C013</td>
<td>RAMRd</td>
<td>Write</td>
<td>On: Read auxiliary 48K RAM</td>
</tr>
<tr>
<td>$C013</td>
<td>RdRAMRd</td>
<td>Read bit 7</td>
<td>Bit 7 tells whether main memory (0) or auxiliary memory (1) is being accessed</td>
</tr>
<tr>
<td>$C014</td>
<td>RdRAMWrt</td>
<td>Read bit 7</td>
<td>Read whether main memory (0) or auxiliary memory (1) is being accessed</td>
</tr>
<tr>
<td>$C016</td>
<td>RdAltZP</td>
<td>Read bit 7</td>
<td>Bit 7 tells whether auxiliary memory (1) or main memory (0) is being accessed</td>
</tr>
<tr>
<td>$C018</td>
<td>Rd80Store</td>
<td>Read bit 7</td>
<td>Bit 7 tells whether 80Store is on (1) or off (0)</td>
</tr>
<tr>
<td>$C01C</td>
<td>RdPage2</td>
<td>Read bit 7</td>
<td>Bit 7 tells whether Page2 is on (1) or off (0)</td>
</tr>
<tr>
<td>$C01D</td>
<td>RdHiRes</td>
<td>Read bit 7</td>
<td>Bit 7 tells whether high resolution is on (1) or off (0)</td>
</tr>
<tr>
<td>$C054</td>
<td>Page2</td>
<td>Read</td>
<td>Off: Select text page 1 and high-resolution page 1</td>
</tr>
<tr>
<td>$C055</td>
<td>Page2</td>
<td>Read</td>
<td>On: If 80Store off, use main memory displays; if on, use auxiliary displays</td>
</tr>
<tr>
<td>$C056</td>
<td>HiRes</td>
<td>Read</td>
<td>Off: Display text page</td>
</tr>
<tr>
<td>$C057</td>
<td>HiRes</td>
<td>Read</td>
<td>On: Show high-res pages; make Page2 switch between high-res pages</td>
</tr>
</tbody>
</table>
3. You can read some soft switches to see whether a given bit is on or off. For example, you can read bit 7 of the RAMWrt switch, at $C014, to find out whether main memory (bank $00) or auxiliary memory (bank $01) is being used for writing.

4. As a precaution against accidents, some soft switches have to be accessed twice in succession before they respond. For example, to turn on the soft switch at $C083, you must carry out a pair of operations, like this:

\[
\text{lda } \$C083 \\
\text{lda } \$C083 \\
\]

Please note that in this case, memory address $C083 is not being written to, but is merely being accessed with a read operation (\text{lda}). If you were writing to it—for example, with a \text{sta} instruction—it wouldn’t matter what was in the accumulator when the operation was carried out. That’s because it’s the act of accessing the switch, not the value written to it, that causes the switch to do its work. When you access a switch with a write operation, you can store any value in it (even a 0) and the result is always the same.
Using Soft Switches

As you may notice in table 4–2, the same name is sometimes used for two or more soft switches. That’s because some switches are activated with one switch and deactivated with another. And some switches are turned on with one address, turned off with another, and read from with still another. In table 4–2, nine switches that select memory banks are grouped under the same name: bank select. The following sections explain the operation of some important switches.

Selecting Main or Auxiliary RAM

Two switches, RAMRd and RAMWrt, select main or auxiliary RAM in the 48K memory space in banks $00 and $01 when the IIGs is in emulation mode. When RAMRd is on and the 80Store switch (which controls display memory) is off, RAMRd selects auxiliary memory for reading. When both 80Store and RAMRd are off, RAMRd selects main memory for reading. When RAMWrt is on and the 80Store switch is off, RAMWrt selects auxiliary memory for writing. When both RAMWrt and the 80Store switch are off, RAMWrt selects main memory for writing. That may sound quite complicated, but after you start using these three soft switches, you’ll become accustomed to how they work.

Both the RAMRd and RAMWrt switches use three memory addresses. One address turns the switch on, one turns it off, and one reads its state. To read the state of RAMRd, RAMWrt, or any other three-address switch listed in table 4–2, just check bit 7 of the appropriate memory address. If the switch is off, bit 7 is cleared to 0. If the switch is on, bit 7 is set to 1.

Selecting Display Memory

When the IIGs is displaying IIc/Ile-style high-resolution graphics, three soft switches—80Store, HiRes, and Page2—can select the portion of RAM used for screen memory. Each of these switches has three memory addresses—one that turns it on, one that turns it off, and one that reads its state by checking bit 7.

If the HiRes switch is off, Page2 switches between text pages 1 and 2. If HiRes is on, Page2 switches between high-resolution graphics pages 1 and 2.

If 80Store is off, RAMRd and RAMWrt determine whether to use the display pages in main or auxiliary RAM, and Page2 selects pages for display only—not for reading or writing. If 80Store is on, however, it overrides RAMRd and RAMWrt with respect to the display pages selected by HiRes and Page2.

The Machine State Register

There is one drawback in using the soft switches in table 4–2. Because they are in slow RAM—memory that runs at the emulation speed of 1 MHz, instead of the native mode speed of 2.8 MHz—the system is slowed down every time a soft switch is accessed directly.
But there is a way to access eight of the most commonly used soft switches without paying the penalty of changing operating speeds. That method is to use a special memory address called the *machine register*. (It's also called the state register or machine state register.) This register is situated at memory address $C068. Table 4–3 shows how each bit in the machine register is used.

### Table 4–3

The Machine State Register

<table>
<thead>
<tr>
<th>Bit</th>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>INTCXROM</td>
<td>Determines whether internal or slot card ROM will be used in the $C100 to $C7FF block of memory</td>
</tr>
<tr>
<td>1</td>
<td>RMBank</td>
<td>Selects the ROM bank in main memory (0) or auxiliary memory (1)</td>
</tr>
<tr>
<td>2</td>
<td>Bank2</td>
<td>Selects the main RAM bank (0) or auxiliary RAM bank (1)</td>
</tr>
<tr>
<td>3</td>
<td>RdROM</td>
<td>Activates the correct bank select switch to read ROM</td>
</tr>
<tr>
<td>4</td>
<td>RAMWrt</td>
<td>Turns the RAMWrt switch off and on</td>
</tr>
<tr>
<td>5</td>
<td>RAMRd</td>
<td>Turns the RAMRd switch off and on</td>
</tr>
<tr>
<td>6</td>
<td>Page2</td>
<td>Turns the Page2 switch off and on</td>
</tr>
<tr>
<td>7</td>
<td>AltZP</td>
<td>Turns the AltZP switch off and on</td>
</tr>
</tbody>
</table>

In this chapter, you saw how much memory is in the IIGs, its location, how it is accessed, and its uses. In chapter 5, you take an inside look at the 65C816 processor and see what makes it go.
One major component that sets the Apple IIs apart from earlier members of the Apple II family is the 65C816 central processing unit, or CPU. The 65C816, as noted in chapter 1, is a 16-bit chip that runs almost three times as fast as the 6502 and 65C02 processors in earlier Apple IIs.

The 65C816 has other advantages over its 8-bit predecessors. Because of its 16-bit data-handling capacity, programs written for the 65C816 are 25 to 50 percent shorter than programs written for earlier 6502–style processors. The 65C816 can also address far more memory than any of its 8-bit counterparts.

In this chapter and in chapter 6, you see how the 65C816 does all those things and what its advanced features mean to the Apple IIs programmer. The instruction set of the 65C816 is described in appendix A.

All in the (6502) Family

The 65C816 is a member of the venerable 6502 family of microprocessors. The first Apple II, built in 1977, was designed around a 6502 chip. Since then, various models of the 6502 have been built into every computer in the Apple II line. The CPU in the Apple IIe was a slightly improved 6502 called the 6502B. The Apple IIc was built around a further expanded 6502 called a 65C02. The 65C02 is equipped with 27 more assembly language instructions
than the original 6502, plus an expanded set of addressing modes. A few months after the 65C02 appeared in the Apple IIc, it became standard equipment in the Apple IIe.

Apple is not the only manufacturer that has used 6502 chips in its products. The Commodore 64's CPU is a 6502-style chip called the 6510, and the Commodore 128 runs on a version of the 6502 called an 8502. Atari still uses 6502 chips in its line of 8-bit computers. Because of their versatility, availability, and low price, 6502-family chips have been widely used in standalone configurations in the fields of robotics and computer-aided manufacturing.

There are a number of important differences between the 65C816 and all its 6502 predecessors, including the original 6502 and the 65C02. For example:

- The 65C816 is the first 16-bit chip in the 6502 family. It can perform calculations on 16-bit values—numbers ranging from 0 to 65,535—without dividing them into smaller numbers as its predecessors had to do.
- All previous 6502-family chips had 16-bit address buses. Therefore, they could address memory locations ranging from $0000 to $FFFF, or from 0 to 65,535 in decimal notation. But the 65C816 has a 24-bit address bus, so it can address up to 16 megabytes of memory (although only 8.25 megabytes of its RAM addressing capability are utilized by the Apple IIos).
- The 65C816 has nine internal registers, three more than its predecessors. In this chapter, you’ll examine all nine of the 65C816’s internal registers.
- The 65C816 operates at a clock speed of 2.8 MHz, compared with a clock speed of 1.024 MHz for all previous members of the 6502 family.
- The 65C816 recognizes 9 new addressing modes and 78 new machine language opcodes. Thus, it can do more with less code than its 8-bit predecessors.
- The 65C816 can be operated in two modes: in native mode as a full-featured 16-bit chip and in an emulation mode as a 65C02. The processor’s emulation mode makes the Apple IIgs compatible with earlier Apple IIs.

Inside the 65C816

The most important components of the 65C816 are illustrated in figure 5–1. They include:

- A 16-bit data bus
- A 24-bit address bus
- Nine internal registers
An arithmetic and logic unit, or ALU

In this chapter, you’ll examine these components in detail, beginning with the 65C816’s data and address buses.

**Buses**

The rectangles across the top and bottom of figure 5–1 represent buses, lines used for the transmission of addresses, instructions, and data. The bus at the top of the illustration is a data bus, and the one at the bottom is an address bus.

Data buses are quite appropriately named; they move data between the registers in the CPU and the memory registers in a computer’s RAM and ROM. An address bus transmits the addresses that data is being moved from and to.

When the 65C816 is operated in 8-bit emulation mode, it has an 8-bit data bus and a 16-bit address bus. It can perform operations on numbers ranging from $00$ to $FF$ (0 to 255 in decimal) and can access memory addresses ranging from $0000$ to $FFFF$ (0 to 65,535 in decimal).

When the processor is running in native mode, it has a 16-bit data bus and a 24-bit address bus. It can perform operations on numbers ranging from $0000$ to $FFFF$ (0 to 65,535 in decimal) and can access memory addresses ranging from $000000$ to $FFFFF$ (0 to 16,772,215 in decimal).

**Internal Registers**

As mentioned, the 65C816 has nine internal registers. They are the

- Accumulator
- X register
- Y register
- Program counter
- Stack pointer
- Processor status register

Figure 5–1

Simplified block diagram of the 65C816
Fundamentals of IIgs Programming

- Data bank register
- Program bank register
- Direct page register

Three of the 65C816’s registers—the data bank register, program bank register, and direct page register—handle the extended addressing functions of the 65C816 and are initialized to 0 when the chip is in emulation mode. But when the 65C816 is in native mode, all nine of its internal registers are active.

Figure 5–2 shows how the 65C816’s registers are used when the chip is in native mode. Figure 5–3 shows the configuration of the registers when the 65C816 is in emulation mode. Now let’s examine each register, in both native mode and emulation mode.

**Accumulator**

The accumulator (abbreviated A or C) is a 16-bit register divided into two 8-bit registers when the 65C816 is in emulation mode. When the 65C816 is in native mode, the accumulator is referred to as the A register. But when the register is split for emulation mode operations, its low-order byte is abbreviated A, its high-order byte is abbreviated B, and the register as a whole is abbreviated C. The accumulator is the 65C816’s busiest register. You’ll take a closer look at it later in this chapter.

![ACCUMULATOR (A OR C)](image)

![DBR (B)](image)

![PBR (K)](image)

![Figure 5–2](image) 65C816 register configuration in native mode
X Register

The X register (abbreviated X) is an 8-bit register when the 65C816 is in 8-bit emulation mode, but expands into a 16-bit register when the processor is in 16-bit native mode. In the 65C816, as in other 6502-family processors, the X register is often used for the temporary storage of data. But it also has an important special feature. It can be incremented with a simple 1-byte assembly language instruction (inx) and decremented with another 1-byte instruction (dex). It is therefore used quite often as a counter and as an index register during loops in programs.

Y Register

The Y register (abbreviated Y) is also an 8-bit register when the 65C816 is in 8-bit emulation mode and expands to a 16-bit register when the processor is in 16-bit native mode. The Y register, like the X register, can be incremented and decremented with a pair of 1-byte instructions (iny and dey). The Y register is also used as an index register and for storing data.
**Program Counter**

The program counter (abbreviated PC) is a pair of 8-bit registers. In both emulation mode and native mode, these two registers are combined and used as one 16-bit register.

The two 8-bit registers that make up the program counter are sometimes referred to as the program counter low (PCL) register and the program counter high (PCH) register. During native mode operations, the contents of the PCL and PCH registers are appended to the value of another 8-bit register called the program bank register. The combined contents of all three registers are then treated as a single 24-bit address. You'll learn more about the program bank register later in this chapter.

It is important to remember that the program counter (and the program bank register, if the 65C816 is running in native mode) always contains the memory address of the next instruction to be executed. When that instruction is carried out, the address of the instruction that follows it is loaded into the program counter.

**Stack Pointer**

The stack pointer (abbreviated S or SP) is a register that always contains the address of the next available memory address in a block of RAM called the stack. It is an 8-bit register in emulation mode and a 16-bit register in native mode. As you may recall from chapter 2, the 65C816 stack is a special block of memory in which data is often stored temporarily during the execution of a program. When the 65C816 is in emulation mode, the stack is always on page 1 in bank $00 (unless a soft switch shifts it to bank $01), so the stack pointer has to be only 1 byte long. But in native mode the stack can start anywhere in bank $00, so the stack pointer has to be 2 bytes long.

When subroutines are used in assembly language programs, the 65C816 often uses the stack as a temporary storage location for return addresses. The stack is also available for use in application programs. The operation of the stack is discussed in more detail in chapter 6, which is devoted to 65C816 addressing.

**Processor Status Register**

The processor status register (often called simply the status register, but abbreviated P) is an 8-bit register that keeps track of the results of operations performed by the 65C816. The processor status register is such an important part of the 65C816 processor that you'll take a closer look at it later in this chapter.

**Program Bank Register**

The program bank register (abbreviated PBR or K) is an 8-bit register initialized to 0 when the 65C816 is in 8-bit emulation mode. When the processor is in native mode, however, the program bank register becomes very important. In native mode, every time the 65C816 has to get an instruction from memory, it gets it from the location pointed to by the concatenation of the
program bank register and the program counter. So, when the 65C816 is in native mode, it uses the program bank register to extend the addressing capability of the program counter to 24 bits.

Because of the hybrid nature of the 65C816, it is not quite accurate to view the program counter and the program bank register as a single register. Sometimes they do work as one register, but more often they don’t. Most of the instructions the 65C816 inherited from the 6502 use the address stored in the program counter, but ignore the bank number stored in the program bank register. In other words, they recognize only short addresses. But there are a few new or redesigned instructions that do treat the PC and the PBR as one 24-bit register. In other words, they recognize long addresses.

Instructions that recognize only short addresses work fine in programs written for the native mode 65C816; they just can’t cross bank boundaries. That usually doesn’t cause any serious problems in IIos programs because a IIos program segment can’t cross a bank boundary. If it tries, the program counter simply rolls over to memory address $0000 in whatever bank the segment started in. For example, if the program counter increments past $FFFF, it rolls over to $0000 without incrementing the program bank register.

Instructions that recognize long addresses are a little easier to work with. You can move them from any address to any other address, without worrying about bank boundaries. Unfortunately, there are only five such instructions: jmp (when it is used to jump to an absolute long or indirect long address), js l (jump to subroutine—long), rtl (return from subroutine—long), brl (branch to long address), and rti (return from interrupt).

Because the program bank register always contains the bank number of the program currently being executed, there is no assembly language instruction for changing the value of the PBR. But there is an instruction—phk—that pushes the value of the PBR onto the stack so that it can be pulled off the stack and into another register. More information on that topic is provided in chapter 6.

Data Bank Register

The data bank register (abbreviated DBR or B) is an 8-bit register that is initialized to 0 when the 65C816 is in 8-bit emulation mode. When the 65C816 is in native mode, the DBR designates the bank currently being used as a data bank by instructions that read and write data.

Usually, the data bank register and the program bank register contain the same bank number, because assembly language programs are ordinarily stored in the same bank as the data they access. But sometimes it is more convenient to store a program in one bank and place a long data segment, such as a bit map, in another. The value of the data bank register can be changed temporarily to permit access to the bit map.

The data bank register works much like the program bank register. When the 65C816 is in native mode and an instruction for fetching or storing data is used with a 16-bit operand, the address specified by the operand is con-
catenated with the value of the data bank register to form a 24-bit address. For example, if a program is running in bank $06, and the 65C816 encounters the instruction

\( \text{lda} \ \$\text{FEF0} \)

the accumulator is loaded with the contents of memory address $06\text{FEF0}$. There are ways to force the 65C816 to access addresses in other banks with instructions such as \text{lda}, but you won’t get into that subject until chapter 6.

The data bank register can be accessed with the instructions \text{phb} and \text{plb}. The \text{phb} instruction pushes the address of the DBR on the stack. The \text{plb} instruction can be used to pull a value off the stack and place it in the data bank register. These operations are explained in more detail in chapter 6.

**Direct Page Register**

An area of memory called page 0 is a very valuable piece of real estate in the memory map of pre-os Apple IIs. In the Apple IIc and the Apple IIe, page 0 extends from memory address $00$ to memory address $\$\text{FF}$ in bank $\$00$ or bank $\$01$ (depending on the soft switch settings), and can therefore be accessed with a 1-byte operand. So instructions that address memory locations on page 0 run faster than they would if they accessed locations elsewhere in memory.

That is not the only reason that space on page 0 is so valuable. Some 65C02 addressing modes, called *indirect addressing modes*, require their operands to be page 0 addresses. As a result, space on page 0 is at a real premium in 8-bit Apple IIs.

In programs written for the Apple IIgs, however, page 0 is no longer the high-rent district. With the help of a new 16-bit register called the direct page register (abbreviated D), a IIgs programmer can move what was once called page 0 to any 256-byte area of memory in bank $\$00$ that begins on a byte boundary. Because it has become a moveable page in the Apple IIgs, it is no longer called page 0, but is referred to as the direct page.

When you want to instruct the IIgs to use a given page as a direct page, all you have to do is place the starting address of the direct page of your choice in the direct page register. You can even give different segments in a program different direct pages, so that a direct page used by one part of a program doesn’t conflict with the direct page used by another.

There are two instructions for accessing the direct page register: \text{phd}, which pushes the value in the direct page register on the stack, and \text{pld}, which pulls a value off the stack and places it in the direct page register. More details about these instructions and direct page addressing are provided in chapter 6.
The Arithmetic and Logical Unit

The arithmetic and logical unit, or ALU, is a component that can perform arithmetic and logical operations on data stored in a computer. It does its work with the help of the 65C816's busiest internal register, the accumulator.

As you shall soon see, the 65C816 wouldn't be much of a microprocessor if someone took away its accumulator. Every time the 65C816 is called upon to perform an operation on a value, the value first has to be placed in the accumulator.

The accumulator does its work with the help of another very busy component, the ALU. Every time the 1105 performs a calculation or a logical operation, the ALU is where the work is actually done.

The ALU performs only two kinds of calculations: addition and subtraction. The ALU solves division and multiplication problems by sequences of addition and subtraction operations.

Another job of the ALU is to compare values. But as far as the 65C816 chip is concerned, the comparison of two numbers is also an arithmetic operation. When the 65C816 chip compares two values, it subtracts one value from the other. Then, by merely checking the results of this subtraction, it can determine whether the subtracted value is more than, less than, or the same as the value it was subtracted from.

As figure 5-1 illustrates, the ALU is often depicted in diagrams as a V-shaped hopper. The ALU has two inputs (traditionally illustrated as the two arms of the hopper) and one output (represented as the bottom of the V). When two numbers are added, subtracted, or compared, one number is placed in the ALU through one of its inputs and the other number is put in through the other input. The ALU then carries out the requested calculation and puts the answer on a data bus so it can be transported to another register.

Here's a more detailed look at what happens inside the accumulator and the ALU when two numbers are added, subtracted, or compared. First, a number is stored in the 65C816's accumulator. Next, the accumulator deposits that number in the ALU through one of the ALU's inputs. The other number is placed in the ALU through its other input. Then the ALU carries out the requested calculation, and the result of the calculation finally appears at the output of the ALU. As soon as the answer appears, it is placed in the accumulator, where it replaces the value originally stored there.

Listing 5-1, a tiny assembly language program titled ADDNRS.S, shows how this process works.

```
Listing 5-1
ADDNRS.S program, version 1

lda #2
adc #2
sta $8000
```

The first statement in the ADDNRS.S program, `lda #2`, means `load`
the accumulator with the literal number 2. As you may recall from chapter 1, the # in front of the numeral 2 means the 2 is interpreted as a literal number. If there were no #, the 2 would be interpreted as the address of a memory register.

The second instruction in the listing, adc, means add with carry. In 65C816 arithmetic, the addition of two numbers often results in a carry from a low-order word to a high-order word (or from a low byte to a high byte if the processor is in emulation mode)—in much the same way that you carry numbers from one column to another in ordinary pencil-and-paper addition. If there was a carry in the ADDNRS.S program, the adc instruction would be able to handle it. Later in this chapter you’ll find out how. But in this addition problem, there is no number to be carried, so the adc instruction only adds 2 and 2.

When the statement adc #2 is executed, the 2 that has been loaded into the accumulator is deposited into one of the ALU’s inputs. The instruction adc #2 is placed in the ALU’s other input. The ALU then carries out this instruction; it adds 2 and 2, and places the sum back in the accumulator.

Now you’re ready for the third and last instruction in the ADDNRS.S program. The numbers 2 and 2 have been added, and their sum is now in the accumulator. The instruction in line 3, sta, means store the contents of the accumulator (in the memory address that follows). Because the accumulator now holds the value 4 (the sum of 2 and 2), the number 4 will be stored somewhere.

The memory address that follows the instruction sta is $8000—the hexadecimal equivalent of the decimal address 32768. So it appears that the number 4 will be stored in memory register $8000.

Now take a close look at the operand in line 3: the hexadecimal number $8000. There is no # in front of the value $8000, so the APW assembler will not interpret it as a literal number. Instead, $8000 is interpreted as a memory address—which is what a number has to be in assembly language if it is not designated as a literal number and carries no other identifying labels.

(Incidentally, if you want the assembler to interpret $8000 as a literal number, you have to write #$8000. When # and $ both appear before a number, the number is interpreted as a literal hexadecimal number. If the third line of the program was sta #$8000, however, there would be a syntax error. That’s because sta is an instruction that must be followed by a value that can be interpreted as a memory address—not by a literal number.)

The Processor Status Register

The processor status register (P) is built differently from the other registers in the 65C816 and is used differently, too. Unlike the 65C816’s other registers, the processor status register isn’t designed for storing or processing numbers. Instead, its 8 bits are flags that keep track of several kinds of important information. Figure 5-4 shows the layout of the processor status register.

As illustrated in figure 5-4, the processor status register can be visu-
alized as a rectangular box containing eight square compartments, with a ninth and tenth compartment sitting on top. (More about those later.) Each of the lower compartments in figure 5-4 represents one of the register’s 8 bits. If a bit has the binary value 1, it is set. If it has the binary value 0, it is reset, or clear.

The bits in the 65C816 status register—like the bits in all 8-bit registers—are customarily numbered from 0 to 7. By convention, the rightmost bit in an 8-bit register is referred to as bit 0, and the leftmost bit is referred to as bit 7.

Now let’s look briefly at each of the P register’s ten flags. Then the operation of each flag is described in greater detail.

**Status Flags**

Four of the processor status register’s eight bits are called status flags. They

---

**The P Register Flags at a Glance**

![Image of P Register Flags at a Glance]

---

**Figure 5–4**

Processor status register

---

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keep track of the results of operations carried out by the other registers inside the 65C816 processor.

- **Bit 0**: carry (c) flag. In arithmetic operations, the carry flag determines whether a number will be carried from one 16-bit integer to another (if the 65C816 is in native mode) or from one 8-bit byte to another (if the 65C816 is in emulation mode).

- **Bit 1**: zero (z) flag. Novice programmers often get confused about the way this flag works; it does the opposite of what you might expect. When the result of a calculation is 0, the zero flag is set. When the result of a calculation is not 0, the zero flag is cleared.

- **Bit 6**: overflow (v) flag. This bit determines if there has been a carry, or overflow, to the leftmost bit in a byte or word as the result of a calculation involving signed numbers.

- **Bit 7**: negative (n) flag. If the result of a calculation is negative, this flag is set. If the result of a calculation is not negative, the flag is cleared.

### Condition Flags

The other four bits in the processor status register are called condition flags. They determine if certain conditions exist with respect to the configuration of the IIGs or the operation of a program.

- **Bit 2**: IRQ disable (i) flag. If the IRQ (interrupt) disable flag is set, interrupts are disabled. If it is clear, they are enabled.

- **Bit 3**: decimal mode (d) flag. If the decimal flag is set, the 65C816 performs addition and subtraction operations in binary coded decimal (BCD) mode. If it is clear, the processor will add and subtract in its normal binary mode.

- **Bit 4**: index register select (x) flag. This flag, together with the e flag (described in a moment), determines whether the 65C02 treats its X and Y registers as 8-bit or 16-bit registers.

- **Bit 5**: memory/accumulator select (m) flag or break (b) flag. When the 65C816 is in emulation mode, bit 5 is a break flag and can be read following an interrupt to determine whether the interrupt was hardware generated or software generated. When the 65C816 is in native mode, however, it doesn’t need a break flag because a set of interrupt vectors make a break flag unnecessary.

  Because a break flag is not needed in native mode operations, bit 5 of the P register is free to be used for another purpose when the 65C816 is in 16-bit mode. During native mode operations, bit 5 is called the memory/accumulator select flag and is used to determine whether the accumulator and the IIGs’s memory registers are treated as 8-bit or 16-bit registers.
Toggling Between Native and Emulation Mode

The processor status register also has a tenth flag. The emulation (e) flag determines whether the 65C816 will operate in native mode or emulation mode. Because the P register contains only eight bits, the e flag is a "hanging bit" that shares bit 0 with the carry (c) flag. Normally, bit 0 is a carry flag, but a special assembly language instruction—`xce`—exchanges the positions of the two flags, placing the e flag in bit 0 and making the c flag the hanging bit. The e flag can then be set or cleared using the mnemonics `sec` (set carry) and `clc` (clear carry). After the e flag is set or cleared, the `xce` mnemonic can switch the e flag and the c flag back to their original positions. As you may have guessed by now, there are some significant differences between the way the 65C816 works in native mode and in emulation mode. Switching the 65C816 back and forth between native mode and emulation mode can be a tricky business. It involves three P register flags—the e, m, and x flags—and setting them so they work together is an important part of 65C816 programming. Here are some handy facts and tips about the e, m, and x flags.

**Emulation Flag**

The e (emulation) flag of the processor status register determines whether the 65C816 will operate as a full-featured 16-bit chip or as an 8-bit 65C02 chip. When the e flag is set to 1, the 65C816 processor is in emulation mode and works exactly like the 65C02 chip in the Apple IIc and later models of the Apple IIe. For example, when the 65C816 is in emulation mode

- It uses an 8-bit accumulator, 8-bit X register, 8-bit Y register, and 8-bit stack pointer.
- It can address only one 64K bank of memory—either bank $00 or bank $01, depending upon soft switch settings.
- It uses page $00 as page 0, and it uses page $01 as the stack.
- To perform arithmetic and logical operations on numbers greater than 8 bits (numbers greater than 255), it must break them into smaller increments.
- When it receives an instruction to fetch data (for example, `lda`), it fetches 1 byte of data at a time, from just one memory location. When it receives an instruction to store data (for example, `sta`), it stores 1 byte of data at a time, in just one memory location.

When the e flag is cleared to 0, the 65C816 goes into native mode. Then it becomes a 16-bit chip, with these characteristics:

- Its accumulator, X register, and Y register are expanded into 16-bit registers.
- Its program bank register and data bank register are activated, giving the capability of addressing up to 16 megabytes of memory (although only 8.25 megabytes of memory are available in the Apple IIgs).
- Its stack pointer is expanded into a 16-byte register, providing it
with the capability of using a stack situated anywhere within bank $00, not limited to a memory capacity of 256 bytes.

- Its direct page register is activated, providing it with the capability of placing its direct page (the equivalent of a page 0) anywhere in bank $00.

- It becomes capable of carrying out arithmetic and logical operations on 16-bit numbers (numbers ranging from 0 to 65,535) without breaking them into smaller increments.

- When it receives an instruction to fetch data (for example, Lda), it fetches 2 bytes of data at a time, from two consecutive memory locations. When it receives an instruction to store data (for example, sta), it stores 2 bytes of data at a time, in two consecutive memory locations.

As explained, the e flag can be set and cleared using the instructions xce, sec, and cLc. There are also APW commands and macros that perform the same actions. You’ll learn more about those in chapter 7 and later chapters.

**Memory/Accumulator Flag**

When the 65C816 is running in emulation mode—that is, when the P register’s e flag is set—the 65C816 accumulator is always 8 bits wide. But when the processor is running in native mode—that is, when the P register’s e flag is clear—the width of the accumulator can be set to either 8 bits or 16 bits, depending upon the setting of the P register’s m (memory/accumulator) flag.

When the 65C816 is in 8-bit mode and the accumulator is 16 bits wide, its low-order bit is the A register, its high-order bit is the B register, and both bytes combined are sometimes referred to as the C register. When the accumulator is configured in this fashion, the accumulator’s B register becomes an extra 65C816 register in which 8-bit values can be stored.

Here’s how the B register works. When the 65C816 is switched from 16-bit mode to 8-bit mode, the accumulator’s high-order bit becomes the B register, and any value that was there remains there. Any time thereafter, a new 65C816 instruction, xba, can exchange the values of the A and B registers. No other 65C816 instruction affects the B register. As long as the 65C816 remains in 8-bit mode, the “hidden” B register can be used as a safe storage space for any 8-bit value.

Here, in summary, is the formula for setting the width of the accumulator. If e = 1, the 65C816 is in emulation mode and the accumulator is 8 bits wide. If e = 0 and m = 0, the 65C816 is in native mode, the accumulator is 16 bits wide, and the accumulator always addresses memory 2 bytes at a time. But if e = 0 and m = 1, the 65C816 is in native mode, the accumulator is 8 bits wide, and the accumulator always addresses memory 1 byte at a time.

When the 65C816 is in native mode and the m flag is used to shorten the accumulator to 8 bits, the data stored in the B register (the accumulator’s high byte) simply stays there. Because the 65C816 does not use the B register during 8-bit operations, the data remains there, untouched, until it is moved
into the lower 8 bits of the accumulator using the xba instruction or until the accumulator is switched back into 16-bit mode.

If you're wondering why anyone would want to use an 8-bit accumulator in 16-bit mode, there's a simple answer. For example, when you need to read a string of 1-byte ASCII characters stored in a block of memory, it's desirable to fetch them and process them 1 byte at a time. Similarly, it's sometimes desirable to write a series of 1-byte values into memory. An 8-bit accumulator can often perform jobs like that more easily and conveniently than a 16-bit accumulator.

The m flag is set using the assembly language mnemonic sep, which stands for set status bits. To use the instruction, just follow it with a 1-byte value that has a set bit in the position corresponding to the bit in the P register you want to set. You don't have to do any bit masking because zeros in the operand have no effect on their corresponding bits. Because the P register's m flag is bit 5 when the 65C816 is in native mode, you set it with the statement

```
sep %00100000
```
or

```
sep #$20
```

which means the same thing.

The m flag is cleared with the instruction rep, which stands for reset status bits. rep works like sep, but in reverse. Give it an operand with a bit set, and it clears the corresponding bit in the P register, without affecting any bits that correspond to zeros in the operation. You could therefore clear the P register's m flag with the statement

```
rep %00100000
```
or

```
rep #$20
```

It is easier to set and clear the m flag with APW directives and macros. You'll see how those methods work starting in chapter 7.

**Index Register Select Flag**

When the 65C816 is running in emulation mode—that is, when the P register's e flag is set—the 65C816's X and Y registers (like its accumulator) are always 8-bit registers. But when the processor is running in native mode—that is, when the P register's e flag is clear—the widths of the X and Y registers (like the width of the accumulator) can be set to either 8 bits or 16 bits, depending upon the setting of the P register's index register select (x) flag.

The x flag sets the width of both the X register and the Y register. The formula for using it is much like the formula for setting the width of the
accumulator. If \( e = 1 \), the 65C816 is in emulation mode and its X and Y registers, like its accumulator, are 8-bit registers. If \( e = 0 \) and \( x = 0 \), the 65C816 is in native mode and the X and Y registers are 16-bit registers that always access memory 2 bytes at a time. But if \( e = 0 \) and \( x = 1 \), the 65C816 is in native mode and the X and Y registers are 8-bit registers that always address memory 1 byte at a time.

The X and Y registers can be placed in 8-bit mode for the same reason that the accumulator can be turned into an 8-bit register. For example, when you need to read a string of 1-byte ASCII characters stored in a block of memory, it's desirable to access them using the X register or the Y register. And when the accumulator is in 8-bit mode, it's usually a good idea to shorten the X and Y registers, too, because it's easier to keep track of registers that are the same length.

One note of caution should be mentioned regarding the use of the x flag. When it is used to reduce the size of the X and Y registers to 8 bits, the contents of their high-order bytes are lost. So before you slice the X and Y registers in half, be sure to save the values of their high bytes if you want to use them later.

The x flag, like the m flag, can be set using the assembly language mnemonic \texttt{sep}. Because the P register's x flag is bit 4, it can be set with the statement

\[
\texttt{sep } \%00010000
\]

or

\[
\texttt{sep } \$10
\]

which means the same thing.

The x flag, like the m flag, can be cleared with the \texttt{rep} instruction:

\[
\texttt{rep } \%0001100000
\]

or

\[
\texttt{rep } \$120
\]

APW directives and macros make it easier to set and clear the x flag. They are covered starting in chapter 7.

Now, as promised, let's take a closer look at each bit, or flag, in the processor status register.

\begin{center}
\textbf{A Closer Look at the P Register's Flags}
\end{center}

\textbf{Carry Flag}

As pointed out in chapter 2, the 65C816 cannot perform arithmetic operations on numbers longer than 16 bits (greater than 65,535) without dividing them into smaller numbers. When the 65C816 chip is in 8-bit emulation mode, its
arithmetic capabilities are reduced even further. In emulation mode, when you need to perform an operation involving a number greater than 255—or even a calculation with a result greater than 255—each number greater than 255 must be broken down into smaller numbers. When the calculation is completed, all numbers that have been split must be patched together before they can be output in a form that makes sense to the user. When the 65C816 is in native mode, it can handle larger numbers. But when an arithmetic operation involves the use of numbers greater than 65,535, they must be broken down into smaller units even when the processor is running in 16-bit mode.

This kind of mathematic "cutting and pasting," as you can imagine, involves a lot of carrying (in addition problems) and borrowing (in subtraction problems). The carry flag of the P register (bit 0) keeps up with all of this carrying and borrowing.

It is therefore considered good programming practice to clear the carry flag prior to an addition operation and to set the carry flag prior to a subtraction operation. If you don't do this, your calculations may be thrown off by the leftover results of previous calculations. The assembly language instruction to clear the P register's carry bit is clc, which stands for clear carry. The instruction to set the carry bit is sec, which stands for set carry.

Here's how the carry bit works in 6502/65C816 addition and subtraction operations. Before a multiprecision addition problem (one that requires the use of more than one word) is performed in 65C816 assembly language, the carry flag of the P register is customarily cleared using clc. Then the low-order words of the two numbers (or the low-order bytes, if the 65C816 is in emulation mode) are added. If this operation results in a carry to a high-order word (or byte), the 65C816 automatically sets the carry flag. Then, when the high-order words (or bytes) of the two numbers are added, the chip automatically adds the value of the carry flag. If the carry flag holds a 0, there is no carry. If it holds a 1, there is a carry, and the result of the operation is correct.

Because it is recommended that the carry flag be cleared before any addition operation, the ADDNRS.S program in listing 5–1 can be improved as shown in listing 5–2. Preceding the addition operation with the clc instruction clears the carry bit, ensuring that no unwanted carry is included in the operation. You'll see more examples of how the carry bit works in addition problems later in this book.

### Listing 5–2

ADDNRS.S program, version 2

```
clc
lda #2
adc #2
sta $8000
```

The carry flag is also used in subtraction problems, but in the opposite way from its use in addition problems. Before a subtraction operation, the carry bit is usually set using sec. Then, if the subtraction operation requires
that a low-order word or byte borrow a number from a high-order word or byte, the number needed is provided by the carry bit. The carry flag has other uses, most of which are described in later chapters.

**Zero Flag**

When the result of an arithmetic or logical operation is 0, the status register’s zero flag (bit 1) is automatically set. Addition, subtraction, and logical operations can all result in changes to the status of the zero flag. The zero flag is often tested in programming loops that count down to 0 and to see if two numbers are equal.

When you write routines that use the zero flag, it’s important to remember one 6502/65C816 convention that may seem odd at first. When the result of an operation is 0, the zero flag is set to 1. When the result of an operation is not zero, the zero flag is cleared to 0. This convention is easy to forget—and can trip you up if you aren’t careful.

There are no assembly language instructions to clear or set the zero flag. It’s strictly a read bit, so instructions to write to it are not provided.

**Interrupt Disable Flag**

The Apple IIos, unlike many earlier members of the Apple II family, supports a wide variety of interrupts, instructions that halt all 6502/65C816 operations temporarily so that more time critical operations can take place. Some interrupts are called *maskable interrupts* because you can prevent them from taking place by setting the interrupt disable flag (bit 2) of the processor status register. Other interrupts are called *nonmaskable interrupts* because they are essential to the operation of a computer and you can’t stop them from taking place.

The most common reason for using the P register’s interrupt disable flag is to write a sequence of code that would not work properly if an interrupt took place while the code is executed. For example, if a program is setting up an interrupt and gets cut off in midstream by another interrupt, the whole program might crash. The best way to keep this kind of disaster from happening is to set the interrupt disable flag, execute the sensitive segment of code, and then clear the interrupt disable flag. That way, an unexpected interrupt cannot come along and crash the program.

The assembly language instruction to clear the interrupt flag is `CLI`. The instruction to set the interrupt flag is `SEI`. Examples showing how this flag works are presented in later chapters.

**Decimal Mode Flag**

The 65C816 processor normally operates in binary mode, using standard binary numbers. But the chip can also operate in binary coded decimal, or BCD, mode. To put the computer in BCD mode, you have to set the decimal flag of the 65C816 status register.

When the 65C816 is in BCD mode, it uses the same ten digits used in the standard decimal system: the numbers 0 through 9. Because the hexa-
decimal digits A through F are not used in the BCD system, they are not recognized by the 65C816 when the IIGs is in BCD mode.

Table 5–1 shows how the IIGs converts the numbers 0 through 9 into BCD numbers when the 65C816 is in BCD mode. It also shows the hexadecimal and binary equivalents of the decimal numbers 0 through 15.

As table 5–1 shows, the binary numbers 1010 through 1111, which equate to the digits A through F in the hexadecimal system and 10 through 15 in the decimal system, are not used when the 65C816 chip is in BCD mode. Instead, the numbers 10 through 15 are written in the BCD system as the separate digits 1 and 0 through 1 and 5, just as they are in the standard decimal system. For example, the number 13 is written in BCD as the binary equivalent of 1 (0001) and 3 (0011). So, when the 65C816 is in BCD mode, it converts the decimal values 11 through 15 into the binary numbers 0001 0000 through 0001 0101.

Because the binary numbers 1010 through 1111 are not used in the BCD system, it takes more memory to store numbers using BCD notation than it does to store non-BCD binary numbers. In many applications (for example, in floating-point arithmetic operations), a full byte of memory is used for each decimal digit in a BCD number. When BCD notation is used in this way, BCD numbers require even more memory.

Figure 5–5 shows how the decimal number 255 is stored in memory as a BCD number if each digit in the number is expressed as an individual byte. In comparison, figure 5–6 shows how the 65C816 chip stores the decimal number 255 in memory if the BCD flag is not set.

As figures 5–5 and 5–6 illustrate, at the rate of one byte per digit, it takes three times as many bytes to store the number 255 in BCD notation as

Table 5–1
BCD-to-Binary Conversion

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

BCD NUMBER: 2 5 5
BINARY EQUIVALENT: 00000010 00000101 00000101

Figure 5–5
Expressing a number in BCD mode

DECIMAL NUMBER: 255
HEXADECIMAL EQUIVALENT FF
BINARY EQUIVALENT 11111111

Figure 5–6
Expressing a number in binary mode

it does in binary notation. There are many applications in which BCD numbers use even more memory. For example, when the 65C816 performs floating-point arithmetic, extra bytes are usually required to indicate how many digits are in the number, whether the number is positive or negative, and how many decimal places are in the number.

In floating-point arithmetic—which is often used in “number-crunching” operations because of its high degree of accuracy—it could take six or more binary numbers to express a three-digit decimal number. Figure 5–7 shows how the number 2.55 is expressed as a 6-byte BCD number. This illustration shows only one of the many methods for converting decimal numbers into BCD numbers for use in floating-point operations.

In addition to using extra memory, BCD arithmetic is slower than binary arithmetic. But because BCD numbers, like decimal numbers, are based on 10, they are also more accurate in arithmetic operations that use fractions and decimal values. So BCD arithmetic is often used in programs in which accuracy of calculations is more important than speed or memory efficiency.

Converting BCD numbers into decimal numbers is also easier than converting standard binary numbers. So BCD numbers are sometimes used in programs that require the instant display of numbers on a video monitor.

When the status register’s decimal mode flag is set, the 65C816 chip performs all its arithmetic using BCD numbers. You probably won’t be using much BCD arithmetic in your assembly language programs—at least not for

DECIMAL NUMBER: 2.55
FLOATING-POINT BCD: 0011 0010 0000 0010 0101 0101

MEANING OF EACH BCD DIGIT

0011 (3): THE NUMBER HAS THREE DIGITS
0010 (2): DECIMAL POINT IS TO THE LEFT OF THE DIGIT 2
0000 (0): THE NUMBER IS POSITIVE (0001 WOULD MEAN NEGATIVE)
0010 (2): FIRST DIGIT (2)
0101 (5): SECOND DIGIT (5)
0101 (5): THIRD DIGIT (5)

Figure 5–7
A floating-point binary number
a while—so you'll usually want to make sure that the decimal flag is clear before the computer starts performing arithmetic operations.

The assembly language instruction that clears the decimal flag is \texttt{cld}. The \texttt{sed} instruction sets it. The \texttt{cld} instruction is often used before arithmetic operations take place to ensure that the 6502/65C816 chip has not been placed and left in decimal mode. So a further improved version of the ADDNRS.S program presented in listing 5–1 is shown in listing 5–3.

**Listing 5–3**

ADDNRS.S program, version 3

<table>
<thead>
<tr>
<th>Line</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>cle</td>
</tr>
<tr>
<td>2.</td>
<td>cle</td>
</tr>
<tr>
<td>3.</td>
<td>lda #2</td>
</tr>
<tr>
<td>4.</td>
<td>adc #2</td>
</tr>
<tr>
<td>5.</td>
<td>sta $8000</td>
</tr>
</tbody>
</table>

**Index Register Select Flag or Break Flag**

Bit 4 of the processor status register is an index register select (x) flag when the 65C816 is in native mode and a break (b) flag when the processor is in emulation mode.

You have seen how bit 4 works in its role as an index register select flag. Now you will take a brief look at how it is used in emulation mode, in its capacity as a break flag.

When the assembly language instruction \texttt{brk} halts a program and the 65C816 is in emulation mode, an interrupt is generated, the program halts, and the b flag is set automatically. If an interrupt is hardware generated, however, the b flag is not set.

The \texttt{brk} instructions that result in the setting of the break flag are often used by program designers during debugging. After a program is debugged, any \texttt{brk} instructions placed in the program for use during debugging are usually removed. Other than the \texttt{brk} mnemonic, there are no assembly language instructions that set or clear the break flag.

**Memory/Accumulator Select Flag**

When the 65C816 is in native mode, bit 5 is the memory/accumulator select flag (m), which we have discussed. In emulation mode and in pre-65C816 processors, bit 5 is not used.

**Overflow Flag**

The overflow flag, bit 6, detects an overflow from the next-to-leftmost bit to the leftmost bit in a binary number. The overflow flag is used primarily in addition and subtraction problems involving signed numbers. When the 65C816 microprocessor performs calculations on signed numbers, each number is expressed as a 15-bit value (or as a 7-bit value in emulation mode), with the leftmost bit designating the number's sign. When the leftmost bit is
used in this way, an overflow from the next-to-leftmost bit to the leftmost bit can make the result of a calculation incorrect. So after a calculation involving signed numbers is performed, the v flag is often tested to see whether such an overflow has occurred. Then, if an unwanted overflow has occurred, you can take corrective action.

The assembly language instruction that clears the overflow flag is clv. The v flag is a read-only bit, so there is no specific instruction to set it.

**Negative Flag**

The negative flag, bit 7, is set when the result of an operation is negative and cleared when the result of an operation is 0. The negative flag is often used in operations involving signed numbers. The negative flag also can be tested to see whether one number is less than another number and used to detect whether a counter in a loop has decremented past 0. Other uses are discussed in later chapters. There are no instructions to set or clear the negative flag; it’s strictly a read-only bit.
In chapter 2, you saw the one-to-one correlation between assembly language and machine language. For every mnemonic in an assembly language program, there's a numeric machine language instruction that means the same thing.

In chapter 5, you saw that while that's the truth, it isn't quite the whole truth. Most instructions in 6502/65C816 assembly language have more than one equivalent instruction in machine language. For example, when the `adc` mnemonic is used in a IIgs program, it can be converted into 15 different numeric instructions when it is assembled into machine language. To understand why this is true, you need to know how to use addressing modes in 6502/65C816 assembly language.

In the world of assembly language programming, an addressing mode is a tool for locating and using information stored in a computer's memory. The 65C816 can access the memory locations in the IIgs in 24 ways; in other words, it has 24 addressing modes.

In this chapter, you examine all 24 of the 65C816’s addressing modes, and you see how to use them in IIgs assembly language. First, though, let’s look at the 15 ways that one mnemonic—`adc`—can be converted into machine language. See table 6–1.

Later in this chapter, you’ll examine all these addressing modes and see how they work in assembly language programs. First, though, let’s compare the assembly language statements and the machine language statements listed in table 6–1.
In the assembly language column, all 15 statements have the same mnemonic, but each has a different operand. In the machine language column, the statements have quite a different structure. There are 15 different opcodes, but only three kinds of operands: the 1-byte operand 03, the 2-byte operand 00 03, and the 3-byte operand 00 03 03.

This arrangement illustrates an important difference between assembly language and machine language, a difference that you first observed in chapter 2. In 6502/65C816 machine language, addressing modes are distinguished by differences in their opcodes. But in 6502/65C816 assembly language, the 24 available addressing modes can be identified by differences in their operands.

The Addressing Modes of the 65C816

Table 6–2 shows the 24 addressing modes recognized by the 65C816. As you can see, they can be divided into five categories:

- Simple addressing
- Indexed addressing
- Indirect addressing
- Stack addressing
- Block move addressing

In this chapter, you’ll examine these five addressing modes and all 24 of the 65C816’s addressing modes.

<table>
<thead>
<tr>
<th>Addressing Mode</th>
<th>Simple Addressing</th>
<th>Indexed Addressing</th>
<th>Indirect Addressing</th>
<th>Stack Addressing</th>
<th>Block Move Addressing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Implied</td>
<td>rts</td>
<td></td>
<td></td>
<td>pha</td>
<td>mvn 6,0</td>
</tr>
<tr>
<td>Immediate</td>
<td>lda #2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Absolute</td>
<td>lda $0C00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Absolute long</td>
<td>lda $030300</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Direct</td>
<td>sta $FA</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Accumulator</td>
<td>inc a (or ina)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Program counter relative</td>
<td>bcc label</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Program counter relative long</td>
<td>brc label</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Absolute indexed with X</td>
<td>lda $0C00,x</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Absolute indexed with Y</td>
<td>lda $0C00,y</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Direct indexed with X</td>
<td>lda $FA,x</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Direct indexed with Y</td>
<td>stx $FA,y</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Absolute long indexed with X</td>
<td>lda $030300,x</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Direct indirect</td>
<td>lda ($FA)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Direct indirect long</td>
<td>lda [$FA]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Absolute indirect</td>
<td>jml ($0300)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Absolute indexed indirect</td>
<td>jsr ($0300,x)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Direct indexed indirect</td>
<td>lda ($FA,x)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Direct indirect indexed</td>
<td>lda ($FA),y</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Direct indirect long indexed</td>
<td>lda [$03],y</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stack</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stack relative</td>
<td>lda $30,s</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stack relative indirect indexed</td>
<td>lda ($30,s),y</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Block source bank, destination</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>bank</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 6-2
The 65C816's 24 Addressing Modes

<table>
<thead>
<tr>
<th>Addressing Mode</th>
<th>Example</th>
<th>Identifier</th>
</tr>
</thead>
<tbody>
<tr>
<td>Implied</td>
<td>rts</td>
<td>i</td>
</tr>
<tr>
<td>Immediate</td>
<td>lda #2</td>
<td>#</td>
</tr>
<tr>
<td>Absolute</td>
<td>lda $0C00</td>
<td>a</td>
</tr>
<tr>
<td>Absolute long</td>
<td>lda $030300</td>
<td>al</td>
</tr>
<tr>
<td>Direct</td>
<td>sta $FA</td>
<td>d</td>
</tr>
<tr>
<td>Accumulator</td>
<td>inc a (or ina)</td>
<td>Acc</td>
</tr>
<tr>
<td>Program counter relative</td>
<td>bcc label</td>
<td>r</td>
</tr>
<tr>
<td>Program counter relative long</td>
<td>brc label</td>
<td>rl</td>
</tr>
<tr>
<td>Absolute indexed with X</td>
<td>lda $0C00,x</td>
<td>a,x</td>
</tr>
<tr>
<td>Absolute indexed with Y</td>
<td>lda $0C00,y</td>
<td>a,y</td>
</tr>
<tr>
<td>Direct indexed with X</td>
<td>lda $FA,x</td>
<td>d,x</td>
</tr>
<tr>
<td>Direct indexed with Y</td>
<td>stx $FA,y</td>
<td>d,y</td>
</tr>
<tr>
<td>Absolute long indexed with X</td>
<td>lda $030300,x</td>
<td>al,x</td>
</tr>
<tr>
<td>Direct indirect</td>
<td>lda ($FA)</td>
<td>(d)</td>
</tr>
<tr>
<td>Direct indirect long</td>
<td>lda [$FA]</td>
<td>[d]</td>
</tr>
<tr>
<td>Absolute indirect</td>
<td>jml ($0300)</td>
<td>(a)</td>
</tr>
<tr>
<td>Absolute indexed indirect</td>
<td>jsr ($0300,x)</td>
<td>(a,x)</td>
</tr>
<tr>
<td>Direct indexed indirect</td>
<td>lda ($FA,x)</td>
<td>(d,x)</td>
</tr>
<tr>
<td>Direct indirect indexed</td>
<td>lda ($FA),y</td>
<td>(d),y</td>
</tr>
<tr>
<td>Direct indirect long indexed</td>
<td>lda [$03],y</td>
<td>[d],y</td>
</tr>
<tr>
<td>Stack</td>
<td>pha</td>
<td>s</td>
</tr>
<tr>
<td>Stack relative</td>
<td>lda $30,s</td>
<td>r,s</td>
</tr>
<tr>
<td>Stack relative indirect indexed</td>
<td>lda ($30,s),y</td>
<td>(r,s),y</td>
</tr>
<tr>
<td>Block source bank, destination</td>
<td>mvn 6,0</td>
<td>xya</td>
</tr>
</tbody>
</table>
Simple Addressing Modes

The 65C816 has the following simple addressing modes:

- Implied addressing
- Immediate addressing
- Absolute addressing
- Absolute long addressing
- Direct addressing
- Accumulator addressing
- Program counter relative addressing
- Program counter relative long addressing

Listing 6–1, titled AddrDemo1, uses four addressing modes. They are all simple addressing modes, but one of them—simple stack addressing—can also be classified as a stack addressing mode (as it is in table 6–2). First you'll examine each addressing mode in the AddrDemo1 program. Then you'll see how each instruction in the program works and what the program does.

---

Listing 6–1
AddrDemo1 program

*  
* ADDRESSING DEMO #1: Four kinds of addressing  
*  

KEEP AddrDemo1

Demo START
result equ $2000

phk ; stack addressing
plb ; stack addressing

lda #$2200 ; immediate address
clc ; implied address
adc #$0022 ; immediate address
sta result ; absolute address

brk ; implied address

END

The four addressing modes used in listing 6–1 are:

- Stack addressing
- Implied addressing
Immediate addressing

Absolute addressing

Let's take a close look at each of these four addressing modes. Then, with the help of some other short programs, you'll examine the rest of the 65C816's 24 addressing modes.

To understand how stack addressing works, it helps to know what a stack is. A stack, sometimes known as a hardware stack, is an area of RAM that is often compared with a stack of plates in a diner. When you place a value on the stack, it "covers up" the value previously in the top position on the stack and becomes the new top value on the stack. To get to the value that was previously on top, you have to remove the value that was just added. Then the value that was on the top of the stack before becomes the top value again.

This stacked plate analogy, as you shall see later in this chapter, is not completely accurate. But we can use it to explain how stack addressing works in the AddrDemol program.

In the AddrDemol program, stack addressing is used in the lines

```assembly
phk ; stack addressing
plb ; stack addressing
```

In these two lines, the value of the 65C816 program bank register is placed on the stack. Then it is pulled off the stack and deposited in the 65C816 data bank register.

The mnemonic in the first line, phk, means *push the program bank register on the stack*. It does exactly what its name suggests. The mnemonic in the second line, plb, means *pull the top value off the stack and place it in the data bank register*. It does what its name implies, too.

When the phk and plb instructions are used together at the beginning of a program, as they are in AddrDemol, they ensure that the program and its data use the same 64K bank of memory. It is sometimes desirable—even necessary—for a program to access data stored in another bank. On those occasions, the value of the data bank register can be changed temporarily. But most of the time, the program bank and the data bank should be the same. If they aren't, instructions that fetch and store data—such as lda and sta—might try to access data in the wrong banks, causing crashes and other programming catastrophes.

Using stack addressing to change the value of the data bank register is indirect and inconvenient, but there's one good reason for it. It's the only method the 65C816 instruction set provides.

Types of Stack Addressing

As table 6–2 shows, there are three major types of stack addressing: simple stack addressing, stack relative addressing, and one complex form of stack addressing called stack relative indirect indexed addressing. In the AddrDemo 1 program, the phk and plb instructions use simple stack addressing. The other two kinds of stack addressing are covered later in this chapter.
Mnemonics that use stack addressing are all 1-byte instructions (which means they don’t have operands), and all but three—\texttt{rts}, \texttt{rtl}, and \texttt{rti}—start with \texttt{p}. Some stack instructions push values onto the stack, some pull values off the stack, and three—the three that begin with \texttt{r}—pull addresses off the stack and use them as addresses to jump to.

\section*{Emulation Mode and Native Mode}

There are some differences between the way stack addressing works when the 65C816 is in 16-bit native mode and 8-bit emulation mode. For example, in emulation mode, the stack pointer is always on page 1 and has only 256 addresses. But when the processor is in native mode, the stack can start at any address in bank 0, and the length of the stack is limited only by the amount of available RAM in that bank.

Another difference is that some instructions push only 1 byte onto the stack in emulation mode, but all instructions push at least 2 bytes onto the stack when the processor is in native mode. The differences between native mode and emulation mode operations are described in table 6–3.

\begin{table}[h]
\centering
\caption{Simple Stack Addressing Operations}
\begin{tabular}{|l|l|}
\hline
Instructions & Operations \\
\hline
\texttt{brk}, \texttt{cop} (software interrupts) & Push PBR, P, and PC onto the stack \\
\texttt{irq}, \texttt{nmi}, \texttt{abort}, \texttt{res} & Push PBR, P, and PC onto the stack \\
(software interrupts) & \\
\texttt{rti} & Pull P, PC, and PBR off the stack \\
\texttt{rts} & Pull PC off the stack \\
\texttt{rtl} & Pull PC and PBR off the stack \\
\texttt{pei} & Pull a direct page word onto the stack \\
\texttt{pea} & Push bytes 3 and 2 of the instruction onto the stack; this is really a push immediate instruction \\
\texttt{per} & Push onto the stack a value obtained by adding the PC to the contents of bytes 3 and 2 of the instruction \\
\texttt{pha}, \texttt{phb}, \texttt{phd}, \texttt{phk}, \texttt{php}, \texttt{phx}, \texttt{phy} & Push register contents onto the stack. (Number of bytes pushed varies, depending on the register pushed and the processor mode.) \\
\texttt{pla}, \texttt{plb}, \texttt{pld}, \texttt{plp}, \texttt{plx}, \texttt{ply} & Pull the top element off the stack and into the register. (Number of bytes pulled varies, depending on the register pushed and the processor mode.) \\
\hline
\end{tabular}
\end{table}

\section*{Implied Addressing}

Another kind of 1-byte addressing—implied addressing—appears in these two lines of the AddrDemo1 program:

\begin{verbatim}
clc ; implied address
\end{verbatim}
The Right Address

Implied Addressing

In the implied addressing mode, the operand is not spelled out, but merely understood, like the understood object of an intransitive verb in English grammar. When you use implied addressing, all you have to type is the three-letter assembly language instruction. Its syntax does not require (in fact does not allow) the use of an expressed operand.

Two lines in the AddrDemo1 program use immediate addressing:

```
lda #$2200

adc #$0022
```

When immediate addressing is used in a 65C816 instruction, the operand that follows the opcode mnemonic is a literal number—not the address of a memory location. So in a statement that uses immediate addressing, # (the symbol for a literal number) always appears before the operand.

When an immediate address is used in an assembly language statement, the assembler does not have to peek into a memory location to find a value. Instead, the value itself is placed directly into the accumulator. Then the operation that the statement calls for can be immediately performed; in other words, an immediate address forms the effective address of an operand.

When the 65C816 is in native mode and its accumulator and index registers are in their 16-bit modes, every instruction that uses immediate addressing has a 2-byte operand. But when the 65C816 is in emulation mode, or when its accumulator and index registers are in their 8-bit modes, instructions that use immediate addressing have 1-byte operands.

The immediate addressing mode is often used to create pointers, or addresses that point to other address. For example, the following code segment converts the address of a block of data called Picture into a pointer stored in a variable called PicPtr:

```
lda #<Picture
sta PicPtr
lda #'>Picture
sta PicPtr+2
```

This fragment of code uses two forms of addressing: immediate addressing and absolute addressing, which are covered in the next sections. Absolute addressing uses an operand that specifies a memory location as its effective address.
In this code, the statements that use immediate addressing are lda #<Picture and lda #'Picture. The statements that use absolute addressing are sta PicPtr and sta PicPtr+2.

This code loads the 24-bit address of the data segment Picture into a pointer situated in a pair of memory addresses labeled PicPtr and PicPtr+2. If the fragment were encountered in an assembly language program, it would load the 24-bit address of the data segment Picture into a 2-word pointer labeled PicPtr, depositing the low-order word of the address in PicPtr and placing the high-order word in PicPtr+2.

In this code, < and ' are special symbols recognized as directives by the APW assembler. They are used as prefixes of the label Picture so that the APW assembler will split the address of the data segment specified by the label Picture into two 16-bit words. One word can then be loaded into the pointer PicPtr, and the other can be loaded into PicPtr+2.

When the APW assembler encounters the statement lda #<Picture, it loads the 2 low bytes of the address of Picture into the pointer PicPtr. When it reaches the statement lda #'Picture, it loads the 2 high bytes of the address of Picture into PicPtr+2. The full address of the data segment Picture is stored, in the 65C816's typical low-byte-first format, in the two memory addresses labeled PicPtr and PicPtr+2. For example, if the address of the data block Picture is $E12000, the value $2000 (the low word of the address) is stored in PicPtr, and the value $00E1 (the high word of the address) is stored in PicPtr+2.

The symbol < in the statement lda #<Picture is optional. It can be eliminated, as it is in these lines of code:

```assembly
lda #Picture
sta PicPtr
lda #'Picture
sta PicPtr+2
```

### Absolute Addressing

One line in the AddrDemo1 program uses absolute addressing:

```assembly
sta result ; absolute address
```

In this line, the word result is a symbolic label defined previously in the program:

```assembly
result equ $2000
```

So the symbolic label result in the statement

```assembly
sta result
```

stands for the hexadecimal value $2000.
If this line was written as

```assembly
sta #result
```

the APW assembler would assemble the value $2000 into a literal number, and the addressing mode used in the statement would be immediate addressing.

In this case, however, the operand of the `sta` mnemonic is not preceded by `#`, so the APW assembler does not interpret it as a literal number. Instead, as you have seen in programs in chapter 2, the operand in the statement `sta result` is interpreted as a memory address. Another way of saying this is that in the AddrDemo1 program, the statement `sta result` uses absolute addressing.

Now you see that in a statement using absolute addressing, the operand is a memory location, not a literal number. In reading and writing operations that use absolute addressing, the operation called for is always performed on the value stored in the specified memory location, not on the operand itself. When a jump instruction (`jmp` or `jsr`) uses absolute addressing, however, the address jumped to is the absolute address that is expressed as the operand.

In both native mode and emulation mode, every instruction that uses absolute addressing has a 16-bit operand. When the 65C816 is in native mode, however, the assembler extends the effective address of the operand to 24 bytes by concatenating it with a bank register. If the instruction that uses absolute addressing is a read or write instruction, such as `lda` or `sta`, the assembler extends the operand to 3 bytes by combining it with the 65C816’s data bank register. If the instruction is a jump instruction (`jmp` or `jsr`), the assembler extends the operand to 3 bytes by combining it with the program bank register.

You have completed an analysis of the addressing modes in the AddrDemo1 program and are ready to see how it works. As noted, the lines

```assembly
phk ; stack addressing
plb; stack addressing
```

copy the contents of the program bank register into the data bank register, so the program accesses data from the same bank in which the program is running. Now let’s look at the lines

```assembly
lda #$2200 ; immediate address
clc ; implied address
adc #$0022 ; immediate address
sta result ; absolute address
```

In the statement `lda #$2200`, the 65C816’s accumulator is loaded with
the literal value $2200. Then the mnemonic clc clears the P register's carry
flag in preparation for an addition operation.

Next, in the statement **adc #$0022**, the literal value $0022 is added
to the value of $2200 that is already in the accumulator. Finally, the statement sta result stores the result of the addition—the number $2222—in an
absolute memory address.

What is this memory address? Because the symbolic label result was
assigned the value $2000 and the mnemonic sta is a write instruction and
not a jump instruction, the APW assembler calculates the effective address
of the operand result by concatenating the value of the result with the contents
of the 65C816's data bank register. In other words, the effective address of
the operand is the address $2000 in whatever data bank the program is loaded
into.

And what data bank is that? Well, frankly, there's no way of knowing.
As you learned in chapter 4, it is up to the IIgs system loader, not the IIgs
programmer, to decide where to place a program when it is loaded into
memory. And when a program has been loaded into memory, the IIgs Memory
Manager can move it. So, when you write a program for the IIgs, you can
never be sure where the program will start in memory or even what bank it
will be loaded into.

When you type, run, assemble, and load the AddrDemo1 program, you
can only be sure that the result of the addition of the numbers $2200 and
$0022 are stored in memory addresses $2000 and $2001 in some bank of
memory.

You won’t have to stay in the dark for very long, however. The last
line in AddrDemo1 is

```assembly
brk ; implied address
```

As soon as you run the program, you will hear a beep from your computer
and will discover that the brk instruction, which ends the program, has
"bounced" the program into the IIgs monitor. You will see the contents of
all the 65C816's registers, including its data bank register (D), listed on the
screen. You can use your monitor's display memory functions (described in
chapter 2) to list the contents of memory addresses $2000 and $2001 in the
64K bank pointed to by the data bank register. If the 2-byte value stored in
those two addresses is $2222—the sum of $2200 and $0022—you’ll know
that the AddrDemo1 program worked properly.

**Direct Addressing**

If you’re an experienced 6502/65C02 programmer, you’re familiar with the
concept of page 0 addressing, a technique that can save time and allow memory
locations to be addressed in some tricky (and quite useful) ways.

In pre-IIgs Apple IIis, page 0 is a 256-byte block of RAM that extends
from memory address $00 through memory address $FF. Every memory
location on page 0 has a 1-byte address and thus can be addressed using a
1-byte operand. Another noteworthy fact about page 0 is that some ad-
dressing—as you shall see later in this chapter—actually requires direct page
operands.
Because the 256 memory addresses on page 0 are so valuable, page 0 is the high-rent district in pre-GS Apple IIs. It is such a desirable piece of real estate, in fact, that the designers of the Apple II operating system, the Apple II monitor, and Applesoft BASIC claimed most of it for themselves. They left only a few bytes free for use in application programs.

Because space on page 0 is so useful and so scarce, designers of 6502-based computers tried for years to increase the amount of page 0 storage space. In designing the Apple IIgs, they finally succeeded. In the IIgs, as you may recall from chapter 4, the concept of page 0 addressing is expanded into something called direct page addressing. This form of addressing allows any page in bank $00 to be used as a page 0 and allows different programs, or even different segments of the same program, to use different pages in bank $00 as their own private page 0.

Because an IIgs program can use any page in bank $00 as a page 0, the form of addressing that was called page 0 addressing is now more properly referred to as direct page addressing. The page of bank $00 memory that is accessed through direct page addressing is no longer known as page 0, but is more properly referred to as the direct page.

In a statement that uses direct page addressing, the operand always consists of just 1 byte—a number from $00 to $FF. When the 65C816 assembles a statement that uses direct addressing, it interprets the operand as an offset that, when added to the contents of the data bank register, specifies the operand's effective address.

That's quite a mouthful, but listing 6–2 is a short program that shows how direct addressing works.

Listing 6–2
AddrDemo2 program

*  
* ADDRESSING DEMO #2: Direct addressing  
*  
KEEP AddrDemo2

<table>
<thead>
<tr>
<th>Demo</th>
<th>START</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>phk</td>
<td></td>
<td>; make program bank and</td>
</tr>
<tr>
<td>plb</td>
<td></td>
<td>; data bank the same</td>
</tr>
<tr>
<td>lda #$2000</td>
<td></td>
<td>; make the direct page</td>
</tr>
<tr>
<td>tcd</td>
<td></td>
<td>; start at $2000</td>
</tr>
<tr>
<td>lda #$5500</td>
<td></td>
<td>; immediate address</td>
</tr>
<tr>
<td>clc</td>
<td></td>
<td></td>
</tr>
<tr>
<td>adc #$0055</td>
<td></td>
<td>; immediate address</td>
</tr>
<tr>
<td>sta $60</td>
<td></td>
<td>; direct page address</td>
</tr>
<tr>
<td>brk</td>
<td></td>
<td>; quit to the monitor</td>
</tr>
<tr>
<td>END</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
How the AddrDemo2 Program Works

AddrDemo2, like AddrDemo1, starts with the instructions:

```
phk                  ; make program bank and
plb                  ; data bank the same
```

These statements, as their comments now reveal, make the program bank and the data bank the same.

The next lines are:

```
lda #$2000          ; make the direct page
tcd                 ; start at $2000
```

These two lines are very important. They set aside page #$20 in bank $00, memory addresses $2000 through $20FF, for use as a direct page.

The next three lines work much like their corresponding lines in the previous program:

```
lda #$5500      ; immediate address
clc
adc #$0055     ; immediate address
```

They add the literal numbers $5500 and $0055, taking care to clear the carry flag before the addition is carried out so that the result of the operation is correct.

The next line is the part of the AddrDemo2 program that you have been waiting for:

```
sta $60           ; direct page offset
```

Using the value $60 as an offset, this line stores the result of the addition of $5500 and $0055 in the direct page address $2060.

The AddrDemo2 program, like the AddrDemo1 program, ends with a brk instruction so that you can use the IIGS monitor to check its results. Type, assemble, and run the program. Then use your monitor to peek into memory addresses $00/2060 and $00/2061. If everything has worked correctly, those two memory locations now hold the 2-byte value $5555—the sum of the addition of $5500 and $0055.

Forcing Absolute Addressing

Now that you know how the AddrDemo2 program works, let's go back and take another look at the line:

```
sta $60
```
If you've written assembly language programs for pre-os Apple IIIs, you may notice that this statement works much differently in the AddrDemo2 program than it would in a 6502 or 65C02 program. In the AddrDemo2 program, the operand $60 in the statement sta $60 is not a complete address, but merely an offset that is used to calculate a direct page address. But if the AddrDemo2 program were written for an 8-bit chip—or for a 65C816 chip running in emulation mode—the operand $60 would be interpreted as a literal address: the page 0 address $60.

This brings us to a problem faced by Apple IIGS assembly language programmers. Because the 65C816 interprets the 1-byte operand in a statement like sta $60 as an offset for calculating a direct page address, there is no straightforward way to access 1-byte addresses in the program bank or data bank currently in use. In other words, there is no direct way to access the addresses $00 through $FF in the current program or data bank.

Suppose you are writing a 65C02 program. You want the operand in the statement sta $60 to be assembled not as a direct page offset, but as absolute memory address $0060 in the current data bank. What would you do?

Fortunately, there is a way out of this dilemma. If you are writing a program with the APW assembler, and you want the statement sta $60 to mean store the value of the accumulator in the absolute address $XX0060 (with XX representing the current data bank), you could force APW to assemble it that way by merely writing

```
sta |$60
```

or

```
sta !$60
```

You can use a vertical bar or an exclamation point as a prefix to force absolute addressing.

The prefix | or the prefix ! can also force absolute addressing in statements that use symbolic labels as operands. For example, if the symbolic label memloc is defined as the value $333 in an assembly language program, the statement

```
lda |memloc
```

or the statement

```
lda !memloc
```
cause the operand memlac to be interpreted as the absolute address $XX0333. So the accumulator is loaded with the value stored at that physical address—not at the address calculated by adding $333 to the contents of the direct page register.

**Forcing Absolute Long Addressing**

Now that you have dealt with the problem of forcing absolute addressing, you’re ready to look at another problem that arises often in ILes assembly language programming. Suppose you are writing a 65C02 program, and you want the operand in the statement `sta $60` to be assembled as the absolute address $000060—in other words, as an absolute long address in bank $00. What would you do?

The APW assembler also provides a solution to this problem. If you are writing a program in which you want the statement `sta $60` to mean *store the value of the accumulator in address $000060*, you can force the assembler to assemble it as an absolute long address by writing

`sta >$60`

The `>` prefix forces absolute long addressing. You’ll see more examples of absolute long addressing later in this chapter.

The `>` prefix can also force absolute long addressing in statements that use symbolic labels as operands. For example, if the symbolic label `memlac` is defined as the value $333 in an assembly language program, the statement

`lda >memlac`

causes the operand `memlac` to be interpreted as an absolute long address. So the accumulator is loaded with the value stored in memory address $000333. But the statement

`lda memlac`

is interpreted as a direct address. In this case, the accumulator is loaded with the value stored in a direct page address calculated by adding the literal value $333 to the contents of the direct page register.

A direct page operand can be written using the `<` prefix, as in the following examples:

`lda <$60`

`lda <memlac`

When `<` is used in this way, it is ignored by the APW assembler. It merely shows people reading the program that the addressing mode is direct addressing.
Absolute Long Addressing

Another example of absolute long addressing appears in listing 6–3, AddrDemo3.

Listing 6–3
AddrDemo3 program

* * ADDRESSING DEMO #3: Absolute long addressing * *

KEEP AddrDemo3

Demo START

phk ; make the program bank
plb ; and data bank the same

lda #$B800 ; immediate address
clc
adc #$00BB ; immediate address
sta $012030 ; absolute long address

brk ; quit to the monitor

END

In the AddrDemo3 program, the lines

lda #$B800 ; immediate address
clc
adc #$00BB ; immediate address
sta $012030 ; absolute long address

add the literal numbers $B800 and $00BB, and store their sum in the absolute long address $012030. After you type, assemble, and run the program, you can confirm that it works by using the IIGs monitor to view the contents of memory addresses $012030 and $012031.

In the AddrDemo3 program, the absolute long address $012030 is expressed in the easiest possible way: as a literal number. Operands are usually expressed as literal numbers in programs that use absolute long addressing.
The accumulator addressing mode performs an operation on a value stored in the 6502/65C816 processor's accumulator. When you use accumulator addressing mode, some assemblers require that you use an a as an operand. The APW assembler requires the use of the a operand in all but three cases. The aliases cp a, de a, and in a can be substituted for the assembly language statements cmp a, dec a, and inc a.

Another example of a statement that uses the accumulator addressing mode (no alias allowed) is as l a. This statement rotates each bit in the accumulator one position to the left, with the leftmost bit (bit 15 in native mode or bit 7 in emulation mode) dropping into the carry bit of the processor status (P) register.

Program counter relative addressing is used for branching—a method for instructing a program to jump to a given routine under certain conditions. There are nine branching instructions in 65C816 assembly language. All begin with b, which stands for branch to, and eight use program counter relative addressing.

Some examples of branching instructions are

- bcc: Branch to a specified address if the carry flag is clear.
- bcs: Branch to a specified address if the carry flag is set.
- beq: Branch to a specified address if the result of an operation is equal to 0.
- bne: Branch to a specified address if the result of an operation is not equal to 0.
- bra: Branch always.

The bra mnemonic is one of two unconditional branching instructions used in 65C816 assembly language. The other unconditional branching mnemonic, br l (branch always—long), uses another form of addressing, called program counter relative long addressing, which is covered in the next section. All nine branching instructions are described in chapter 5, in the section devoted to the 65C816 instruction set.

The nine branching mnemonics are often used with three other instructions called comparison instructions. Typically, a comparison instruction compares two values, and the conditional branch instruction then determines what should be done according to the result of the comparison.

The three comparison instructions are

- cmp: Compare the number in the accumulator with . . .
- cpx: Compare the value in the X register with . . .
- cpy: Compare the value in the Y register with . . .

Conditional branching instructions can also follow arithmetic operations, logical operations, and various kinds of bit testing operations.

Usually, a branch instruction causes a program to branch to a specified address if certain conditions are met or not met. A branch might be made,
for example, if one number is larger than another, if two numbers are equal, or if an operation results in a positive, negative, or zero value.

(The AddrDemo4 program shows one way to use program counter relative addressing. We present this program and examine it line by line in a few moments.)

As you saw in chapter 5, one disadvantage of the eight branching instructions that use program counter relative addressing is their very short range: a displacement of $-128$ bytes to $+127$ bytes counting from the end of the branching instruction.

But the 65C816 has one branching instruction—br l—that can cause a program to branch to any address within the current program bank. So br l, instead of accepting a 1-byte operand like all other branching instructions, takes a 2-byte operand. The br l instruction’s 2-byte operand is interpreted as an offset. This offset is added to the value of the program bank register to calculate the destination address of the branch.

Because br l is an unconditional branching instruction, you cannot use it to test the outcome of an arithmetic or comparison operation and then branch if some condition is or is not met. You can use it, however, with conditional branching instructions to extend their range. For example, in this code sequence

```
lda value
bne next
brl longbranch
next lda something
```

the value of the variable labeled value is tested to see if it equals 0. If it equals 0, the br l instruction causes a long-range branch to a segment of code labeled longbranch. If value is not equal to 0, the program continues. Except for a few extra cycles of machine time, the effect is the same as if the segment were coded

```
lda value
beq shortbranch
```

but the branch is a long one.

### Indexed Addressing

In indexed addressing, the 65C816’s X and Y registers provide an index that is used to calculate an effective address. The 65C816 has five kinds of indexed addressing:

- Absolute indexed addressing with X
- Absolute indexed addressing with Y
- Direct indexed addressing with X
- Direct indexed addressing with Y
- Absolute long indexed addressing with Y

Let’s examine each of these five types of indexed addressing.

**Absolute Indexed Addressing with X**

An indexed address, like a relative address, is calculated using an offset. But in an indexed address, the offset is determined by the current contents of the X or Y register.

A statement that uses absolute indexed addressing with X can be written this way:

```
lda $0C00,x
```

The second and third bytes of the statement are added to the X register to form the low-order 16 bits of the operand’s effective address. The high-order 8 bits of the effective address are taken from the data bank register. In other words, the value of the X register is used as an offset to calculate the lower 16 bits of the effective address, and the upper 8 bits come from the direct page register.

Listing 6–4, AddrDemo4, is a short program that uses indexed addressing. The routine is designed to move byte-by-byte through a string of ASCII characters, storing the string in a text buffer. When the string is stored in the buffer, the routine ends.

**Listing 6–4**

* ADDRESSING DEMO #4: Program counter relative addressing and absolute indexed addressing *

```
KEEP AddrDemo4

demo START
txtbuf equ $2000
eol equ $0d

phk
plb ; make the program bank
plb ; and data bank the same

ldx #0
loop lda text,x
sta txtbuf,x
cmp #eol
beq fini
inx
```

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The text to be moved is labeled `text`, and the buffer to be filled with text is labeled `txtbuf`. As you can see by looking at the line labeled `text`, the text to be read ends with an end-of-line (EOL) character, the ASCII character $0d$. The EOL character equates to the Return key on the IIgs keyboard.

As the program proceeds through the string, it tests each character to see if it is a carriage return. If the character is not a carriage return, the program moves to the next character. If the character is a carriage return, there are no more characters in the string, and the routine ends.

In addition to showing how absolute indexed X addressing works, the program also demonstrates the use of program counter relative addressing. In the sequence

```assembly
ldx #0
loop  lda text,x
      sta txtbuf,x
      cmp #eol
      beq fini
      inx
      bra loop
```

the branching instructions `beq` and `bra` control the loop that prints text on the screen.

Absolute indexed addressing with Y works like absolute indexed addressing with X except it uses a different index register. A statement that uses absolute indexed addressing with Y can be written as

```assembly
lda $0000,y
```

The second and third bytes of the statement are added to the Y register to form the low-order 16 bits of the operand's effective address. The high-order 8 bits of the effective address are taken from the data bank register. In other words, the value of the Y register is used as an offset to calculate the lower 16 bits of the effective address, and the upper 8 bits come from the direct page register.
A statement that uses direct indexed addressing with X looks like one that uses absolute indexed addressing with X, except it has a 1-byte operand. For example:

```plaintext
Lda $30,x
```

In this statement, the second byte is added to the sum of the direct page register and the X register to form a 16-bit effective address. In other words, the X register is used as an offset to calculate the lower 16 bits of the effective address, and the upper 8 bits come from the direct page register.

The APW assembler always interprets a 2-byte instruction written in the form `Lda $30,x` as a direct indexed address. You must use special prefixes when you want the operand to be interpreted as a data bank offset or as a long address in bank $00, rather than as a direct page offset. These prefixes are the same ones that distinguish between direct addressing and absolute addressing.

In indexed addressing modes, as in unindexed addressing modes, the prefix `I` (or `!`) forces the APW assembler to interpret a 1-byte indexed operand as an absolute indexed address. And the prefix `>` forces the assembler to interpret a 1-byte indexed operand as an absolute long indexed address. Thus, in the statement

```plaintext
Lda $40,x
```

the assembler concatenates the address $40 with the contents of the data bank register. Then it adds the value of the X register to calculate the effective address.

In the statement

```plaintext
Lda $40,x
```

the value of the X register is added to the address $000040. The result of that calculation is the effective address.

Direct indexed addressing with Y works like direct indexed addressing with X, except it uses a different register. The following statement uses direct indexed addressing with Y:

```plaintext
Lda $30,y
```

In this statement, the second byte of the instruction is added to the sum of the direct page register and the Y register to form a 16-bit effective address. In other words, the Y register is used as an offset to calculate the lower 16 bits of the effective address, and the upper 8 bits are taken from the direct page register.

It should come as no surprise by now to learn that the APW assembler always interprets a 2-byte instruction written in the form `Lda $30,y` as a
direct indexed address. So, in this case also, you must use a special prefix when you want the operand to be interpreted as a data bank offset or as a long address in bank \$00. This prefix is the same one you have been using for the same purpose in other addressing modes: the symbol \$\$. Thus, in the statement

\texttt{lda \$40,x}

the assembler concatenates the address \$40 with the contents of the data bank register. It then adds the value of the \texttt{X} register to calculate the effective address.

There is nothing new in any of this, but you may be surprised to know that the syntax

\texttt{lda >$40,y}

is never invoked to force the assembler to use absolute long indexed addressing with \texttt{Y}. That's because there is no such addressing mode. In \texttt{65C816} assembly language, the \texttt{X} register is the only index register that can be used for absolute indexed addressing.

In absolute long indexed addressing, the effective address is calculated by adding a long (24-bit) address to the value of the \texttt{X} register. There is no comparable addressing mode that uses the \texttt{Y} register.

A statement that uses absolute long indexed addressing with \texttt{X} can be written this way:

\texttt{lda $E16000,x}

The value of the \texttt{X} register is added to the long address \$E16000 to form the operand's effective address.

### Indirect Addressing

In \texttt{65C816} assembly language, indirect addressing modes are modes in which data in memory is accessed indirectly, that is, through pointers contained in other memory locations.

The \texttt{65C816} has seven indirect addressing modes:

- Direct indirect addressing
- Direct indirect long addressing
- Absolute indirect addressing
- Absolute indexed indirect addressing
- Direct indexed indirect addressing
- Direct indirect indexed addressing
- Direct indirect long indexed addressing

We’ll sort this out in the following sections.

**Absolute Indirect Addressing**

Absolute indirect addressing is really made up of two addressing modes: one is used with the `jmp` (jump) instruction and the other is used with the `jml` (jump—long) instruction.

When absolute indirect addressing is used with `jmp`, the syntax is

```
jmp ($4000)
```

A `jml` instruction that uses absolute indirect addressing looks like this:

```
jml ($E1A000)
```

In both formats, a symbolic label can be substituted for the address inside the parentheses.

When absolute indirect addressing is used with the `jmp` instruction, the address inside the parentheses is a pointer to a memory address. This address and the following memory address contain the lower 16 bits of the effective address of the operand. The program bank register contains the upper 8 bits of the effective address. These two values are concatenated, and the result is the complete effective address of the operand.

When the absolute indirect addressing mode is used with the `jml` instruction, the parentheses that follow the instruction contain a long (24-byte) address. This address and the next two memory addresses contain all 3 bytes of the destination address.

**Direct Indirect Addressing**

Direct indirect addressing uses the syntax

```
lda ($FB)
```

or

```
lda (<$FB)
```

Notice that in each case, the value inside the parentheses is only 1 byte long.

When you use direct indirect addressing, the operand is an offset that is added to the contents of the direct page register to calculate the lower 16 bits of the operand’s effective address. The upper 8 bits of the effective address are taken from the direct page register.

**Direct Indirect Long Addressing**

Direct indirect long addressing uses the syntax

```
lda [$FB]
```

or
Notice that in each case, the value inside the parentheses is only 1 byte long.

When you use direct indirect long addressing, the operand is an offset that is added to the contents of the direct page register to calculate the operand's long (24-byte) effective address.

Two of the 65C816's indirect addressing modes—direct indexed indirect addressing and direct indirect indexed addressing—are so closely related that it makes sense to examine them in combination.

If you think their names are confusing, you're not the first one with that complaint. Here's a memory trick to help eliminate the confusion. Direct indexed indirect addressing—which has an \( x \) in the second word of its name—is an addressing mode that uses the \( X \) register. Direct indirect indexed addressing—which doesn't have an \( x \) in the second word of its name—uses the \( Y \) register. With that introduction, let's examine both of these indirect addressing modes—beginning with direct indexed indirect addressing.

The syntax for a statement that uses direct indexed indirect addressing is

\[
\text{lda} \ [\langle<\$FB, x\rangle]
\]

or

\[
\text{lda} \ (\$FB,x)
\]

Notice that the value inside the parentheses is only 1 byte long.

The most common use for direct indexed indirect addressing is to calculate addresses using tables of pointers, or jump tables, located on the direct page. Each address in a direct page jump table is 16 bits long, and must be added to the contents of the current data bank register to yield an effective address. Hence, each item in a direct page jump table is a 2-byte pointer to a 3-byte address situated in the data bank of the program currently being executed.

In a statement that uses direct indexed indirect addressing, both the value of the \( X \) register and the value that appears in front of it are offsets used to calculate the operand's final address.

When the 65C816 encounters a statement that uses direct indexed indirect addressing, it first adds the value of the \( X \) register to the contents of the direct page register. Then it adds this sum to the value inside the parentheses (that is, the second byte of the instruction). The result is a pointer to the low-order 16 bits of the operand’s effective address. The high-order 8 bits of the effective address are taken from the data bank register.

An example might help clarify this process. Suppose memory address \$B0 on the direct page holds the number \$00, memory address \$B1 on the direct page holds the number \$80, and the \( X \) register holds the number 0, as follows:
Now suppose you are running a program that contains the direct indexed indirect instruction \texttt{Lda ($\text{B}0, x$)}. If all these conditions exist when the IIgs encounters the instruction \texttt{Lda ($\text{B}0, x$)}, the 65C816 chip adds the contents of the X register (0) to the hexadecimal number $\text{B}0$. The sum of $\text{B}0$ and 0 is $\text{B}0$.

Next, the 65C816 checks the contents of the direct page memory addresses $\text{B}0$ and $\text{B}1$. It finds the number $\text{0}0$ in the direct page memory address $\text{B}0$ and the number $\text{8}0$ in the direct page address $\text{B}1$.

Because the 65C816 convention is to store 16-bit numbers in memory with the low byte first, the processor interprets the number in $\text{B}0$ and $\text{B}1$ as $\text{8}0\text{0}0$. So it loads the accumulator with the number $\text{8}0\text{0}0$, the 16-bit value stored in $\text{B}0$ and $\text{B}1$. It then concatenates that value with the contents of the data bank register. The result is the operand’s effective address.

Now let’s suppose when the IIgs encounters the statement \texttt{Lda ($\text{B}0, x$)}, its 65C816’s X register holds the number $\text{0}4$, instead of the number $\text{0}0$.

Here is a table illustrating those values, plus a few more equates you’ll be using soon:

\begin{align*}
\text{Direct page} + \text{B}0 &= \#\text{0}0 \\
\text{Direct page} + \text{B}1 &= \#\text{8}0 \\
\text{Direct page} + \text{B}2 &= \#\text{D}0 \\
\text{Direct page} + \text{B}3 &= \#\text{FF} \\
\text{Direct page} + \text{B}4 &= \#\text{FC} \\
\text{Direct page} + \text{B}5 &= \#\text{1}C \\
\text{X register} &= \#\text{0}4 \\
\end{align*}

If these conditions exist when the IIgs encounters the instruction \texttt{Lda ($\text{B}0, x$)}, the 65C816 adds the number $\text{0}4$ (the value in the X register) to the number $\text{B}0$. It then checks memory addresses $\text{B}4$ and $\text{B}5$. In those two addresses, it finds the address $\text{1}C\text{FC}$ (low byte first). It then concatenates that value with the contents of the data bank register. The result is the operand’s effective address.

Until the advent of the 65C816 and direct page addressing, direct indexed indirect addressing was called simply indexed indirect addressing and required the use of jump tables on page 0. Free space on page 0 was so difficult to find that indexed indirect addressing was not used very often in application programs.

With the 65C816, there is no longer any reason to avoid using direct indexed indirect addressing. In programs written for the IIgs, direct page addresses are so readily available that any application program can use as many as the programmer desires. So, if you ever need to include jump tables in a IIgs program, you might consider using direct indexed indirect addressing.
Direct Indirect Indexed Addressing

Direct indirect indexed addressing uses the syntax

\texttt{lda (}$SBFB$,y

or

\texttt{lda (<}$SBFB$,y

Direct indirect indexed addressing uses the Y register (never the X register) as an offset to calculate the base address of the beginning of a table. The starting address of the table has to be stored on the direct page, but the table itself is stored in the bank currently being used as a data bank.

When the APW assembler encounters a direct indirect indexed address in a program, it first adds the number in parentheses—the second byte of the instruction—to the contents of the data bank register. The sum of that operation is combined with the contents of the data bank register to form a 24-bit base address. Finally, that address is added to the value of the Y register to form the effective address of the operand.

Here's an example of how direct indirect indexed addressing is used. Suppose the 65C816 chip is running a program and comes to the instruction \texttt{lda (}$SB0$,y. First it looks into direct page memory addresses $SB0$ and $SB1$. Suppose it finds the number $SB0$ in direct page address $S00$ and the number $SB50$ in direct page address $SB1$. And suppose the Y register contains a 0. The following illustrates these conditions:

\begin{align*}
\text{Direct page} + S0B0 &= #$S00 \\
\text{Direct page} + S0B1 &= #$SB50 \\
\text{Y register} &= #$SB04
\end{align*}

If these conditions exist when the 65C816 encounters the instruction \texttt{adc (}$SB0$,y, the processor concatenates the numbers $S00$ and $SB50$, and it comes up with the address $SB5000$ (in the 65C816 chip's peculiar low-byte-first fashion). It then adds the contents of the Y register ($SB04$) to the number $SB5000$—for a total of $SB5004$.

The processor then combines the 16-bit number $SB5004$ with the 8-bit value of the data bank register. The result is the 24-bit effective address of the operand.

Direct indirect indexed addressing is a valuable tool in assembly language programming. Only one address—the starting address of a table—has to be stored on the direct page. Yet that address, added to the contents of the Y register, can be used as a pointer to locate any other address in memory.

Direct Indirect Long Indexed Addressing

Direct indirect long indexed addressing uses the syntax

\texttt{lda [}$SBFB$,y

or

\texttt{lda (<}$SBFB$,y

6—The Right Address
In direct indirect long indexed addressing, the Y register is used as an offset to calculate the base address of the beginning of a table. The starting address of the table has to be stored on the direct page, but the table itself can be stored anywhere in memory.

In direct indirect long indexed addressing, the value in parentheses (the second instruction of the address) is added to the contents of the direct register. The sum of these two numbers is an address on the direct page. In this address and the two addresses that follow, a 24-bit base address is stored. This base address is added to the value of the Y register to form the 24-bit effective address of the operand.

Absolute Indexed Indirect Addressing

Absolute indexed indirect addressing is used with only two instructions: `jmp` (jump) and `jsr` (jump to subroutine). It provides a means for jumping to any address in memory with a jump table placed in the current program bank. The syntax is

```
jmp ($0300,x)
```

Or, when a 1-byte operand is used and the assembler must be forced to generate a 2-byte instruction, the syntax is:

```
jmp ($30,x)
```

A symbolic label can be substituted for the literal address in each of these examples.

In a statement that uses absolute indexed indirect addressing, the value inside the parentheses is added to the value of the X register to form a 16-bit address. This address is combined with the contents of the program bank register to form a 24-bit base address. Finally, this base address is added to the value of the X register, forming the operand’s 24-bit effective address.

Stack Addressing

The 65C816 has three stack addressing modes:

- Stack relative addressing
- Stack relative indirect indexed addressing
- Simple stack addressing

To understand how stack addressing works, it is essential to have an understanding of what a stack is, and what it does.
The Stack

A stack, as pointed out in the beginning of this chapter, is an area of memory often used for the temporary storage of data that is waiting to be processed. In pre-OS Apple IIs, the stack is exactly 256 bytes long and occupies page 1—memory addresses $100$ through $1FF$—in either main or auxiliary memory. In the IIcs, the stack can be placed anywhere in bank $00$. The only restriction on its length is the availability of free RAM in bank $00$.

In both the IIcs and earlier Apples, the stack is called a LIFO (last-in first-out) block of memory. It is often compared to a spring-loaded stack of plates in a diner. When you put a number in the memory location on top of the stack, it covers up the number that was previously on top. So the number on top of the stack must be removed before the number under it—which was previously on top—can be accessed.

Although the stacked plate analogy is a useful technique for describing how the stack works, it is not completely accurate. Actually, the stack is nothing but a block of RAM—and blocks of RAM don’t really move up and down like a stack of plates inside the IIcs. When you place a number on the 65C816 stack, here’s what really happens.

Suppose, for simplicity, that you have placed the stack on page 1 in memory bank $00$. (The stack was in this location in earlier Apple IIs, so we’ll keep it there for this description.)

Now the block of memory in which the stack is situated—in this case, page 1 in bank $00$—is used in stack operations from high memory downward. The first number stored in a page 1 stack is in register $01FF$, the next number is placed in register $01FE$, and so on. A program can keep placing values on the stack, in this from-the-top-down fashion, until it runs out of free RAM. When the stack is on page 1, it will run out of free memory when it reaches memory address $100$ because all RAM below that address is claimed by page 0. By starting the stack higher in memory, you can make the stack bigger. But because we’re using page 1 for the stack in this example, the last stack address that we can currently use is memory address $100$.

As you saw in chapter 5, the 65C816 chip keeps track of stack manipulations with the help of a special register called the stack pointer. In the 65C816, the stack pointer is a 16-bit address, and the upper 8 bits always hold the number of the page where the stack starts. When the stack starts on page 1, for instance, the high byte of the stack pointer holds a 1.

When there is nothing stored on the stack, the value of the stack pointer’s low byte is $0FF$. If there are 256 bytes on the stack, the value of the stack pointer’s low byte is $00$.

As soon as a value is stored on the stack, the 65C816 chip automatically decrements the stack pointer by 1. And each time another value is stored on the stack, the stack pointer is decremented again. Therefore, the stack pointer always points to the address of the next value that will be stored on the stack.

Stack Operations

Suppose several numbers are stored on the stack. And let’s also suppose you want to retrieve one of those values from the stack. What will happen?

When a number stored on the stack is retrieved, the value of the stack pointer is incremented by 1. That effectively removes one value from the stack, because the next value stored on the stack has the same position on
the stack as the one that was removed. That’s a little tricky to comprehend, given the upside-down nature of the stack. Figure 6-1 will help you understand how this works. This figure shows an empty stack, with the stack pointer pointing to the first available address on the stack: $01FF.

![Stack Pointer and Addresses Diagram](image)

**Figure 6-1**
How the stack pointer works

Now let’s place a number (whose value is arbitrary) on the stack. This kind of operation is illustrated in figure 6-2. In this figure, the value of the stack pointer is decremented, and the number placed on the stack is now stored at the highest address in the stack, memory register $01FF.

![Stack Pointer and Addresses Diagram](image)

**Figure 6-2**
Placing a number on the stack

Figure 6-3 shows what happens if you place another number (also with an arbitrary value) on the stack. The stack pointer is decremented again, and a second number is now on the stack.

Figure 6-4 shows what happens if you “remove” one number from the stack. Stack address $01FE still holds the value $B0, but the value of the stack pointer is decremented and now points to memory address $01FE. So the next number placed on the stack will be stored at memory address $01FE. When that happens, the number previously stored in that stack position—$B0—will be erased.

To see how that works, we’ll store one more number on the stack. This time, for no special reason, the value of the number placed on the stack is $17. This process is illustrated in figure 6-5. Register $01FE now holds the
value $17. The value of the stack pointer is decremented, the value $B0 is erased by the value $17, and the next number placed on the stack will be stored in memory register $01FD.

**How the IIgs Uses the Stack**

As mentioned, the 65C816 often uses the stack for temporary data storage during the operation of a program. When a program jumps to a subroutine, for example, the processor pushes onto the top of the stack the memory address
that the program will have to return to. Then, when the subroutine ends with an rts instruction, the return address is pulled from the top of the stack and loaded into the 65C816's program counter. Then the program can return to the proper address, and normal processing can resume.

**Instructions that Use Stack Addressing**

As you saw at the beginning of this chapter, phk and plb are two instructions that use stack addressing. Other mnemonics that use this addressing mode include:

- **pha**: Push the contents of the accumulator onto the stack.
- **phx**: Push the contents of the X register onto the stack.
- **phy**: Push the contents of the Y register onto the stack.
- **php**: Push the contents of the P register onto the stack.
- **pla**: Pull the top value off the stack and deposit it in the accumulator.
- **plp**: Pull the top value off the stack and deposit it into the P register.

The php and plp operations are often included in assembly language subroutines so that the contents of the P register won't be erased during subroutines. When you jump to a subroutine that may change the status of the P register, it's a good idea to begin the subroutine by pushing the contents of the P register onto the stack. Then, just before the subroutine ends, you can restore the P register's previous state with a php instruction. This ensures that the P register's contents aren't destroyed during the subroutine.

Programs written for the IIGS often use stack addressing because of the way the IIGS Toolbox is designed. As you shall see in part 2, most routines in the Toolbox are called by placing values on the stack, accessing a macro, and then pulling values off the stack when the macro returns. We go into more detail about how to do that in chapter 7.

The 65C816, as pointed out at the beginning of this section, has three addressing modes that use the stack. One of these modes, simple stack addressing, was covered at the start of this chapter. The other two, stack relative addressing and stack relative indirect indexed addressing, are examined next.

**Stack Relative Addressing**

Stack relative addressing is the first addressing mode in the 6502 chip family that has made it possible to access a byte in the stack without removing the last byte pushed onto the stack. A statement that uses stack relative addressing is written in this format

\[
\text{lda 3,s}
\]

The value that follows the mnemonic is an offset that is added to the contents of the stack pointer to form the effective address. When the statement is assembled into machine code, the operand is assembled as a single byte. Because the stack is always in bank $00, the effective address calculated by adding the operand to the stack pointer is always 16 bytes long.
In determining what offset to use to access a value on the stack, it is important to remember that offsets used in stack relative addressing start at 1, not at 0. The stack pointer always points to the next available stack location, which is 1 byte below the last byte pulled off the stack. So, to load the accumulator with the last value pushed onto the stack using stack relative addressing, you would use this statement:

```
lda 1,s
```

**Stack Relative Indirect Indexed Addressing**

You can use stack relative indirect indexed addressing to access a value indirectly, with a pointer pushed onto the stack. The format of a statement that uses stack relative indirect indexed addressing is

```
lda ($30,s),y
```

Stack relative indirect indexed addressing works much like direct indirect indexed addressing. The value between the parentheses is a 1-byte offset. The 65C816 adds this offset to the contents of the stack pointer to form the lower 16 bits of a base address in bank $00. The upper 8 bits of the base address are taken from the data bank register. Finally, the value of the Y register is added to this base address, and the result is the effective 24-byte address of the operand.

**A Warning**

Now that you know how stack addressing works, it’s time to add a note of warning: The 65C816 stack can be a dangerous section of memory for novice programmers to play with. When you use the stack in an assembly language routine, it’s extremely important when the routine ends to leave the stack exactly as you found it. If you’ve placed a value on the stack during a routine, it must be removed from the stack before the routine ends and normal processing resumes. Otherwise, there might be “garbage” on the stack when the next routine is called, and that can result in program crashes, memory wipeouts, and various other programming disasters. Remember: Mismanagement of the hardware stack is extremely hazardous to the health of assembly language programs.

**Block Move Addressing**

The 65C816 has one addressing mode for block moves. It is called block source bank, destination bank addressing. This addressing mode is used by two instructions: `mvn` (block move next, or block move negative) and `mvp` (block move previous, or block move positive). The syntax is

```
mvn 0,0
```

A statement that uses block move addressing takes a 2-byte operand. In source code written using the APW assembler, these 2 bytes are separated by a comma. The first byte of the operand specifies the 64K bank of memory that
a block of data is being moved to, and the second byte specifies the bank in which the source data lies. The Y register contains the lower 16 bits of the destination address. The X register contains the lower 16 bits of the source address. The number of bytes to be moved, minus 1, is contained in the C register, the 65C816’s 16-bit accumulator. More details about how block move addressing mode works can be found in chapter 5 and appendix A, which deals with the 65C816 instruction set.
PART 2

The Apple IIgs Toolbox
CHAPTER 7

Introducing the IIgs Toolbox

*Using the Event Manager and the Memory Manager*

The biggest difference between the Apple IIgs and earlier members of the Apple II family is the IIgs has a gigantic Toolbox: a collection of more than 800 prewritten routines that greatly simplify the writing of sophisticated programs.

We have encountered a number of the tools in the IIgs Toolbox in previous chapters, but we haven't gone into detail about how they work. In this chapter, you are formally introduced to the various tool kits in the Toolbox, and you take a close look at what they are and what they do.

**Tool Sets**

The 800-plus routines in the IIgs Toolbox are divided into *tool sets*, or collections of related routines. Each routine in a tool set performs one function, or fundamental operation. For example, the QuickDraw II tool set contains one routine that draws a rectangle, another that draws an oval, and so on.

Some tool sets in the Toolbox manage important features of the Apple IIgs and are therefore called *managers*. For example, the IIgs Memory Manager allocates, deallocates, and keeps track of all memory used by the computer. The Event Manager keeps track of mouse and keyboard operations and
calls other manager tools, such as the Menu Manager and the Window Manager. The Menu Manager and the Window Manager, as their names imply, manage IIgs operations that involve menus and windows.

**What the Toolbox Can Do**

The most important reason for learning how to use the Toolbox is that it can take care of much of the drudgery that otherwise is the responsibility of the programmer. It can free your application so it can concentrate on its most important tasks rather than deal with routine background work and trivial details.

Another reason for using the Toolbox is that its routines are always available to help you perform many important tasks. Most of the remarkable capabilities of the IIgs are accessed easily through the IIgs Toolbox, the various tool sets in the Toolbox, and each set’s individual tools.

**What the Toolbox Contains**

The tools in the IIgs Toolbox are listed in chapter 1. We’ll list them again, in more detail.

**The Big Five**

Five vital IIgs tool sets are dubbed the “Big Five.” All these tools must be used in every event-driven IIgs application because they are the basic framework upon which other tools build. The “Big Five” tools are

- The Tool Locator, which provides the mechanism for dispatching tool calls. You don’t need to know a tool’s memory location; the Tool Locator knows, and it retrieves the tool when you make a tool call.

- The Memory Manager, which allocates, deallocates, and keeps track of all memory used in every program. When your application needs memory, it must request it from the Memory Manager. When a well-written application ends, it calls the Memory Manager again to deallocate the memory it no longer needs.

- The Miscellaneous Tool Set, which includes mostly system-level routines that must be available for other tool sets. The Miscellaneous Tool Set is vital to the operation of the IIgs. It keeps track of mouse movements, takes care of battery-powered memory functions, and handles interrupts. All tools except the Tool Locator and the Memory Manager depend on the tools in the Miscellaneous Tool Set in some way.

- QuickDraw II, which controls the graphics environment of the IIgs and draws objects and text when the computer is in super high-resolution graphics mode. QuickDraw II draws the menus, windows, controls, and other object used by many of the tools in the Toolbox.
The Event Manager, which manages all the Ilcs's event-driven programming. The Event Manager keeps track of keyboard and mouse events, maintains a queue of the events that take place, and passes information about events to the application.

Another important group of tools control the Ilgs desktop interface. The desktop interface tool group is the interface between the Ilgs user and the computer's programs. Most of the Ilgs programs you write will use desktop interface utilities such as the Window Manager, Menu Manager, Dialog Manager, and LineEdit Tool Set.

The tool sets in the desktop interface group are

- The Window Manager, which draws, updates, maintains, and deallocates windows. Because the Ilgs is designed to be used in a window environment, the Window Manager is one of the most important tools in the Toolbox.

- The Control Manager, which draws pushbuttons, scroll bars, and other objects on the super high-resolution screen. When the Control Manager draws controls, you can activate them by clicking the mouse. In this way, you can scroll windows, turn functions off and on, and cause various other things to happen. The Control Manager is primarily a low-level tool set whose functions are used by other tools such as the Window Manager. But the Control Manager can also create and manipulate user-designed controls.

- The Menu Manager, which controls and maintains pull-down menus and items in menus. Because the Ilgs is designed to be used in a menu environment, the Menu Manager is one of the most important tool sets in the Toolbox.

- The LineEdit Tool Set, which performs much the same function in the super high-resolution environment that the Text Tool Set performs when the computer is in text mode. The LineEdit Tool Set places text on the screen and allows the user to edit it. In addition, LineEdit offers "cut-and-paste" operations that provide convenient methods for editing, deleting, and moving text.

- The Dialog Manager, which offers a convenient and easy-to-use interface between the Ilgs and the user. The Dialog Manager creates windows to display messages and can accept user input. Windows created by the Dialog Manager can warn the user of dangers or special situations and provide the user with an easy method for making decisions and passing them to a Ilgs program.

- The Scrap Manager, which offers the user a method of storing information temporarily so it can be moved to another location, document, or application. When information is no longer needed, the Scrap Manager can delete it.

- The Desk Manager, which manages desk accessories, mini-applications executed while other applications are running. The Desk
The IIGS Toolbox

Manager controls clocks, calculators, note pads, and other useful
desktop utilities.

- The Standard File Operations Tool Set, which provides an easy-to-
  use interface with ProDOS 16 in a super high-resolution
  environment. When the Standard File Operations Tool Set is
  activated, it presents a special dialog window that can load, save, 
  open, and close disk files without requiring the user to master the
  technical details of ProDOS 16.

- The List Manager, a low-level tool set used primarily by other tool
  sets, such as the Standard File Operations Tool Set and the Font
  Manager. The List Manager creates lists of items, such as files and
  fonts, and is also available for use in application programs.

- The Font Manager, which keeps track of the character fonts
  available to the IIGS and provides applications with information about
  them. The Font Manager can tell you how many fonts are available
  and the characteristics of those fonts. It can also underline text, print
  in boldface or italics, and print text of various sizes on a printer or
  the screen.

- QuickDraw II Auxiliary, which adds special capabilities to
  QuickDraw II. The tools in the QuickDraw II Auxiliary tool set can
  combine various drawing calls into a single picture, shrink and
  reduce drawn objects and the bit maps used to create screen
  windows, and draw icons and other objects on the super high-
  resolution screen.

Math Tool Sets The Apple IIGS has two tool sets that perform arithmetic and mathematic
operations:

- The Integer Math Tool Set, which includes routines that perform
  operations using integers. The Integer Math Tool Set handles
  integers, long integers, and signed fractional numbers. It can also
  convert integers, hexadecimal numbers, and decimal numbers from
  one form to another and from one base to another.

- The SANE Tool Set, which supports the Standard Apple Numerics
  (SANE) mathematics package. With the SANE Tool Set, the IIGS
  can carry out extended-precision calculations in accordance with the
  widely accepted IEEE standard.

The Print Manager The Print Manager allows applications to use standard QuickDraw II routines
to print text or graphics on a printer. It can interface an application with a
standard dot-matrix printer such as an Apple ImageWriter, or a laser printer
such as the Apple LaserWriter, or a network of laser printers.
The IIgs has three sound-related tool sets:

- The Sound Tool Set, which provides a method for using the IIgs’s sound hardware without using specific hardware input-output addresses.
- The Note Synthesizer, which creates notes, sound patterns, and waveforms with sound-synthesizing techniques similar to those used by synthesizers in professional sound studios.
- The Note Sequencer, which provides a convenient method for incorporating sequences of musical notes into a program.

The Apple IIgs has one group of tools that are categorized as specialized tools. They include:

- The Apple Desktop Bus (ADB) Tool Set, which interfaces the IIgs with its keyboard, mouse, and other I/O devices such as graphics tablets and game controllers.
- The Scheduler, which prevents a tool call from crashing the system by asking for a temporarily unavailable system resource.
- The Text Tool Set, which provides an interface between Apple II character device drivers and applications running in native mode.

How To Use the Toolbox

In early models of the IIgs, many of the tools in the Toolbox were provided on the system disk and had to be loaded into RAM. In newer models, increasing numbers of tools have been taken off the system disk and included in ROM. More tools are instantly available to application programs without using disk space, loading time, or what would otherwise be free memory.

You seldom need to keep track of a tool’s location or even whether the toolkit that contains the tool is in ROM or RAM. A tool set called the Tool Locator keeps track of all tools for you and takes care of most of the “housekeeping” involved in loading and unloading tools.

The Tool Locator is automatically initialized when ProDOS 16 is booted, and from then on you can use it any time you like. In an assembly language program written using APW, the easiest way to use the Tool Locator is to decide what tools you will use in a program and then make the APW macro call

_LoadTools

All the tools you’ll need in your program are then loaded into memory.
Making the LoadTools Call

Before you can make a LoadTools call, you have to design a tool table containing the identification number and lowest suitable version number of each tool set you plan to use in your program. The available tools are listed in table 7-1.

### Table 7-1
Tools in the IIgs Toolbox

<table>
<thead>
<tr>
<th>Tool Number</th>
<th>Tool</th>
<th>Version on System Disk 3.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Tool Locator</td>
<td>0201</td>
</tr>
<tr>
<td>2</td>
<td>Memory Manager</td>
<td>0200</td>
</tr>
<tr>
<td>3</td>
<td>Miscellaneous Tool Set</td>
<td>0200</td>
</tr>
<tr>
<td>4</td>
<td>QuickDraw II</td>
<td>0202</td>
</tr>
<tr>
<td>5</td>
<td>Desk Manager</td>
<td>0202</td>
</tr>
<tr>
<td>6</td>
<td>Event Manager</td>
<td>0201</td>
</tr>
<tr>
<td>7</td>
<td>Scheduler</td>
<td>0200</td>
</tr>
<tr>
<td>8</td>
<td>Sound Manager</td>
<td>0200</td>
</tr>
<tr>
<td>9</td>
<td>Apple Desktop Bus</td>
<td>0201</td>
</tr>
<tr>
<td>10</td>
<td>SANE</td>
<td>0202</td>
</tr>
<tr>
<td>11</td>
<td>Integer Math Tool Set</td>
<td>0200</td>
</tr>
<tr>
<td>12</td>
<td>Text Tool Set</td>
<td>0200</td>
</tr>
<tr>
<td>13</td>
<td>Not used</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Window Manager</td>
<td>0201</td>
</tr>
<tr>
<td>15</td>
<td>Menu Manager</td>
<td>0200</td>
</tr>
<tr>
<td>16</td>
<td>Control Manager</td>
<td>0201</td>
</tr>
<tr>
<td>17</td>
<td>System Loader</td>
<td>0103</td>
</tr>
<tr>
<td>18</td>
<td>QuickDraw Auxiliary</td>
<td>0202</td>
</tr>
<tr>
<td>19</td>
<td>Print Manager</td>
<td>0102</td>
</tr>
<tr>
<td>20</td>
<td>LineEdit Tool Set</td>
<td>0200</td>
</tr>
<tr>
<td>21</td>
<td>Dialog Manager</td>
<td>0200</td>
</tr>
<tr>
<td>22</td>
<td>Scrap Manager</td>
<td>0102</td>
</tr>
<tr>
<td>23</td>
<td>Standard File Operations Tool Set</td>
<td>0200</td>
</tr>
<tr>
<td>24</td>
<td>Disk Utilities</td>
<td>0100</td>
</tr>
<tr>
<td>25</td>
<td>Note Synthesizer</td>
<td>0100</td>
</tr>
<tr>
<td>26</td>
<td>Note Sequencer</td>
<td>0100</td>
</tr>
<tr>
<td>27</td>
<td>Font Manager</td>
<td>0201</td>
</tr>
<tr>
<td>28</td>
<td>List Manager</td>
<td>0201</td>
</tr>
</tbody>
</table>

The LoadTools call must be used with a carefully designed tool table to work properly. The first word in the tool table must contain the number of tool sets that will be loaded. Next, you must list the ID number of each tool set, along with the minimum acceptable version number of each tool set to be loaded. Listing 7-1 shows how the LoadTools call is included in a IIgs assembly language program.
Introduction to the JIGS Toolbox

Listing 7-1
Tool loading routine

* * ROUTINE FOR LOADING TOOLS *

Listing 7-1
Tool loading routine

* ROUTINE FOR LOADING TOOLS *

LoadEmUp START

PushLong #ToolTable
_LoadTools

rts

ToolTable
dc i'13'
; no. of tools to load
dc i'$04,$0100'
; quickdraw
dc i'$05,$0100'
; desk manager
dc i'$06,$0100'
; event manager
dc i'$0E,$0000'
; window manager
dc i'$0F,$0100'
; menu manager
dc i'$10,$0100'
; control manager
dc i'$12,$0000'
; qd auxiliary
dc i'$13,$0000'
; print manager
dc i'$14,$0000'
; line edit
dc i'$15,$0000'
; dialog manager
dc i'$17,$0100'
; std file manager
dc i'$1B,$0100'
; font manager
dc i'$1C,$0000'
; list manager

END

Initializing Tools

Some tool sets—such as the Tool Locator, the Text Tool Set, and the Integer Math Tool Set—are present in ROM at all times and thus do not have to be loaded before they are used. But most tool sets do have to be loaded and then have to be started up, or initialized. When you’re finished using a tool set, you should shut it down.

It is very easy to initialize a tool set, and it is just as easy to shut one down. To initialize or shut down a tool set, you make a specific call. The following call, for example, initializes the LineEdit Tool Set:

_LEStartup

and this call shuts it down:

_LEShutdown

The sample programs in the rest of this book give you plenty of practice in starting up and shutting down tool sets.
There are two important points to think about when you plan to call an II*gs tool from your application. One is tool dependency, making sure certain tools are loaded and initialized before other tools that rely on them are called. The second point is making sure the II*gs is in 16-bit native mode before any tools are loaded, initialized, and called.

It is very important to start up tools in the correct order. A tool set dependency chart, which shows what tools have to be started before other tools can be used, appears in Table 7-2. You can practice starting up tool sets in the proper order by typing, assembling (or compiling), and running the sample programs in chapters 8 through 13.

**Table 7-2**

**Tool Set Dependency**

<table>
<thead>
<tr>
<th>Hex</th>
<th>Dec</th>
<th>Tool Set</th>
<th>Tool Locator</th>
<th>Memory Manager</th>
<th>Misc. Tool Set</th>
<th>Quick-Draw II</th>
<th>Event Manager</th>
<th>Window Manager</th>
<th>Control Manager</th>
<th>Menu Manager</th>
<th>LineEdit Tool Set</th>
<th>Dialog Manager</th>
<th>Scrap Manager</th>
<th>List Manager</th>
</tr>
</thead>
<tbody>
<tr>
<td>$01</td>
<td>1</td>
<td>Tool Locator</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$02</td>
<td>2</td>
<td>Memory Manager</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$03</td>
<td>3</td>
<td>Misc. Tool Set</td>
<td></td>
<td></td>
<td>$0102</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$04</td>
<td>4</td>
<td>Quick-Draw II</td>
<td></td>
<td>$0102</td>
<td>$0102</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$12</td>
<td>18</td>
<td>Quick-Draw II</td>
<td></td>
<td>$0102</td>
<td>$0102</td>
<td>$0102</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>$06</td>
<td>6</td>
<td>Event Manager</td>
<td>$0102</td>
<td>$0102</td>
<td>$0102</td>
<td>$0102</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$0E</td>
<td>14</td>
<td>Window Manager</td>
<td>$0102</td>
<td>$0102</td>
<td>$0102</td>
<td>$0102</td>
<td>$0100</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$10</td>
<td>16</td>
<td>Control Manager</td>
<td>$0102</td>
<td>$0102</td>
<td>$0102</td>
<td>$0100</td>
<td>$0103</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$0F</td>
<td>15</td>
<td>Menu Manager</td>
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<td>$0102</td>
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<td>$0102</td>
<td>$0100</td>
<td>$0103</td>
<td>$0103</td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>$14</td>
<td>20</td>
<td>LineEdit Tool Set</td>
<td>$0102</td>
<td>$0102</td>
<td>$0102</td>
<td>$0102</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$15</td>
<td>21</td>
<td>Dialog Manager</td>
<td>$0102</td>
<td>$0102</td>
<td>$0102</td>
<td>$0100</td>
<td>$0103</td>
<td>$0103</td>
<td>$0103</td>
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<td>$0100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$16</td>
<td>22</td>
<td>Scrap Manager</td>
<td>$0102</td>
<td>$0102</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>$05</td>
<td>5</td>
<td>Desk Manager</td>
<td>$0102</td>
<td>$0102</td>
<td>$0102</td>
<td>$0100</td>
<td>$0103</td>
<td>$0103</td>
<td>$0103</td>
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<td>$0101</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$17</td>
<td>23</td>
<td>Standard File Tool Set</td>
<td>$0102</td>
<td>$0102</td>
<td>$0102</td>
<td>$0100</td>
<td>$0103</td>
<td>$0103</td>
<td>$0103</td>
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<td>$0101</td>
<td>$0100</td>
<td></td>
</tr>
<tr>
<td>$1C</td>
<td>28</td>
<td>List Manager</td>
<td>$0102</td>
<td>$0102</td>
<td>$0102</td>
<td>$0100</td>
<td>$0103</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$13</td>
<td>19</td>
<td>Print Manager</td>
<td>$0102</td>
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<td>$0102</td>
<td>$0100</td>
<td>$0103</td>
<td>$0103</td>
<td>$0103</td>
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<td>$0101</td>
<td>$0100</td>
<td>$0100</td>
<td></td>
</tr>
<tr>
<td>$1B</td>
<td>27</td>
<td>Font Manager</td>
<td>$0102</td>
<td>$0102</td>
<td>$0102</td>
<td>$0100</td>
<td>$0103</td>
<td>$0103</td>
<td>$0103</td>
<td>$0100</td>
<td>$0101</td>
<td>$0101</td>
<td>$0100</td>
<td></td>
</tr>
</tbody>
</table>
It is also important to make sure the IIgs is in native mode, rather than emulation mode, when you use the Toolbox in a program. When the 65C816 is in native mode, its e, m, and x flags are all set to 0, providing it with a 16-bit accumulator and 16-bit index registers. Almost all the tools in the Toolbox require the 65C816 to be in native mode and simply will not work if the processor is in its 8-bit state. Exceptions to this rule are rare and are documented in the Apple IIgs Toolbox Reference.

The Memory Manager

The Memory Manager, like the Tool Locator, resides in ROM and thus does not have to be loaded or initialized. It goes into action as soon as you turn on the IIgs. From then on, it controls the allocation, deallocation, and positioning of every byte in the computer’s memory. The Memory Manager constantly keeps track of how much memory is free and which blocks of memory are allocated to which programs.

The Memory Manager works closely with ProDOS 16 and the System Loader to provide needed memory spaces for loading programs and data and to provide buffers for input and output. All Apple IIgs software, including the System Loader and ProDOS 16, must obtain memory space by making requests (calls) to the Memory Manager.

When a block of memory is allocated by the Memory Manager, it is assigned a number of important attributes that the Memory Manager stores in a special location. These attributes determine how the Memory Manager may modify each block (such as moving it or deleting it), if each block can be purged from memory, if it must be placed in memory in a special way (for example, starting on a page boundary), and what program owns it.

When a program asks for a block of memory, it must pass to the Memory Manager a list of attributes that it wants to assign to the block. These attributes are passed in the form of a word. This is shown in figure 7–1 and is examined more closely later in this chapter. When a group of attributes is assigned to a block of memory, the Memory Manager takes them into account whenever it has to purge, allocate, deallocate, or compact memory.

How an Application Obtains Memory

When an application makes a ProDOS 16 call that requires allocation of memory (such as opening a file or writing from a file to a memory location), ProDOS 16 first obtains any needed memory blocks from the Memory Manager and then performs its tasks. Likewise, the System Loader requests any needed memory either directly or indirectly (through ProDOS 16 calls) from the Memory Manager. Conversely, when an application informs the operating system that it no longer needs memory, that information is passed to the Memory Manager, which in turn frees the application’s allocated memory. In all these cases, the memory allocation and deallocation is automatic as far as the application is concerned.

When an application needs memory for its own use, it must request the memory directly from the Memory Manager. In a few moments, you’ll see how a program can request memory from the Memory Manager.
The IIgs Toolbox

How the Memory Manager Uses Memory

From the Memory Manager's point of view, the memory in the IIgs is divided into three categories:

- Allocatable memory (managed by the Memory Manager). There are no special restrictions on the use of this memory. It includes banks $02 through $DF and parts of banks $EO and $EI.

- Special memory (managed by the Memory Manager and allocatable except under special conditions). There are certain restrictions on the use of this memory because it is used like Apple IIe and IIc memory when the IIgs is in emulation mode. Special memory may not be used by desk accessories, tool sets, and other routines that might be called while IIc/IIe-style applications are running. Banks $00 and $01 and parts of banks $E0 and $E1 are special memory.

- Unmanaged memory (reserved and not managed by the Memory Manager). This category of memory includes the language card area from $D000 to $DFFF in banks $00, $01, $E0, and $E1, addresses $0000–$0800 in banks 0 and 1, and addresses $0000–$2000 in banks $E0 and $E1. The Memory Manager marks this memory as "busy" at startup time and does not interfere with it thereafter.

Figure 7-2 shows how the Memory Manager handles allocatable, special, and unmanaged memory.

Pointers and Handles

Because the Memory Manager can move a memory block and thus change its starting address, IIgs applications cannot use simple pointers to access entry points in memory. Instead, each time the Memory Manager allocates a memory block, it returns to the requesting application a special kind of pointer called a handle. Then the application that owns the memory block can always access it safely by using its handle, rather than an ordinary pointer.

A handle is sometimes described as a "pointer to a pointer." It is a fixed, or unmovable, memory location that contains the address of a simple pointer. The handles used by the IIgs are kept in an unmovable, unpurgeable
How To Assign a Handle

Before a program can request a block of memory (and a handle) from the Memory Manager, it must obtain a user identification code, or user ID, from the Memory Manager. To get a user ID, a program can make the `MMStartup` call, in this fashion:
In this example, a word is pushed onto the stack so that \texttt{MMStartup} has a place on the stack to push its data. Then the APW macro \texttt{MMStartup} makes the \texttt{MMStartup} call. When you make the call, it assigns a user ID number and places it on the stack. When the call returns, the user ID assigned by the Memory Manager is pulled off the stack and placed in a program variable called \texttt{MyID}.

If you’re wondering why the \texttt{MMStartup} call has to be made to get a user ID, the answer is simply that that’s the way it’s done. Because the Memory Manager is a ROM-based tool and is always active, it doesn’t have to be started with a startup call. But the conventional way to get a user ID is to request it with an \texttt{MMStartup} call. And more than one \texttt{MMStartup} call can be made in a program. This would all be less confusing if the \texttt{MMStartup} call had a different name. You just have to remember that the \texttt{MMStartup} call does not really start up the Memory Manager. It is used primarily for obtaining user IDs.

After you have a user ID from the Memory Manager, you can request as many memory blocks as you like. As long as the Memory Manager has enough free RAM available, it will assign memory blocks and return handles. You have to keep track of the handles the Memory Manager assigns and what you’re using them for. One good reason to keep track of handles is that you must dispose of any handles before you end the application. Otherwise, they remain in memory after the application ends, wasting memory space and possibly interfering with other programs.

Before you can dispose of a handle, though, you have to get one. Listing 7–2 is a fragment of assembly language code that shows how to get a handle from the Memory Manager.

\begin{verbatim}
Listing 7–2
Getting a handle from the Memory Manager

PushLong #0 ; space for result
PushLong #$8000 ; size of block
PushWord MyID ; user ID
PushWord #0 ; attributes
PushLong #0 ; Location (0=don't care)
_MMNewHandle
PullLong MyHandle

The call to get a block of memory (along with a handle) is \texttt{NewHandle}. But before you make a \texttt{NewHandle} call, you must push these parameters on the stack:
\begin{itemize}
    \item A space for a result (1 word).
    \item The size of the block of memory being requested (2 words). In
\end{itemize}
\end{verbatim}
How the Memory Manager Uses Handles

After a handle is assigned to a block of memory and the program that owns the handle is told what the handle is, the Memory Manager can move the block as often as needed, and the block’s handle will not change. If the Memory Manager changes the location of the block, it updates the address stored in the handle, but does not change the address of the handle. Thus, the application that owns the memory block can always use the block’s handle to access it, no matter how often the block itself is moved in memory.

Dereferencing a Handle

If an application is sure that a block of memory will always remain in the same spot—that is, if it has requested a locked and unpurgeable handle—the application can access the block by its pointer as well as by its handle. To obtain a pointer to a particular block or location, a special kind of operation called dereferencing is used. Listing 7–3 is a routine that dereferences a handle—that is, it tells you what its handle is. The segment of code that appears in listing 7–3 is used in several programs in part 2.

Listing 7–3
Dereferencing a handle

<table>
<thead>
<tr>
<th>Deref</th>
<th>START</th>
</tr>
</thead>
<tbody>
<tr>
<td>sta</td>
<td>DPTemp</td>
</tr>
<tr>
<td>stx</td>
<td>DPTemp+2</td>
</tr>
<tr>
<td>ldy</td>
<td>#4</td>
</tr>
<tr>
<td>lda</td>
<td>[DPTemp],y</td>
</tr>
<tr>
<td>ora</td>
<td>#$8000</td>
</tr>
<tr>
<td>sta</td>
<td>[DPTemp],y</td>
</tr>
<tr>
<td>dey</td>
<td>dey</td>
</tr>
<tr>
<td>lda</td>
<td>[DPTemp],y</td>
</tr>
<tr>
<td>tax</td>
<td></td>
</tr>
<tr>
<td>lda</td>
<td>[DPTemp]</td>
</tr>
<tr>
<td>rts</td>
<td></td>
</tr>
</tbody>
</table>

In a dereferencing operation, the application reads the address stored

---

listing 7–2, the length of the block being requested is $8000, or 32K.

- The user ID of the application requesting the block (1 word).
- The block’s attributes (1 word). A diagram of this word appears in figure 7–1. (An explanation of each bit is provided later in this chapter.)
- The starting address of the block (2 words). Unless there is an overwhelming need to store a block in a specific location, this parameter should be #0 so that the Memory Manager determines where to store the block being requested.

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in the location pointed to by the handle. That address is the pointer to the block. If the Memory Manager moves the block, the pointer is no longer valid.

Because the Memory Manager does not allocate and deallocate memory in any order, memory can become fragmented into a jumble of free and allocated memory blocks. When this happens, the Memory Manager may not be able to allocate a requested block, even if enough free memory is available. So the Memory Manager has the capability of compacting memory, or moving all relocatable blocks so that bigger blocks of memory become available. Figure 7–3 shows how the Memory Manager compacts memory.

As you can guess by looking at figure 7–3, when fixed and locked blocks are present in memory, the Memory Manager can’t do a very good job of compacting memory. For this reason, applications should avoid requesting fixed and locked blocks, and settle for movable blocks when possible.

Purging Memory

If the Memory Manager compacts as much memory as possible and still can’t allocate a block, it tries to purge any blocks marked unlocked and purgeable. When a block is purged, its contents are discarded, and the memory it occupied is free for other uses.

When a block is purged, its handle remains allocated, but the value of the master pointer that its handle points to is set to 0, or nil. A handle that points to a nil master pointer is called an empty handle. When the block of memory assigned to a handle is purged, an application asks the Memory

![Figure 7-3](image_url)
Manager to reallocate the purged block. After a block of memory is purged, however, the data in it is irretrievably lost, so only the memory—not the data—can be retrieved by a program.

Properties of Memory Blocks

As mentioned, an application program can control the properties of a memory block by setting up a memory attributes word and passing it to the Memory Manager in a _NewHandle call. Most attributes in an attributes word are defined when the block is allocated and can’t be changed. Some attributes, however, can be modified after allocation.

The layout of a memory attributes word is shown in figure 7–1. In each bit position, a value of 1 means the attribute defined by the bit applies to the block. You might think of setting the bit to 1 as applying a restriction to the block.

**Allocation Attributes**

When a block is allocated, several bits in the attributes word set restrictions on how the block is allocated. These attributes can only be set when the block is allocated. The allocation attributes are

- **Fixed.** If a block is fixed, it cannot be moved when memory is compacted. Code blocks are usually fixed, but data blocks usually should not be fixed.
- **Bank boundary limited.** Specifies that a block must not cross banks. Code blocks may never cross banks, and making a data bank cross bank boundaries is very risky.
- **Special memory usable.** Specifies that the block may be allocated in special memory, or memory used by the IIc and Ile. Special memory includes banks $00 and $01 and screen memory.
- **Page aligned.** For timing or other special reasons, code or data may need to be page aligned.
- **Fixed address.** The block must be at a specified address when allocated. A fixed address attribute should be used only in special situations, for example, in allocating a graphics screen.
- **Fixed bank.** The block must start in a specified bank, for example, on the direct page.

**Modifiable Attributes**

As noted, the Memory Manager can move or purge a block while making room for a new block. The attributes that determine whether a block can be moved or purged can be changed by an application after a block is created. These attributes are

- **Locked.** When a block is locked, it is unmovable and unpurgeable regardless of the setting of the fixed or purge level attributes. A block can thus be locked temporarily while it is being executed or referenced.
The IIGs Toolbox

- Purge level. Purge level is a 2-bit number defining the purge priority of a block.

  When the Memory Manager starts purging blocks of memory, the order of the purging is based on the purge level of the block. The purge level is a 2-bit number specifying the purging priority of the block. The values are:

  3  Most purgeable (used by System Loader)
  2  Next most purgeable
  1  Least purgeable
  0  Not purgeable

  Application programs should use only purge levels 0, 1, and 2; level 3 is reserved for the System Loader. When some applications exit, the memory is not freed but its blocks are set to level 3. The old application can thus be restarted without accessing the disk if the new application did not need the space. If the Memory Manager purges any blocks of an application in this state, it purges all of that application’s blocks.

The Event Manager

Because the IIGs is designed to use event-driven programming, the Event Manager is a vital tool set. It allows applications to monitor the actions initiated by the user—such as movements using the mouse, keyboard, and keypad—and to respond accordingly.

In an event-driven program, the actions tracked and handled by the Event Manager are known, logically enough, as events. For example, when the user presses or releases the button on top of the mouse, that is a mouse down or mouse up event. When the user presses a key on the keyboard, that is a key down event. If the user presses a key and holds it down, that is an auto-key event.

When an event recognized by the Event Manager takes place, the Event Manager may report it immediately or place it in a queue, according to its priority. When the Event Manager has a series of events waiting in its queue, it removes and reports them, one at a time. But they are not necessarily reported in the order in which they were detected because some events have higher priorities than others. You examine the priorities of events later in this section.

When the Event Manager detects a user-generated event—such as a mouse button being pressed or a key being held down—it places information about the event in a record in memory called an event record. The application can then access the contents of the event record to find out what kind of event has taken place so that it can determine what to do. You see what an event record looks like and how it is used later in this section.

When a user-generated event is detected, and information about it is placed in an event record, the application using the Event Manager decides what to do about the reported event. But not all events detected by the Event
Manager are generated by the user. The Event Manager is also used by other tools in the IIgs Toolbox. For example, the Window Manager uses events to coordinate the order and display of windows on the screen. When toolkits such as the Window Manager use the Event Manager, they often decide what to do about the event notifications they receive.

Later in this section, you see how application programs and other tools in the IIgs Toolbox use the Event Manager. Before that, though, let’s see what kinds of events are handled by the Event Manager.

**Types of Events**

Events handled by the Event Manager can be categorized by types. Some types of events report actions by the user. Others are generated by the Window Manager, the Control Manager, device drivers, or even the application being executed. The IIgs system handles some events before the application ever sees them, but it leaves others for applications to handle. We’ll now pause to examine the types of events the Event Manager can handle.

**Mouse Events**

When you press the button on the top of the IIgs mouse, the system generates a mouse down event. When you release the button, the system generates a mouse up event. Movements of the mouse update the cursor position but are not reported as events.

**Keyboard Events**

When you press any character key on the IIgs keyboard or keypad, the system generates a key down event. The character keys include all keys except Shift, Caps, Lock, Control, Option, and Apple, which are called modifier keys. Modifier keys are treated differently and generate no keyboard events of their own. When an event is posted, the state of the modifier keys is reported in a special modifier field in the event record. The program using the Event Manager then decides what the pressing of a modifier key should do.

The character keys on the keyboard and keypad also generate auto-key events when you hold them down. Two different time intervals are associated with auto-key events. The first auto-key event is generated after an initial delay has elapsed since the key was originally pressed. This is called the repeat delay. Subsequent auto-key events occur each time a certain repeat interval has elapsed since the last such event. This is called the repeat speed. You can change these values by using the IIgs Control Panel.

**Window Events**

The Window Manager generates events to coordinate the display of windows on the screen. (You examine the Window Manager in greater detail in chapter 10.) Events generated by the Window Manager are divided into two categories: activate events and update events.

An activate event is generated each time an inactive window becomes active or an active window becomes inactive. Activate and deactivate events generally take place in pairs; that is, one window is deactivated and then another is activated.
An update event takes place when all or part of a window's contents need to be drawn or redrawn, usually as a result of the user opening, closing, activating, or moving a window.

**Other Events**

There are other events the Event Manager can handle. For example:

- Device driver events, which (as you might guess) are generated by device drivers. A device driver event can signify the receipt or interruption of I/O data.

- A desk accessory event, which takes place when you activate a classic desk accessory such as the IIgs Control Panel.

- Application events, which are defined by application programs. A program can define as many as four application events of its own and can use them for any purpose. A call titled `PostEvent` places application-defined events in the event queue.

**Priorities of Events**

When the Event Manager is active, it collects events from a variety of sources and reports them to the application on demand, one at a time. But, as noted, the events are not necessarily reported in the order in which they took place because some have a higher priority than others. The Event Manager places events in a queue and handles them according to a strict priority system.

In general, the Event Manager retrieves events from the event queue in the order in which they were posted. But the way in which types of events are generated and detected causes some events to have a higher priority than others. Also, not all events are kept in the event queue. Furthermore, when an application asks for an event, it can specify the types of events it is interested in, and this can cause the Event Manager to pass over some events in favor of others.

If the queue becomes full, the Event Manager begins discarding old events to make room for new ones as they're posted. Discarded events are always the oldest ones in the queue.

Events are carried out by the Event Manager in the following order:

1. Activate events (a window becoming inactive before another window becomes active). Activate events have priority over all other types of events. They are detected in a special way and are never actually placed in the event queue. The Event Manager's `GetNextEvent` and `EventAvail` routines (which you look at in more detail later) check for pending activate events before looking in the event queue, so they always return such an event if one is available. Because of the special way the routines detect activate events, there can't be more than two such events pending at the same time. At most, there is one event for a window becoming inactive, followed by another event for a window becoming active.
2. Switch events (reserved for future use). Switch events also remain outside the event queue. If no activate events are pending, the `GetNextEvent` and `EventAvail` routines check for a switch event before looking in the event queue. If a switch event is available, the routines check to see if any update events are pending. If so, they return the update event to the application. `GetNextEvent` and `EventAvail` return switch events to the application only if update events are pending. This ensures that all windows are updated before the application is switched.

3. Mouse down, mouse up, key down, auto-key, device driver, application-defined, and desk accessory events (handled in order of posting). This category includes all event types placed in the event queue. With the exceptions noted previously, the Event Manager retrieves them from the queue in the order of their posting. The `GetNextEvent` and `EventAvail` calls only return events from this category.

4. Update events (in front-to-back window order). Update events, like activate and switch events, are not placed in the event queue, but are detected in another way. If no higher priority event is available, `GetNextEvent` and `EventAvail` check for windows whose contents need to be drawn. If they find one, they return an update event for that window. `GetNextEvent` and `EventAvail` also check the order (from front to back) in which windows are displayed on the screen. If two or more windows require updating, `GetNextEvent` and `EventAvail` return an update event for the frontmost window.

**Event Records**

When the Event Manager detects an event, it returns information about the event in an event record. The event record includes the following information:

- Type of event detected
- Time the event was posted, in ticks since system startup
- Location of the mouse when the event was posted, expressed in global (screen) coordinates
- State of mouse buttons and modifier keys when the event was posted
- Additional information that might be required for a particular type of event, such as which key the user pressed or which window is being activated

Every event, including a null event, results in data being entered into an event record by the Event Manager. Listing 7–4 shows how an event record is included in a data section of a program.
The What Field

The What field of an event record contains an event code that tells what kind of event was detected by the Event Manager. The Event Manager's event codes, and their meanings, are listed in Table 7-3.

The Message Field

The Message field contains an event message that returns additional information about the detected event. The nature of this message depends on the event type, as shown in Table 7-4.

The Modifiers Field

The Modifiers field of an event record shows the state that various keys and control buttons were in when an event was posted. In addition, the ActiveFlag and ChangeFlag bits in the Modifiers field provide further information about activate events. See Table 7-5.

### Table 7-3

<table>
<thead>
<tr>
<th>Code</th>
<th>Name</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>NullEvt</td>
<td>Null event</td>
</tr>
<tr>
<td>1</td>
<td>MouseButtonEvt</td>
<td>Mouse down event</td>
</tr>
<tr>
<td>2</td>
<td>MouseUpEvt</td>
<td>Mouse up event</td>
</tr>
<tr>
<td>3</td>
<td>KeyDownEvt</td>
<td>Key down event</td>
</tr>
<tr>
<td>4</td>
<td>Undefined</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>AutoKeyEvt</td>
<td>Auto-key event</td>
</tr>
<tr>
<td>6</td>
<td>UpdateEvt</td>
<td>Update event</td>
</tr>
<tr>
<td>7</td>
<td>Undefined</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>ActivateEvt</td>
<td>Activate event</td>
</tr>
<tr>
<td>9</td>
<td>SwitchEvt</td>
<td>Switch event</td>
</tr>
<tr>
<td>10</td>
<td>DeskAccEvt</td>
<td>Desk accessory event</td>
</tr>
<tr>
<td>11</td>
<td>DriveEvt</td>
<td>Device driver event</td>
</tr>
<tr>
<td>12</td>
<td>App1Evt</td>
<td>Application-defined event</td>
</tr>
<tr>
<td>13</td>
<td>App2Evt</td>
<td>Application-defined event</td>
</tr>
<tr>
<td>14</td>
<td>App3Evt</td>
<td>Application-defined event</td>
</tr>
<tr>
<td>15</td>
<td>App4Evt</td>
<td>Application-defined event</td>
</tr>
</tbody>
</table>
### Table 7-4
#### Event Messages

<table>
<thead>
<tr>
<th>Event Type</th>
<th>Event Message</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mouse down</td>
<td>Button number (0 or 1) in low word; high word undefined</td>
</tr>
<tr>
<td>Mouse up</td>
<td>Button number (0 or 1) in low word; high word undefined</td>
</tr>
<tr>
<td>Key down</td>
<td>ASCII code in low word, low byte; low word, high byte clear; upper 3 bytes undefined</td>
</tr>
<tr>
<td>Auto-key</td>
<td>ASCII code in low word, low byte; low word, high byte clear; upper 3 bytes undefined</td>
</tr>
<tr>
<td>Activate</td>
<td>Pointer to window</td>
</tr>
<tr>
<td>Update</td>
<td>Pointer to window</td>
</tr>
<tr>
<td>Device driver</td>
<td>Defined by device driver</td>
</tr>
<tr>
<td>Application</td>
<td>Defined by application</td>
</tr>
<tr>
<td>Switch</td>
<td>Undefined</td>
</tr>
<tr>
<td>Desk accessory</td>
<td>Undefined</td>
</tr>
<tr>
<td>Null</td>
<td>Undefined</td>
</tr>
</tbody>
</table>

### Table 7-5
#### Modifiers Field of an Event Record

<table>
<thead>
<tr>
<th>Bit</th>
<th>Name</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>ActiveFlag</td>
<td>0 = Window being deactivated</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 = Window being activated</td>
</tr>
<tr>
<td>1</td>
<td>ChangeFlag</td>
<td>0 = No change</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 = Active window being changed to system or application window</td>
</tr>
<tr>
<td>2</td>
<td>Reserved</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Reserved</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Reserved</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Reserved</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>BtnOState</td>
<td>0 = Mouse button down</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 = Mouse button up</td>
</tr>
<tr>
<td>7</td>
<td>Btn1State</td>
<td>0 = Mouse button 2 down</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 = Mouse button 2 up</td>
</tr>
<tr>
<td>8</td>
<td>Apple key</td>
<td>0 = Apple key up</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 = Apple key down</td>
</tr>
<tr>
<td>9</td>
<td>Shift key</td>
<td>0 = Shift key up</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 = Shift key down</td>
</tr>
<tr>
<td>10</td>
<td>Caps lock key</td>
<td>0 = Caps lock up</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 = Caps lock down</td>
</tr>
<tr>
<td>11</td>
<td>Option key</td>
<td>0 = Option key up</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 = Option key down</td>
</tr>
<tr>
<td>12</td>
<td>Control key</td>
<td>0 = Control key up</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 = Control key down</td>
</tr>
<tr>
<td>13</td>
<td>Keypad</td>
<td>0 = Key pressed on keyboard</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 = Key pressed on keypad</td>
</tr>
<tr>
<td>14</td>
<td>Reserved</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Reserved</td>
<td></td>
</tr>
</tbody>
</table>
Bits 6 through 13 of the **Modifiers** field show the state of the mouse button and modifier keys at the time an event was posted. The **Btn0State** and **Btn1State** bits (bits 6 and 7) are set to 1 if the corresponding mouse button is up. The bits for the five modifier keys are set to 1 if their corresponding keys are down.

The **ActiveFlag** is set to 1 if a window pointed to by the event message is being activated or set to 0 if it is being deactivated. The **ChangeFlag** bit is set to 1 if the active window is being changed from an application window to a system window, or vice versa. Otherwise, it is set to 0.

### Loading and Initializing the Event Manager

Now that you know how to interpret event records, you're ready to load and initialize the Event Manager. Before the Event Manager tool set is started up, it must be loaded. In most cases, the best way to load the Event Manager is with the Tool Locator's `LoadTools` call, described previously in this chapter.

When the Event Manager is loaded, several other operations must be carried out before it can be started. For example, before a call to start the Event Manager can be issued, these tool sets must be in memory and initialized:

- **Tool Locator.** (No action needed; initialization is automatic.)
- **Memory Manager.** (Does not have to be loaded; must be initialized if a user ID is needed.)
- **Miscellaneous Tool Set.** (Must be loaded and initialized.)
- **QuickDraw II.** (Must be loaded and initialized.)

Before a program can start up the Event Manager, it must also obtain four direct pages that are reserved for use by QuickDraw II and the Event Manager. The QuickDraw tool set requires three reserved direct pages and the Event Manager requires three. Listing 7–5 is a fragment of code that shows how to set up three private direct pages for QuickDraw and one for the Event Manager.

### Listing 7–5

**Reserving direct pages for QuickDraw and the Event Manager**

```
PushLong  #0 ; space for handle
PushLong  #$300 ; eight pages
PushWord MyID
PushWord  #$C001 ; locked, fixed, fixed bank

PushLong  #0
_NewHandle
```

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7—Introducing the Ilgs Toolbox

pla
sta DPHandle
pla
sta DPHandle+2

lda [DPHandle]
sta DPPointer

In listing 7-5, the Memory Manager call NewHandle obtains the direct page workspace that QuickDraw and the Event Manager need. The parameters passed to NewHandle specify a block size of $400 (three pages for QuickDraw and one for the Event Manager) and an attribute word of $C001, or %1100 0000 0000 0001. This parameter tells the Memory Manager that the block it assigns should be locked and fixed and should be situated in bank $00.

When QuickDraw and the Event Manager have the reserved page zeros they need, they can be started up with the calls QDStartup and EMStartup. Listing 7-6 shows how QuickDraw and the Event Manager are initialized in a program.

Listing 7-6
Starting the Event Manager

*** INITIALIZE QUICKDRAW II ***

lda DPPointer ; pointer to direct page
ph
PushWord #$ScreenMode ; either 320 or 640 mode
PushWord #$160 ; max size of scan line
PushWord MyID
_QDStartup
ErrorCheck 'Could not start QuickDraw.'

*** INITIALIZE EVENT MANAGER ***

lda DPPointer ; pointer to direct page
clc
adc #$300 ; QD direct page + #$300
ph
PushWord #20 ; queue size
PushWord #0 ; Xclamp low
PushWord #$MaxX ; Xclamp high
PushWord #0 ; Y clamp low
PushWord #200 ; Y clamp high
PushWord MyID
_EMStartup
ErrorCheck 'Could not start Event Manager.'
Writing an Event Loop

When you load the Event Manager, start the tools it uses, and supply QuickDraw and the Event Manager with the direct page space they need, you are ready to write a program that uses an event loop handled by the Event Manager.

Some ruffles and flourishes would be appropriate at this point because learning to write event loops is one of the most important skills you’ll master in your quest to become an Apple IIgs programmer. If you follow Apple’s IIgs interface guidelines—and you should, if you want your programs to be user-friendly and compatible with future models of the IIgs—every program you write has to be based on an event loop. After you start writing event loop programs, you’ll probably be glad you did. Event-driven programs are easier to write, understand, and use than old-fashioned sequential-style programs. In an event-driven program, a very short main loop controls an extremely complex program, and a quick glance usually tells you a lot about how the program works.

Listing 7–7 is the main loop of a simple event-driven program, called EVENT.S1, which is listed in its entirety later in this section. Let’s pause for a look at its main loop and then move on to the complete program.

Listing 7–7
Main loop of an event-driven program

<table>
<thead>
<tr>
<th>Again</th>
<th>PushWord #0</th>
<th>; space for result</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PushWord #$000A</td>
<td>; key down &amp; mouse down events</td>
</tr>
<tr>
<td></td>
<td>PushLong #EventRecord</td>
<td></td>
</tr>
<tr>
<td></td>
<td>_GetNextEvent</td>
<td></td>
</tr>
</tbody>
</table>

    pla
    beq Again

    lda EventWhat |
    asla |
    tax

    jsr (EventTable,x) |

    lda QuitFlag |
    beq again

    rts
How an Event Loop Works

As listing 7–7 illustrates, the heart of a typical event loop is the Event Manager call `GetNextEvent`. When you call `GetNextEvent`, you have to pass it three parameters:

- A 1-word space on the stack, which `GetNextEvent` fills with a value before it returns.
- A 1-word mask, which tells `GetNextEvent` what kinds of events to look for and what kinds of events to ignore. An event mask is a word in which each bit stands for one type of event. By setting certain bits and leaving other bits clear, you instruct the Event Manager to be on the lookout for certain types of events, and to pay no attention to others. Table 7–6 lists the Event Manager’s event mask. When the Event Manager is in an event loop, it reports each type of event that has a bit set in the event mask and ignores each event whose corresponding bit is clear. If you pass the Event Manager an event mask of $FFFF, it reports on all events detected.
- A pointer to an event record. When an application uses the Event Manager, it must place an event record somewhere in memory. Then, when the Event Manager posts an event, it can place important information about the event in the event record.

When the Event Manager processes a `GetNextEvent` call, it returns a 1-word Boolean value: a nonzero value (true) if an event was detected and a zero value (false) if there was no event.

The `GetNextEvent` call is usually used in a loop. In listing 7–7, `GetNextEvent` is used in the loop labeled `Again`. Each time the loop makes a cycle, `GetNextEvent` is called. Then the 1-word Boolean value returned by `GetNextEvent` is pulled off the stack. If `GetNextEvent` does not detect an event, the program branches back to the line labeled `Again` and makes another `GetNextEvent` call.

Interpreting the Event Record

If `GetNextEvent` detects an event, it places information about the event in an event record, which must be set up by the program using the Event Manager. Listing 7–8 is an event record you’ll be using in the EVENT.S1 program later in this chapter.

Listing 7–8

Event record in the EVENT.S1 program

<table>
<thead>
<tr>
<th>EventData</th>
<th>DATA</th>
</tr>
</thead>
<tbody>
<tr>
<td>EventRecord</td>
<td>anop</td>
</tr>
<tr>
<td>EventWhat</td>
<td>ds 2</td>
</tr>
<tr>
<td>EventMessage</td>
<td>ds 4</td>
</tr>
<tr>
<td>EventWhen</td>
<td>ds 4</td>
</tr>
<tr>
<td>EventWhere</td>
<td>ds 4</td>
</tr>
<tr>
<td>EventModifiers</td>
<td>ds 2</td>
</tr>
</tbody>
</table>

END
### Table 7-6
Event Manager's Event Mask

<table>
<thead>
<tr>
<th>Bit</th>
<th>Name</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Not used</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Mouse down mask</td>
<td>0 = No mouse down event</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 = Mouse down event</td>
</tr>
<tr>
<td>2</td>
<td>Mouse up mask</td>
<td>0 = No mouse up event</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 = Mouse up event</td>
</tr>
<tr>
<td>3</td>
<td>Key down mask</td>
<td>0 = No key down event</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 = Key down event</td>
</tr>
<tr>
<td>4</td>
<td>Not used</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Auto-key mask</td>
<td>0 = No auto-key event</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 = Auto-key event</td>
</tr>
<tr>
<td>6</td>
<td>Update mask</td>
<td>0 = No update event</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 = Update event</td>
</tr>
<tr>
<td>7</td>
<td>Not used</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Activate mask</td>
<td>0 = No activate event</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 = Activate event</td>
</tr>
<tr>
<td>9</td>
<td>Switch mask</td>
<td>0 = No switch event</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 = Switch event</td>
</tr>
<tr>
<td>10</td>
<td>Desk accessory mask</td>
<td>0 = No desk accessory event</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 = Desk accessory event</td>
</tr>
<tr>
<td>11</td>
<td>Device driver mask</td>
<td>0 = No device driver event</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 = Device driver event</td>
</tr>
<tr>
<td>12</td>
<td>Not used</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Application-defined events</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Application-defined events</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Application-defined events</td>
<td></td>
</tr>
</tbody>
</table>

As listing 7-8 shows, the event record in the EVENT.S1 program has five elements, or fields:

- **What** field, called EventWhat. In this field, the Event Manager returns a code telling what kind of event was detected. The event codes that can be returned in this field are listed in table 7-3.

- **Message** field, called EventMessage. The nature of this message depends on the type of event detected, as shown in table 7-4.

- **When** field, called EventWhen. In this field, the Event Manager returns the number of clock ticks since the system was last started.

- **Where** field, called EventWhere. In this field, the Event Manager places the location of the mouse, in global coordinates, when the event was posted.

- **Modifiers** field, called EventModifiers. When a GetNextEvent call returns, this field contains information about
activate events and the states of certain keyboard keys and hand-controller buttons when an event was posted. A bit-by-bit explanation of this field is in table 7–5.

**Using an Event Table**

When the Event Manager detects an event and places information about it in an event record, the EVENT.S1 program uses a block of data called an event table to decide what to do about the event. An event table is simply a table of pointers to subroutines that an application program uses to respond to events of various types. In the EVENT.S1 program, when the GetNextEvent call detects an event and places its event code in the What field of an event record, an addressing mode called absolute indexed indirect addressing interprets the event code returned by the Event Manager and jumps to the appropriate subroutine. Listing 7–9 shows the event table used in the EVENT.S1 program.

<table>
<thead>
<tr>
<th>EventTable</th>
<th>DATA</th>
</tr>
</thead>
<tbody>
<tr>
<td>dc 'ignore'</td>
<td>; 0 null</td>
</tr>
<tr>
<td>dc 'doQuit'</td>
<td>; 1 mouse down</td>
</tr>
<tr>
<td>dc 'ignore'</td>
<td>; 2 mouse up</td>
</tr>
<tr>
<td>dc 'doQuit'</td>
<td>; 3 key down</td>
</tr>
<tr>
<td>dc 'ignore'</td>
<td>; 4 undefined</td>
</tr>
<tr>
<td>dc 'ignore'</td>
<td>; 5 auto-key down</td>
</tr>
<tr>
<td>dc 'ignore'</td>
<td>; 6 update event</td>
</tr>
<tr>
<td>dc 'ignore'</td>
<td>; 7 undefined</td>
</tr>
<tr>
<td>dc 'ignore'</td>
<td>; 8 activate</td>
</tr>
<tr>
<td>dc 'ignore'</td>
<td>; 9 switch</td>
</tr>
<tr>
<td>dc 'ignore'</td>
<td>; 10 desk acc</td>
</tr>
<tr>
<td>dc 'ignore'</td>
<td>; 11 device driver</td>
</tr>
<tr>
<td>dc 'ignore'</td>
<td>; 12 application</td>
</tr>
<tr>
<td>dc 'ignore'</td>
<td>; 13 ap</td>
</tr>
<tr>
<td>dc 'ignore'</td>
<td>; 14 ap</td>
</tr>
<tr>
<td>dc 'ignore'</td>
<td>; 15 ap</td>
</tr>
<tr>
<td>dc 'ignore'</td>
<td>; 0 in desk</td>
</tr>
</tbody>
</table>

Listing 7–10, a fragment of code, uses indexed indirect addressing to loop through an event table to look for an event code returned by the GetNextEvent call.

In the first line of listing 7–10, the 65C816 accumulator is loaded with the event code that the Event Manager placed in the EventWhat field of the event record. In the next line, an asl a instruction multiplies the event code
Looping through an event table

```
lda EventWhat   ; get event code
asl a          ; code * 2 = table location
tax            ; X is index register
jsr(EventTable,x) ; look up event's routine
```

now in the accumulator by 2. Because each address in the event table is 2 words, this operation converts the code in the accumulator to the proper offset for the address in the table the program is looking for.

When this offset is calculated, the `tax` instruction copies it into the X register. Finally, in the last line of the example, the absolute indexed indirect addressing mode is used to jump to the desired subroutine.

The EVENT.S1 Program

Now that you know how event loops work, you're ready to type, assemble, and execute the EVENT.S1 program. This program prints a message on the screen and then goes into an event loop. During the event loop, an event mask allows the `GetNextEvent` call to respond only to key down and mouse down events, so nothing more will happen until a key or the button on the IIgs mouse is pressed. When the mouse button or a key is pressed, another message is printed on the screen and the program ends. The complete listing of the EVENT.S1 program (listing 7–12) is at the end of this chapter.

Using the IIgs Toolbox from C

If all you wanted to do in C was write standard, vanilla-flavored, UNIX-style programs, you probably wouldn't be using an Apple IIgs. The real fun (and possible profit) in using the IIgs is in creating programs with razzle-dazzle features like windows, pull-down menus, and glorious color and sound. Thanks to the IIgs C Interface Library, which allows you to make IIgs Toolbox calls from C programs, you can put the IIgs through all its spectacular paces from programs written in C.

The APW C compiler, which was used to write all the C programs in this book, fully supports the use of the IIgs Toolbox from C. In addition to the definitions needed to use the standard C library routines, the APW directory `LIBRARIES/CINCLUDE` contains all you need (probably more than you need) to use all the Toolbox calls and data structures in C programs. In addition, APW has made thousands of predefined tool-related constants available to C programmers. These include bit-flag attribute values and the error codes returned by tools. The IIgs C Interface Library also contains many other miscellaneous values to convey special information to and from various tool calls.
Pascal-Type Functions

APW C implements an extension to standard C that allows you to use a special set of Pascal calling conventions as well as standard C conventions. In Pascal, the arguments passed to a function are pushed onto the stack from left to right, so the rightmost argument ends up at the top of the stack. In normal C functions, the leftmost argument winds up on top. Pascal-type functions—and this includes all Ilgs Toolbox routines and any functions you compile from Pascal source code—expect space for any values they return to be pushed onto the stack before they are called. Instead of returning values in the A and X registers as you might expect a well-behaved C call to do, they place the values they return in the space reserved for them on the stack. Naturally, if the space is not reserved, whatever is there is "clobbered" by the returned values, and your program gets the wrong values back when the call returns.

You'll rarely have to worry about any of this, however, as long as you use the Ilgs C Interface Library. Unless you are writing modules in Pascal that are called from C or writing your own Toolbox routines, you won't need to declare anything as Pascal to make Toolbox calls. In APW C, all the conversion details needed to make Toolbox calls are included in a special collection of header files in APW/LIBRARIES/CINCLUDE.

C Toolbox Header File

You don't need to look at the contents of APW's header files to use them in making Toolbox calls. All you have to do is use an #include definition to include the names of the tool sets you need in the heading of your program, then make sure you follow the calling conventions listed under C at the bottom of each page in the Apple Ilgs Toolbox Reference. It may be instructive, however, to look at one or two of APW's header files. You can print one to the printer by making this shell call:

```
#type 2/cinclude/control.h >.printer
```

If you use the APW editor instead of your printer to look at a header file, make sure you don't inadvertently change the file's contents. If you do, be sure you don't save the changes when you quit. Better yet, lock your disk or make a copy of the file and open the copy with the editor.

When you print the contents of a header file on the screen or the printer, the first thing you'll see is a heading, which is a comment. Under that, you'll see something like this:

```
#ifndef _quickdraw_
#include <quickdraw.h>
#endif

#ifndef _event_
#include <event.h>
#endif

#ifndef _control_
#define _control_
```
Next are the real contents of the file. Because the definitions that follow depend in part on definitions provided in other headers, they have to be included first. That's why two `#include` statements head up the file. Because C "complains" if you try to compile the same group of definitions more than once, conditional compilation protects against this occurrence:

```c
#ifndef _control_

The last line:

```c
#define _control_
```

ensures that the definitions that follow are never recompiled during this compilation.

Next you'll see a long list of constant definitions, each preceded by the expression

```c
#define
```

These definitions allow you to use certain named constants described in Apple's Toolbox and C manuals without looking up their values. They make your code easier to write and read. The comments tell you a little about the use of each constant. The ones that say `error` are values placed in the global variable `_toolErr` if an error is detected by one of the tool calls.

After the constant definitions, you'll see a listing of type definitions. These allow you to declare variables in your source that match the structures expected by various tool calls. For instance, you can write:

```c
CtlRecHndl myCtl;
```

You can then store a control's handle, returned by `NewControl` or another function, in the variable called `myCtl`. For example:

```c
myCtl = NewControl(........);
```

Then there is a listing of function declarations. For example:

```c
extern Pascal CtlRecHndl NewControl() inline(Ox0000, dispatcher);
```

This declares a Pascal function returning 4 bytes (long) to be interpreted as a pointer-to-a-pointer to `CtlRecHndl`. It also tells the compiler to insert the inline trap instructions in the object code instead of the usual `jsl` function name generated for normal C functions.
At the end of the function declarations is the line

```
#endif
```

That’s the ending required by the conditional compilation directive at the beginning of the file.

**The Inline Trap Call**

In Ilgs C, almost all Toolbox routines are called with the aid of an inline trap. This mechanism is provided so that the linker won’t go looking in C libraries for Toolbox routines when it runs across their names in C programs. The inline trap mechanism distinguishes Toolbox calls from C library calls so that this won’t happen.

Because tool calls are not located where the linker can find them and because they may be moved as tools are revised, a routine called the Tool Dispatcher, which is always located at address $E1000, uses a jump table to access each tool. This table is updated with each revision of the tools. To call a tool in assembly language, you push the tool number onto the stack and then do a long jump (j $l ) to $E1000. The engineers who designed APW C could have placed assembled routines for making each call into CLIB, and then you could have called them just as you would any other library routine. But this method would increase the size of CLIB and be inefficient, because it would turn each tool call into two nested subroutine calls.

Instead, they designed the inline trap, which inserts dispatcher calls directly into the object code generated by the C compiler. That’s why it is called inline. You will never need to use this call directly; it is used automatically by the function definitions in the headers. But knowing how it works and why it is there gives you a better understanding of what happens when you make a tool call.

**Making Calls with Glue**

A few tool routines are not accessed using inline dispatcher calls placed in your object code. These routines return too much data on the stack, have arguments smaller than a word (less than 2 bytes), or are otherwise not directly compatible with the APW C compiler. For these, routines called glue have been written in assembly language, assembled, and added to CLIB. The glue routines accept input supplied by compiled C code, adapt it (if necessary) to the format required by the call, execute an inline trap, and pass any results back to the calling routine in a way that can be handled easily in C. If you look in an appropriate C header file, you’ll see that such calls look like ordinary C function declarations. For example, in the file misctool.h, you can find this line:

```
extern TimeRec ReadTimeHex();
```

Because of this function, the call ReadTimeHex is accessed by a long jump (j $l ) instead of an inline trap call. This, in turn, causes the APW linker to find a glue routine called ReadTimeHex in CLIB and link it with
your program. Again, all the details are handled for you. All you have to do is make the call and pass it any required arguments (in this case there are none).

Two very important definitions in the types.h file are

```c
char *Pointer;
```

and

```c
Pointer *Handle;
```

Many of the tools in the IIGs Toolbox deal with handles, or pointers to pointers. A handle, as you may recall from chapter 4, is a variable in which the address of another variable, called a master pointer, is stored. All handles must be assigned by the Memory Manager. Much of the data used by the tools in the Toolbox has to be referenced with handles, rather than directly with pointers. The use of handles allows the Memory Manager to compact memory by shuffling data around and purging programs and data that are no longer being used. During this procedure, the address of the master pointer, which the handle points to, remains constant. But the value contained in the master pointer is updated by the Memory Manager whenever the data to which it points is moved.

The definitions of pointer and handle in the types.h file are generic definitions. Because the data type char is a byte, the smallest addressable unit of memory, the definitions `char *Pointer;` and `Pointer *Handle;` are handy for referencing general-purpose data. Most Toolbox routines don’t require you to specify the data structure. You just indicate the location of the data structure or, specifically, its master pointer. Variables of type handle are perfect for storing this information. If you want to access the first byte of information pointed to by a handle’s master pointer you can write

```c
**myhandle
```

In some cases, the data pointed to, or at least the part of the data closest to the beginning of the block, has a specified structure. In such cases, an appropriate data structure is defined in an appropriate toolbox header file. These definitions use the C `typedef` statement. A `typedef` statement declares certain names to stand for a particular data structure or some other complex data type. For each of these definitions, a pointer type and a handle type are also provided. For example, at the end of the definition of a `CtRec` in ctl.h, you’d see

```c
} CtRec, *CtRecPtr, **CtRecHndl;
```

There is an advantage to defining a type that is a handle to a specific structure. When you make a call that gives you a handle to some data that is structured as follows:
CtIRecHnd1 myHandle;
myHandle = GetWindowControls();

myHandle is set to the address of the master pointer for the active window's first control. If you want to know the size, shape, and location of this control, you can write

Rect myRect;
myRect = (*myHandle)->ctlRec;

The EVENT.C Program

The EVENT.C program needs no introduction. It's a C language version of the EVENT.S1 program. The EVENT.C program appears in listing 7–13 at the end of this chapter.

The EVENT.C program uses the standard C library routine printf to display a message on the IIGS text screen. Because this program is interested only in key down and mouse down events, a #define statement creates a mask for the Event Manager GetNextEvent call. Thus, the result of GetNextEvent can be treated as a Boolean-type value. It returns a nonzero value (true) when a key or the mouse button is pressed, and it returns a zero value (false) if a key down or mouse down event is not detected. By setting a done flag to a nonzero value and using it for the condition of the while loop in the EVENT.C program, you guarantee that the loop will end.

Actually, you can compress the while loop even more, eliminating the need for a done flag:

while(!GetNextEvent(SIMPLE_MASK,&myEvent));

Although this line accomplishes the same thing as the loop in the program, the syntax we chose is more commonly encountered in event loops that actually do something. That is why it is used in the EVENT.C program.

Listing 7–11, titled INITQUIT.C, is not a complete C program. You can tell that right away because it doesn't have a main() function. Instead, it's an include file designed to be used with the EVENT.C program. If you want to type and run EVENT.C, you have to type INITQUIT.C, save it on disk, and then include it in EVENT.C with the line

#include "initquit.c"

which is the first line of the EVENT.C program.

INITQUIT.C does two important things. First, using #include statements, it provides EVENT.C with the Toolbox interface files it needs. It then provides the C functions needed to start up and shut down the tools that are loaded and initialized.
The INITQUIT.C program is designed to be used not only with the EVENT.C program, but also with two other programs—PAINTBOX.C and SKETCHER.C—that you encounter in chapter 8. So it’s easy to see why it is separated from the rest of the code in EVENT.C. By typing it separately and treating it as an include file, you can create it once and then use it in three different programs. It can be modified and used in even more programs—and you will see it again, in expanded versions, in later chapters.

**Listing 7–11**

INITQUIT.C program

```c
#include <TYPES.H>
#include <LOCATOR.H>
#include <MEMORY.H>
#include <MISCTOOL.H>
#include <QUICKDRAW.H>
#include <EVENT.H>

#define MODE 0     /* 320 graphics mode */
#define MaxX 320    /* max X for cursor (for Event Mgr) */
#define dpAttr attrLocked+attrFixed+attrBank /* for allocating direct page space */

int MyID;     /* for Memory Manager */

int ToolTable[] = {2,
                   4, 0x0100,     /* QD version 1.1 */
                   6, 0x0100,     /* Event version 1.1 */
                   };

StartTools()   /* start up these tools: */
{
    TLStartUp();     /* Tool Locator */
    MyID = MMStartUp();     /* Mem Manager */
    MTStartUp();     /* Misc Tools */
    LoadTools(ToolTable);     /* load tools from disk */
    ToolInit();     /* start up the rest */
}

ToolInit()     /* init the rest of needed tools */
{
    char **y;

    y = NewHandle(0x400L,MyID,dpAttr,0L);     /* reserve 4 pages */
}
```
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QDStartUp((int) *y, MODE, 160, MyID);  /* uses 3 pages */
EMStartUp((int) (*y + 0x300), 20, 0, MaxX, 0, 200, MyID);

ShutDown()  /* shut down all of the tools we started */
{
    GrafOff();
    EMShutDown();
    QDShutDown();
    MTShutDown();
    MMSHutDown(MyID);
    TLShutDown();
}

EVENT.S1 and EVENT.C Listings

Listing 7–12
EVENT.S1 program

*  
*  EVENT.S1  
*  
; This program prints a message on the screen and then goes into  
; an event loop. During the loop, the _GetNextEvent mask allows  
; the Event Manager to look only for key down and mouse down  
; events. When one of these is detected, the loop ends, another  
; message is printed on the screen, and the program ends.

*** A FEW ASSEMBLER DIRECTIVES ***

    Title 'Event'

    ABSADDR on
    LIST off
    SYMBOL off
    65816 on
    mcopy event.macros

    KEEP Event

*  
*  BEGINNING OF PROGRAM  
*
Begin
   START
   Using QuitData
   jmp MainProgram ; skip over data
   END

* * SOME DIRECT PAGE ADDRESSES AND A FEW EQUATES *
*

DPData START
DPPointer gequ $10 ; direct page pointer
DPHandle gequ DPPointer+4

ScreenMode gequ $00 ; 320 mode
MaxX gequ 320 ; X clamp high

END

* * MAIN PROGRAM LOOP *
*

MainProgram START

phk
plb

tdc ; get current direct page
sta MyDP ; and save it for the moment

jsr ToolInit ; start up all tools we'll need

*** SET UP INPUT AND OUTPUT SLOTS ***

PushWord #0 ; set input to slot 3
PushLong #3
/SetInputDevice
PushWord #0
/InitTextDev

PushWord #0
PushLong #3 ; set output to slot 3
/SetOutputDevice
PushWord #1
/InitTextDev
jsr PrintMsg1 ; print message on screen
jsr EventLoop ; check for key & mouse events

*** WHEN EVENT LOOP ENDS, WE’LL SHUT DOWN ***

jsr Shutdown
jmp Endit

MyDP

ds 2

END

* * EVENT LOOP *

EventLoop

START
Using QuitData
Using EventTable
Using EventData

Again

PushWord #0 ; space for result
PushWord #$000A ; key down & mouse down events
PushLong #EventRecord
_GetNextEvent
pla
beq Again
lda EventWhat
asl a
tax
jsr (EventTable,x)
lda QuitFlag
beq again

rts

END

* * ROUTINE THAT PRINTS OPENING STRING *

PrintMsg1

START

_GrafOff

PushWord #$8C ; clear screen
_WriWriteChar
PushLong #StartMsg
_WriteCString

rts

StartMsg dc c'Ress any key to continue: ',h'OdO0'

END

* THIS IS WHERE WE INITIALIZE OUR TOOLS *

ToolInit START using MMData

*** START UP TOOL LOCATOR ***

_TLStartup ; Tool Locator

*** INITIALIZE MEMORY MANAGER ***

PushWord #0
_MMStartup

pla
sta MyID

*** INITIALIZE MISC. TOOLS SET ***

_MTStartup

*** GET SOME DIRECT PAGE MEMORY FOR TOOLS THAT NEED IT ***

PushLong #0 ; space for handle
PushLong #$800 ; eight pages
PushWord MyID
PushWord #$C001 ; locked, fixed, fixed bank
PushLong #0
_NewHandle

pla
sta DPHandle
pla sta DPHandle+2

lda [DPHandle]
sta DPPPointer
*** INITIALIZE QUICKDRAW II ***

lda DPPointer ; pointer to direct page
pha
PushWord #ScreenMode ; either 320 or 640 mode
PushWord #160 ; max size of scan line
PushWord MyID
_QDStartup

*** INITIALIZE EVENT MANAGER ***

lda DPPointer ; pointer to direct page
clc
adc #$300 ; QD direct page + #$300
pha ; (QD needs 3 pages)
PushWord #20 ; queue size
PushWord #0 ; X clamp low
PushWord #MaxX ; X clamp high
PushWord #0 ; Y clamp low
PushWord #200 ; Y clamp high
PushWord MyID
_EMStartup

rts

END

* THE ROUTINE THAT ENDS THE PROGRAM *

EndIt

START
Using QuitData
Using MMData

PushWord #$8C ; clear screen
_WriteChar

PushLong #EndMsg
_WriteCString

PushWord MyID
_MMShutdown

jsr Shutdown

_Quit QuitParams
EndMsg          dc c'Thank You.\',h'0d00'

   END

*  
*  SHUT DOWN ALL THE TOOLS WE STARTED UP  
*  
ShutDown       START
   Using MMData

   _EMShutDown
   _QDShutDown
   _MTShutDown

   PushLong DPHandle
   _DisposeHandle

   PushWord MyID
   _MMShutDown
   _TLShutDown

   rts

   END

*  
*  ROUTINE THAT SETS THE QUIT FLAG  
*  
doQuit         START
   Using QuitData

   lda #$8000
   sta QuitFlag
   rts

   END

*  
*  A USEFUL AND CONVENIENT WAY NOT TO DO ANYTHING  
*  
Ignore        START

   rts

   END
7—Introducing the IIGS Toolbox

* DATA SEGMENTS *

EventData DATA

EventTable DATA

dc 'ignore' ; 0 null
dc 'doQuit' ; 1 mouse down
dc 'ignore' ; 2 mouse up
dc 'ignore' ; 3 key down
dc 'ignore' ; 4 undefined
dc 'ignore' ; 5 auto-key down
dc 'ignore' ; 6 update event
dc 'ignore' ; 7 undefined
dc 'ignore' ; 8 activate
dc 'ignore' ; 9 switch
dc 'ignore' ; 10 desk acc
dc 'ignore' ; 11 device driver
dc 'ignore' ; 12 application
dc 'ignore' ; 13 application
dc 'ignore' ; 14 application
dc 'ignore' ; 15 application
dc 'ignore' ; 0 in desk

END

EventData DATA

EventRecord anop ; table for Event Manager
EventWhat ds 2
EventMessage ds 4
EventWhen ds 4
EventWhere ds 4
EventModifiers ds 2

END

QuitData DATA

QuitFlag ds 2
QuitParams dc i40'
dc i40'
dc i40'

END

MMDData DATA

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Listing 7–13
EVENT.C program

#include "initquit.c"
#include <stdio.h>    /* needed for putchar */

#define SIMPLE_MASK (mDownMask + keyDownMask)

EventRecord myEvent;
Boolean done = false;

main()
{
    StartTools();
    PrintMsg();
    EventLoop();
    ShutDown();
}

PrintMsg() /* send message to stdout, then switch display */
{
    putchar(0x80);  /* clear screen */
    printf("Press any key to continue\n");
    GrafOff();      /* display standard text screen */
}

EventLoop()
{
    while(!done)
    {
        done = GetNextEvent(SIMPLE_MASK,&myEvent);
    }
There are more than 800 tools in the Apple IIgs Toolbox, and more than a fourth of them are in one tool set: QuickDraw II. QuickDraw II is the tool set that draws everything on the screen when the IIgs is in super high-resolution screen mode. It is used not only by application programs, but also by other tools. When the Window Manager places a window on the screen, all the window’s components—scroll bars, title bar, and so on—are drawn by QuickDraw II. When a pushbutton appears in a dialog box, the button and its contents are drawn by QuickDraw II. Even text displayed on a super high-resolution screen is drawn by QuickDraw II.

You can also use the QuickDraw II tool set in your own application programs. This chapter contains two type-and-run programs that demonstrate some of QuickDraw’s capabilities. One of the programs, PAINTBOX, draws a rectangle on the screen. The other, SKETCHER, displays a white screen on which you can draw sketches using the IIgs mouse.

Before those programs are presented, though, a description of how QuickDraw II works is helpful. So the first section of this chapter is devoted to a description of QuickDraw II.

What QuickDraw II Can Do

When the Apple Macintosh was designed, its high-resolution screen display was controlled by a tool set called QuickDraw. Now, with the advent
of the IIgs, a IIgs version of the original QuickDraw tool set has been designed—QuickDraw II. When IIgs programmers talk about QuickDraw II, they often leave off the II and refer to it simply as QuickDraw. So when you see the term QuickDraw in this book, please remember that, unless otherwise specified, we are discussing QuickDraw II.

The QuickDraw II tool set can draw various kinds of objects on a screen:

- Lines (straight or irregular)
- Rectangles (including squares)
- Ovals (including circles)
- Arcs (actually segments of circles)
- Polygons (multisided figures)
- Regions (collections of other kinds of objects)

QuickDraw can perform the following graphic operations on rectangles, rounded-corner rectangles, ovals, arcs, regions, and polygons:

- Framing, which outlines the shape
- Painting, which fills the shape with a specified color or pattern
- Erasing, which paints the shape using the current background color or background pattern
- Inverting, which inverts the pixels in the shape

**Point Data Structure**

Every object drawn in QuickDraw is made up of points. In QuickDraw, a *point data structure* contains two integers. The first integer in the structure defines the point’s vertical, or Y, coordinate. The second integer defines the point’s horizontal, or X, coordinate. Thus, a point can be defined in an assembly language program as

```assembly
APoint anop
YCoord ds 2
XCoord ds 2
```

**Rectangle Data Structure**

When you define a rectangle, QuickDraw stores it in memory as a data structure. In QuickDraw, a *rectangle data structure* is made up of two point structures. One of the points defines the upper left corner of the rectangle, and the other defines the lower right corner of the rectangle. Thus, it takes only four integers to define the size and location of a rectangle. So a rectangle can be defined this way in an assembly language program:

```assembly
ARect anop
UYCoord ds 2
UXCoord ds 2
LYCoord ds 2
LXCoord ds 2
```
To draw a rectangle in QuickDraw, you pass its coordinates to a rectangle drawing call such as FrameRect or DrawRect. The FrameRect call outlines a rectangle using the current color, size, pattern, and mask of the current QuickDraw pen. The PaintRect call paints a rectangle on the screen using the current pen color, pen pattern, and pen mask. The QuickDraw pen and its attributes are described later in the chapter.

The rectangle data structure is also used for drawing three other kinds of objects: ovals, arcs, and round rectangles. To draw an oval using QuickDraw, you define a rectangle and pass its coordinates to an oval drawing call, such as FrameOval or PaintOval. The FrameOval call works much like FrameRect. It outlines an oval using the current color, size, pattern, and mask of the current QuickDraw pen. The PaintOval call paints an oval on the screen using the current pen color, pattern, and mask.

In QuickDraw jargon, arcs are actually segments of circles. To draw an arc in QuickDraw, you first define the rectangle in which it will lie. Then you pass the rectangle’s coordinates, along with the angle described by the arc, to the FrameArc or PaintArc call. From then on, the FrameArc and PaintArc calls work like FrameOval and PaintOval.

“Round rectangles,” in QuickDraw lingo, are actually rounded-cornered rectangles. To draw a round rectangle in QuickDraw, you pass the rectangle’s coordinates and the height and width of its rounded corners to a round rectangle drawing call such as FrameRRect or PaintRRect. QuickDraw takes care of the rest of the details.

Point and rectangle data structures are not the only kinds of data structures. QuickDraw uses many other data structures, and some of them are described later in this chapter.

Regions and polygons make up a unique category in QuickDraw’s library of data structures. A region data structure is a QuickDraw object made up of other QuickDraw objects. A polygon data structure is a figure that can have any number of straight sides.

To set up a region or a polygon, you can’t just “fill in the blanks” as you do with other kinds of structures. The next section describes regions and polygons and how they are created in Ilgs programs.

Regions

A region is a data structure that can contain other structures, such as rectangles, ovals, arcs, and rectangles. To initialize a region, you must use the QuickDraw call NewRgn. This call sets up a region and gives you a handle to it. After you create a region using the NewRgn call, you can open it for drawing using OpenRgn.

When you create and open a region, you can draw objects in it by using
the object framing calls FrameRect, FrameOval, and FrameRRect. Each call adds an object to the region you are creating.

When you finish drawing a region, you close it with the CloseRgn call. From then on, you can draw the region on the screen by passing its handle to a region drawing call such as FrameRgn or PaintRgn.

**Polygons**

Polygons are created in a similar way: with a sequence of calls to QuickDraw routines. Before you can start drawing a polygon, you issue the QuickDraw call OpenPoly. The OpenPoly call sets up a polygon and provides you with a handle to it. You can then define the polygon using LineTo calls.

You begin to define a polygon by moving the QuickDraw pen to the polygon’s starting point and drawing a line from there to the next point. You can then draw another line from that point to the next point, and so on.

When you finish defining a polygon, you close it with the ClosePoly call. From then on, you can draw or paint it on the screen by passing its handle to polygon drawing calls such as FramePoly and PaintPoly.

The data structure for a polygon consists of two fixed length fields followed by a variable length array. The following shows the data structure for a polygon. (It is presented only for your information, because you will probably never have to set up a polygon data structure in a program. QuickDraw’s polygon calls do that for you when they are used as described in this section.)

- **PolySize**: An integer
- **PolyBBox**: A rectangle
- **PolyPoints**: An array [0 ...?] of points

The PolySize field of a polygon data structure contains the size, in bytes, of the polygon variable. The maximum size of a polygon is 32K bytes. The PolyBBox field is a rectangle that encloses the polygon. PolyPoints is a dynamic array that expands as necessary to contain the points of the polygon. It specifies the starting point of a polygon and each successive point to which a line is drawn.

When QuickDraw II draws a polygon, it moves its pen to the starting point of the polygon and then draws a series of lines to the remaining points, in the same way points are set up when the polygon is defined. In other words, QuickDraw “plays back” the same series of operations it uses to define the polygon. As a result, polygons are not treated exactly the same as other QuickDraw II shapes. For example, the procedure that frames a polygon draws outside the actual boundary of the polygon, because QuickDraw II line drawing routines draw below and to the right of the pen location.

Routines that fill a polygon with a pattern, however, stay inside the boundary of the polygon. If the polygon’s ending point isn’t the same as its starting point, these routines add a line between them to complete the shape.

A polygon is also scaled differently from a similarly shaped region if it is being drawn as part of a picture. When a slanted line is stretched, it is...
drawn more smoothly if it’s part of a polygon rather than part of a region. You may find it helpful to keep in mind the conceptual difference between polygons and regions. A polygon is treated more as a continuous shape; a region is treated more as a set of bits.

Pixel Maps and Conceptual Drawing Planes

When you create an object, QuickDraw places the object in a two-dimensional plane called a *conceptual drawing space*. When an object is placed in this drawing space, its position, like a position on a map, can be pinpointed with coordinates.

There is one fact about a conceptual drawing space that may be a little difficult to grasp. The plane that it describes does not exist anywhere in the IIgs’s memory. When an object is defined in QuickDraw’s conceptual drawing space, the object exists only as a mathematic image described by coordinates. The object thus takes up much less space in memory than it would if it were stored as a bit-mapped image.

But, before the object can be drawn—for example, on the IIgs screen or on a printer—enough space to hold the drawing must be reserved in memory. The memory area in which objects can be drawn is known as a *pixel map*. A pixel map is made up of tiny dots called picture elements, or pixels. After you create a pixel map, the objects drawn on it can be printed or displayed.

The Big Picture

The conceptual drawing space in which QuickDraw can store objects, measured in pixels, extends from −16K to +16K horizontally and from −16K to +16K vertically—a space large enough to hold 1,024,000,000 pixels. Figure 8–1 is a simplified diagram of the IIos’s conceptual drawing plane.

This plane is divided into four segments. The coordinate numbered 0,0 is in the middle of the plane. Thus, if you wanted to draw a point in the exact center of the plane, its coordinate would be 0,0.

The segments above and to the left of coordinate 0,0 use negative coordinates. Only the segments below and to the right of 0,0 use positive horizontal coordinates and positive vertical coordinates. For this reason, most of the drawing takes place in the lower right segment of QuickDraw’s conceptual drawing plane.

If the entire conceptual drawing space of an Apple IIgs were transferred to a giant pixel map, the map would measure four screens wide by eight screens high (or eight screens wide by four screens high). You could create such a map and display it on your screen, using Window Manager scroll bars to move it, if the IIgs had enough memory capacity.

You don’t need that much memory, however, to make full use of the conceptual drawing plane. Even with an unexpanded IIgs system, you can draw objects anywhere in QuickDraw’s conceptual drawing space. But before you can transfer an object or a picture from QuickDraw’s conceptual drawing
space to an actual pixel map, you have to make sure there is enough room in the computer’s memory to store the pixel map on which your object or picture will be drawn.

**Using Pixel Maps**

As mentioned, a pixel map is an area of memory that can contain an actual drawing of a graphic image. This image, like an image stored in a conceptual drawing space, is made up of a rectangular grid of pixels. Each pixel on a pixel map has a value that displays a color on the Ilgs screen or prints it on a printer. Thus, the value assigned to each pixel in a pixel map is a color code.

Pixels on a pixel map, like coordinates in QuickDraw’s conceptual drawing space, can be thought of as points in a Cartesian coordinate system; that is, each pixel on a pixel map has a horizontal coordinate and a vertical coordinate. In QuickDraw II, as in the original QuickDraw system for the Macintosh, the coordinates on a pixel map fall on lines that separate the pixels on the map, rather than on the pixels themselves. This method of assigning coordinates is illustrated in figure 8-2.
This system of assigning coordinates makes it very easy to determine when a pixel falls within a given rectangle and when it does not. Knowing whether a pixel is inside a rectangle is quite important in QuickDraw II because many calls deal only with pixels that fall in specific rectangles.

Pixel Maps and Screen Memory

When QuickDraw is initialized, the pixel map it draws on is set by default to the same area of memory that displays the super high-resolution screen, memory address $E12000 to memory address $E19CFF. Thus, when you start QuickDraw, its default drawing area is the screen. However, QuickDraw can draw in any block of free RAM as easily as it can draw on the screen, and applications can instruct QuickDraw to draw anywhere in memory.

Graphics Modes

The IIGS has two super high-resolution graphics modes: a 320-pixel mode and 640-pixel mode. When the IIGS is in 320 mode, the pixel map it uses for its screen display measures 320 pixels wide by 200 pixels high. In 640 mode, its screen display measures 640 pixels wide by 200 pixels high.

Each horizontal line on the IIGS screen is called a scan line. So, in both 320 mode and 640 mode, the super high-resolution screen is 200 scan lines high.

Both super high-resolution screen modes use a “chunky”-style pixel organization; the bits used to draw a given pixel on the screen are contained in adjacent bits within 1 byte. In both 320 mode and 640 mode, each scan line on the screen uses 160 bytes of memory. But the degree of “chunkiness” used by each mode is different. In 320 mode, 4 bits represent each pixel display on the screen. In 640 mode, only 2 bits create each screen pixel. Consequently, using 640 mode doubles the number of pixels that can be displayed in each scan line, although the number of bytes used for each scan line is the same in 320 mode and 640 mode.

The use of 640 mode does involve one important trade-off, however. Because only 2 bits define each screen pixel in 640 mode and 4 bits define each pixel in 320 mode, the number of colors that can be displayed in 640 mode is reduced. In 320 mode, sixteen discrete colors can be displayed on the screen simultaneously. In 640 mode, only four discrete colors can be displayed.

This limitation of 640 mode is not as bad as it sounds. With the help of a technique called dithering, you can create repeating color patterns that make it appear that more than four colors are displayed. A full description of dithering is beyond the scope of this chapter, but complete instructions for using dithering techniques are in chapter 16 (the chapter on QuickDraw II) of the Apple IIGS Toolbox Reference.

The number of colors displayed in both 320 mode and 640 mode can be increased with special interrupts called scan-line interrupts. Instructions for using scan-line interrupts are in chapter 4 (the video and graphics chapter) of the Apple IIGS Hardware Reference.
Selecting a Graphics Mode

When QuickDraw is initialized, it determines which graphics mode to use by looking at a parameter passed to it in the QDStartup call. As you will see in the programs later in this chapter, the QDStartup call has four parameters, one of which is called MasterSCB. If you pass the value $00 to the QDStartup call in this parameter, QuickDraw starts in 320 mode. If you pass the parameter $80, QuickDraw starts up in 640 mode.

There are also calls that change the graphics mode used inside a program. Descriptions of these calls, and instructions for using them in programs, are in the Apple IIgs Toolbox Reference.

Selecting Colors

In both 320 mode and 640 mode, the IIgs selects colors to be displayed on the screen from a block of RAM data called a color palette. The IIgs has sixteen color palettes, and each scan line can take its colors from any color palette. Each pixel on a scan line can be drawn in any of the sixteen colors that make up the palette being used by that line. And the 16 colors in each palette can be chosen from 4,096 colors.

When you write programs for the IIgs, you will rarely, if ever, have to deal with color palettes by directly accessing their memory addresses. QuickDraw II has a full complement of calls to select and manipulate color palettes and the colors they contain. For example, the SetColorTable call sets a color table to specific values, and the GetColorTable call fills a color table with the contents of another color table. There are also calls for getting and setting single colors in color tables.

You can do just about anything with color palettes by using the color table and color entry calls QuickDraw provides. To use colors and color tables effectively, however, it is helpful to know a little about how the IIgs creates and displays color on its screen.

The color palettes used by the IIgs extend from memory address $E19E00 through memory address $E19FFF—an area that begins just 256 bytes higher than the RAM block used for screen memory. There are sixteen color palettes in this space, with 32 bytes used by each palette. Each color palette contains codes for sixteen colors, with 2 bytes used for each color.

A color table, then, is a table of sixteen 2-byte entries, or words. The low nibble of the low byte of each word represents the intensity of the color blue. The high nibble of the low byte represents the intensity of the color green. The low nibble of the high byte represents the intensity of the color red. The high nibble of the high byte is not used. The following illustrates the structure of each color represented in a color palette:

<table>
<thead>
<tr>
<th>High Byte</th>
<th>Low Byte</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Nibble</td>
<td>Low Nibble</td>
</tr>
<tr>
<td>Reserved</td>
<td>Red</td>
</tr>
</tbody>
</table>

As mentioned, each pixel is displayed differently in each of the super high-resolution modes: 4 bits represent each pixel color in 320 mode, and 2 bits represent each pixel color in 640 mode. The higher resolution in 640...
mode carries a penalty. A pixel may be displayed in any of sixteen colors in 320 mode, but a pixel may be one of only four colors in 640 mode.

In both modes, the color information to display each pixel is placed in the RAM area reserved for screen memory in a linear and contiguous manner. The first byte of screen memory, in memory address $E12000, corresponds to the upper left corner of the screen display. The last byte in screen RAM, memory address $E19CFF, corresponds to the lower right corner of the screen. Each scan line uses 160 bytes of screen memory.

In 320 mode, it takes 4 bits to determine each pixel color, so two pixels are stored in every byte in the super high-resolution screen buffer. Because 4 bits of data determine the color of each pixel, each pixel on a scan line can represent one of the sixteen colors in the palette that controls the scan line on which the pixel appears.

In 640 mode, color selection is more complicated. In this mode, the 640 pixels in each horizontal line occupy 160 adjacent bytes of memory, and each byte holds 4 pixels that appear side by side on the screen. And the sixteen colors in the palette that controls the scan line are divided into four groups of four colors each. In other words, each palette used for a scan line in 640 mode contains four mini-palettes, each one made up of four colors.

By making careful use of the four mini-palettes used for each scan line, a program can increase the apparent number of colors used in each scan line in 640 mode. Unfortunately, the way in which colors are taken from the four mini-palettes used by each scan line is not intuitive.

The first pixel in each scan line can use any one of the four colors in the third mini-palette in the scan line’s full palette. The second pixel can use any of the four colors in the full palette’s fourth mini-palette. The third pixel can use any of the four colors in the main palette’s first mini-palette. And the fourth pixel can use any of the four colors in the second mini-palette. The way this system works is shown in figure 8–3.

This process repeats itself for each successive group of four pixels in each scan line. Thus, even though a given pixel can be one of only four

<table>
<thead>
<tr>
<th>PIXEL VALUE</th>
<th>PALETTE</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>COLOR 1</td>
</tr>
<tr>
<td>1</td>
<td>COLOR 2</td>
</tr>
<tr>
<td>2</td>
<td>COLOR 3</td>
</tr>
<tr>
<td>3</td>
<td>COLOR 4</td>
</tr>
<tr>
<td>0</td>
<td>COLOR 5</td>
</tr>
<tr>
<td>1</td>
<td>COLOR 6</td>
</tr>
<tr>
<td>2</td>
<td>COLOR 7</td>
</tr>
<tr>
<td>3</td>
<td>COLOR 8</td>
</tr>
<tr>
<td>0</td>
<td>COLOR 9</td>
</tr>
<tr>
<td>1</td>
<td>COLOR 10</td>
</tr>
<tr>
<td>2</td>
<td>COLOR 11</td>
</tr>
<tr>
<td>3</td>
<td>COLOR 12</td>
</tr>
<tr>
<td>0</td>
<td>COLOR 13</td>
</tr>
<tr>
<td>1</td>
<td>COLOR 14</td>
</tr>
<tr>
<td>2</td>
<td>COLOR 15</td>
</tr>
<tr>
<td>3</td>
<td>COLOR 16</td>
</tr>
</tbody>
</table>

Figure 8–3
Mini-palettes in 640 mode
colors, different pixels in a line can take on any of the colors in a palette. With the help of dithering, software written in 640 mode can display 16-color graphics and 80-column text on the same screen.

Dithering techniques increase the apparent number of colors on a screen by placing certain colors next to each other. (Your eye blends them.) By alternating colors in even and odd mini-palettes, a skilled programmer can control this blending and can thus obtain full-color capabilities in 640 mode. Instructions for using dithering techniques are in chapter 16 of the Apple IIgs Toolbox Reference.

Scan-Line Control Bytes

In both 320 mode and 640 mode, the colors used for each scan line on the screen are controlled with a group of RAM bytes called scan-line control bytes, or SCBs.

Each scan-line control byte represents one scan line on the IIgs screen. For each horizontal screen line, you can use the appropriate scan-line control byte to select

- The 16-color palette from which the scan line will take its colors.
- If the scan line will use color fill mode. Color fill mode streamlines the process of drawing consecutive pixels in the same color on a scan line. Color fill is available only in 320 mode and is described more fully in the Apple IIgs Hardware Reference.
- If a scan-line interrupt should be generated for the scan line. (Instructions for using scan-line interrupts are in the Apple IIgs Hardware Reference.)
- Whether the scan line will use 320-pixel or 640-pixel resolution.

Each of these scan-line attributes is controlled by 1 bit, or group of bits, in the SCB for the line. The bits in a scan-line control byte, and what they do, are described in table 8–1.

How To Use SCBs

When you write programs for the IIgs, you will rarely, if ever, need to manipulate QuickDraw’s scan-line control bytes by accessing them directly. The QuickDraw tool set has several calls to get and set SCBs. It is easier (and safer) to work with SCBs using these calls than it is to access them directly by their memory locations. Calls that can be used to control SCB settings include GetSCB, which returns the SCB setting for a given scan line, SetSCB, which sets an SCB that controls a given line, and SetAllSCBs, which sets all the SCBs on the screen to a specified value.

Descriptions of all SCB calls, and instructions for using them, are outlined in chapter 16 (the QuickDraw II chapter) of the Apple IIgs Toolbox Reference.

Where To Find SCBs

The block of memory that contains QuickDraw’s scan-line control bytes extends from memory address $E19D00 through memory address $E19DFF.
Table 8-1  
Structure of a Scan-Line Control Byte

<table>
<thead>
<tr>
<th>Bit</th>
<th>Name</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>320/640 mode flag</td>
<td>1 = Horizontal resolution equals 640 pixels.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0 = Horizontal resolution equals 320 pixels.</td>
</tr>
<tr>
<td>6</td>
<td>SCB interrupt flag</td>
<td>1 = Interrupt generated for this scan line. (When this bit is 1, the</td>
</tr>
<tr>
<td></td>
<td></td>
<td>scan line interrupt status bit is set at the beginning of the scan</td>
</tr>
<tr>
<td></td>
<td></td>
<td>line.)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0 = Scan line interrupts disabled for this scan line.</td>
</tr>
<tr>
<td>5</td>
<td>Color fill mode flag</td>
<td>1 = Color fill mode enabled. (This mode is available in super hi-res</td>
</tr>
<tr>
<td></td>
<td></td>
<td>320-pixel mode only.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>In 640-pixel mode, color fill mode is disabled.)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0 = Color fill mode disabled.</td>
</tr>
<tr>
<td>4</td>
<td>Palette select code</td>
<td>Reserved; do not modify.</td>
</tr>
<tr>
<td>0–3</td>
<td></td>
<td>Palette (0–15) chosen for this scan line.</td>
</tr>
</tbody>
</table>

This section of memory, as shown in figure 8-4, falls between the area of memory for the super high-resolution screen map and the area of memory for the color palettes that control the colors of the pixels on the screen.

The address of the scan-line control byte for each scan line is $E19DXX$, where XX is the hexadecimal value of the line. For example, the control byte for the first scan line (line 0) is located in memory location $9D00$, the control byte for the second scan line (line 1) is in location $9D01$, and so on.

(Actually, only the first 200 bytes of the 255 bytes in the memory page beginning at $E19D00$ are scan-line control bytes. The remaining 55 bytes are reserved for future expansion. To make sure your programs are compatible with future Apple II products, you should not modify these 55 bytes.)

GrafPorts

Now that you know a few facts about QuickDraw II, you’re ready for more detail. To understand how QuickDraw II works, you need to be familiar with a data structure called a GrafPort. Without GrafPorts, there would be no such thing as a QuickDraw tool set.

Here is a summary of what GrafPorts are and what they do. First, a GrafPort is not a block of data designed to be displayed on the IIgs screen. Rather, it is a data structure that contains important information that QuickDraw uses to create a screen display.

A GrafPort, like most other kinds of QuickDraw data structures, is made up of records. Some of the records in a GrafPort data structure are also data structure. A GrafPort data structure also includes integers, pointers,
Drawing Environments

The data stored in a GrafPort is sometimes referred to as a *drawing environment*. A drawing environment is simply a collection of data that QuickDraw can refer to easily when it needs to draw a screen display.

The advantage of the GrafPort system is that it allows a complex drawing environment to be maintained in a single, easily accessible record. By switching between GrafPorts, QuickDraw can change drawing environments very rapidly and can thus create many different kinds of screen displays quite efficiently. More than one GrafPort can be stored in memory, and it is not unusual to have several GrafPorts in memory at one time. When a program uses several screen windows, for example, each window has a GrafPort of its own.

Using GrafPorts

In QuickDraw, all graphic operations are performed in GrafPorts. Before a GrafPort can be used, it must be allocated and initialized with the QuickDraw call `OpenPort`. But most applications do not call `OpenPort` directly. They use the Ilgs Window Manager, which makes the call for them.

The QuickDraw call `ClosePort` closes a GrafPort when it is no longer needed. The GrafPort itself can be disposed of with the Memory Manager call `DisposeHandle`. The Window Manager will also make these calls for you when it is used to control the windows in a program.

In an application that uses multiple windows, each window is a separate GrafPort. If an application draws into more than one GrafPort, the `SetPort`
call sets up the GrafPort that is used for the drawing. Again, the Window Manager makes this call when it manages the windows in a program.

At times, an application needs to preserve the current GrafPort. In this case, the GetPort call saves the current port, and the SetPort call sets the port to be drawn in. Then, when drawing in the second port is completed, SetPort is used again to restore the previous port. The Window Manager also takes care of making these calls when it manages the windows and GrafPorts in a program.

### Structure of a GrafPort Record

The fields in a GrafPort include information on such topics as:

- The area of memory (the pixel map) in which images are drawn. This area of memory is pointed to by a pointer in the GrafPort record.
- Whether images are drawn in 320 mode or 640 mode.
- How drawings are trimmed, or clipped, to fit in the areas in which they lie.
- The size, shape, and pattern of the pen used for drawing.
- The font used for displaying text and how text is styled.
- Where objects that are drawn are stored in memory.

The structure of a GrafPort is no secret. It has been published by Apple and is listed in table 8–2. Apple strongly recommends, however, that programmers avoid the temptation of directly modifying the fields in GrafPorts. Instead, programmers are advised to access fields in GrafPorts only through QuickDraw calls.

If you count all the bytes in the GrafPort in table 8–2, you will see that a GrafPort data structure is 170 ($AA) bytes long. So, in an Apple IIgs assembly language program, the memory space required for one GrafPort could be set aside as follows:

```
GrafPort ds $AA
```

### PortInfo Data Structure

As mentioned, a GrafPort data structure includes many kinds of values: handles, integers, pointers, and even smaller data structures. In a GrafPort structure, each of these values is known as a field. Thus, the first field in a GrafPort structure, as table 8–2 illustrates, is a data structure within a data structure: in this case, a 16-byte structure called PortInfo. When a PortInfo structure lies outside a GrafPort structure, it is often called a LocInfo structure. And when a LocInfo structure is used in a call that transfers pixel map data from one area of memory to another (such as PPToPort or PaintPixels), it is often referred to as a SrcLocInfo structure. So, in QuickDraw jargon, a PortInfo structure, a LocInfo structure, and a SrcLocInfo structure are all the same.

Now let’s see what a PortInfo (or LocInfo, or SrcLocInfo) structure looks like, and how it’s used in a GrafPort data structure. The layout of a LocInfo structure is illustrated in listing 8–1.
**Table 8-2**
The Structure of a GrafPort

<table>
<thead>
<tr>
<th>Field</th>
<th>Length</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Port Information</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PortInfo</td>
<td>16 bytes</td>
<td>LocInfo data structure</td>
</tr>
<tr>
<td>PortRect</td>
<td>8 bytes</td>
<td>Rectangle data structure</td>
</tr>
<tr>
<td>ClipRgn</td>
<td>4 bytes</td>
<td>Handle to a region</td>
</tr>
<tr>
<td>VisRgn</td>
<td>4 bytes</td>
<td>Handle to a region</td>
</tr>
<tr>
<td>BkPat</td>
<td>32 bytes</td>
<td>Pattern data structure</td>
</tr>
<tr>
<td><strong>Pen State Data Structure</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PnLoc</td>
<td>4 bytes</td>
<td>Point structure</td>
</tr>
<tr>
<td>PnSize</td>
<td>4 bytes</td>
<td>Point structure</td>
</tr>
<tr>
<td>PnMode</td>
<td>2 bytes</td>
<td>Integer</td>
</tr>
<tr>
<td>PnPat</td>
<td>32 bytes</td>
<td>Pattern data structure</td>
</tr>
<tr>
<td>PnMask</td>
<td>8 bytes</td>
<td>Mask data structure</td>
</tr>
<tr>
<td>PnVis</td>
<td>2 bytes</td>
<td>Integer</td>
</tr>
<tr>
<td><strong>Font and Text Data</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FontHandle</td>
<td>4 bytes</td>
<td>Handle to a font</td>
</tr>
<tr>
<td>FontID</td>
<td>4 bytes</td>
<td>Long integer</td>
</tr>
<tr>
<td>FontFlags</td>
<td>2 bytes</td>
<td>Integer</td>
</tr>
<tr>
<td>TxSize</td>
<td>2 bytes</td>
<td>Integer</td>
</tr>
<tr>
<td>TxFace</td>
<td>2 bytes</td>
<td>Word</td>
</tr>
<tr>
<td>TxMode</td>
<td>2 bytes</td>
<td>Integer</td>
</tr>
<tr>
<td>SpExtra</td>
<td>4 bytes</td>
<td>Fixed point data structure</td>
</tr>
<tr>
<td>ChExtra</td>
<td>4 bytes</td>
<td>Fixed point data structure</td>
</tr>
<tr>
<td><strong>ForeGround and Background Color Data</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FGColor</td>
<td>2 bytes</td>
<td>Integer</td>
</tr>
<tr>
<td>BGColor</td>
<td>2 bytes</td>
<td>Integer</td>
</tr>
<tr>
<td>PicSave</td>
<td>4 bytes</td>
<td>Handle</td>
</tr>
<tr>
<td>RgnSave</td>
<td>4 bytes</td>
<td>Handle</td>
</tr>
<tr>
<td>PolySave</td>
<td>4 bytes</td>
<td>Handle</td>
</tr>
<tr>
<td>GrafProcs</td>
<td>4 bytes</td>
<td>Pointer (Usually a null pointer, set to 0)</td>
</tr>
<tr>
<td>ArcRot</td>
<td>2 bytes</td>
<td>Integer</td>
</tr>
<tr>
<td>UserField</td>
<td>4 bytes</td>
<td>Long integer</td>
</tr>
<tr>
<td>SysField</td>
<td>4 bytes</td>
<td>Long integer</td>
</tr>
</tbody>
</table>

Add up the bytes in a **LocInfo** structure, and you’ll see that the structure is 16 bytes long. The first integer in a **LocInfo** structure is called a **LocInfoSCB**.
Listing 8–1  
LocInfo Data Structure

<table>
<thead>
<tr>
<th>Field</th>
<th>Value</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>LocInfo</td>
<td>anop</td>
<td></td>
</tr>
<tr>
<td>LocInfoSCB</td>
<td>ds 2</td>
<td>$00 for 320, $80 for 640</td>
</tr>
<tr>
<td>LocInfoPicPtr</td>
<td>ds 4</td>
<td>pointer to pixel image</td>
</tr>
<tr>
<td>LocInfoWidth</td>
<td>ds 2</td>
<td>scan line width (#160 is standard)</td>
</tr>
<tr>
<td>LIBoundsRect</td>
<td>ds 8</td>
<td>format: 0, 0, 200, 320</td>
</tr>
</tbody>
</table>

**LocInfoSCB Field**

When a LocInfo structure appears inside a GrafPort data structure, the LocInfoSCB field defines the screen resolution of the pixel image that the GrafPort points to. If the value of LocInfoSCB is $00, the pixel image is displayed in 320 mode. If the value of LocInfoSCB is $80, the pixel image is displayed in 640 mode. An SCB can have other values, as explained previously in this chapter.

**LocInfoPicPtr Field**

The next field in a PortLocInfo structure—the LocInfoPicPtr field—is a pointer to the pixel map that the GrafPort describes. When a GrafPort is initialized, the pixel map that PortLocInfo points to is the super high-resolution screen. An application can change the LocInfoPicPtr field, however, to point to any area of memory in which a pixel map can be stored.

**LocInfoWidth Field**

The LocInfoWidth field of a LocInfo structure defines the maximum width, in bytes, of a scan line on the screen. In both 320 mode and 640 mode, the most common value for this field is the width, in bytes, of one screen-sized scan line: 160, or $A0 in hexadecimal notation.

**LIBoundsRect Field**

The LIBoundsRect field is a data structure that describes a rectangle. The rectangle described by the LIBoundsRect structure describes a bounds rectangle: a rectangle that encloses the pixel map (or, sometimes, a portion of the pixel map) that the current GrafPort is using. This pixel map is the same one pointed to by the LocInfoPicPtr field of the LocInfo data structure. More information about bounds rectangles is presented later in this chapter.

An LIBoundsRect structure is made up of four integers, or words. Each of these words defines one coordinate of the current GrafPort’s bounds rectangle. The order of these coordinates is: top left Y coordinate, top left X coordinate, lower right Y coordinate, and lower right X coordinate. Because a IIgs screen measures 200 scan lines down by 320 pixels across (in 320 mode), the coordinates used in the LIBoundsRect structure exactly covering a 320-mode screen are 0,0,200,320.
Drawing with a Pen in QuickDraw II

QuickDraw does most of its drawing using a structure called a *pen*. Each GrafPort in a program has one (and only one) graphics pen, which the GrafPort uses for drawing lines, shapes, and text. A QuickDraw pen has five characteristics: location, size (height and width), drawing mode, drawing pattern, and drawing mask.

When a pen draws an image in a GrafPort, the pen location can always be expressed as a point in the GrafPort's coordinate system or, if a pixel map is used, as a pair of coordinates on the pixel map. The point that defines the location of a pen—like any other point used in QuickDraw—can be located using two integers, or words: an integer defining the point's vertical (Y) coordinate and an integer defining the point's horizontal (X) coordinate.

In QuickDraw, the position of a pen is defined as the point where the next line, shape, or character will begin. This point can be anywhere on a GrafPort's coordinate plane. The top left corner of the pen is at the pen location; the pen hangs below and to the right of this point. When a pen is in a given location, the QuickDraw call LineTo makes it draw a line, and the call MoveTo moves it to another point without drawing a line. The MoveTo and LineTo calls are used in a type-and-run program, SKETCHER, which is presented at the end of this chapter.

The pen used in QuickDraw II is rectangular. Its width and height are controlled by several different QuickDraw calls, including SetPenSize, SetPenState, GetPenSize, and GetPenState. The default size of a QuickDraw pen is a 1-by-1 pixel square. A pen can be set to this size with the QuickDraw call PenNormal. The width and height of a pen can range from coordinate $0000,0000$ to coordinate $3FFE,3FFE$ (or 16382,16382 in decimal notation). If either the pen width or the pen height is less than 1, the pen will not draw a visible line.

**Pen Patterns**

In addition to having a specific size, a QuickDraw pen also has a specific pattern. A *pen pattern* is a 64-pixel image laid out as an 8-by-8 pixel square. When QuickDraw is initialized, it uses a pen pattern made up of all zeros. This type of pen pattern draws a solid line on the screen.

You can set the pen to draw in a pattern on the screen by setting up the pattern in memory and then making the QuickDraw call SetPenPat. When you want a pen to draw on the screen in a solid color other than black, you can use the QuickDraw call SetSolidPenPat. Instructions for using both of these calls are in chapter 16 of the *Apple IIgs Toolbox Reference*.

Actually, there are two kinds of QuickDraw patterns: pen patterns and background patterns. But both use the same kind of data structure: a 32-byte structure that is a small pixel image. After you set the contents of a pattern, you can use it as either a background pattern or a pen pattern. QuickDraw doesn't care.
In a data segment of a program, either kind of pattern is defined like this:

```
Pattern0       ds 32
```

QuickDraw programs often use pen patterns that define repeating designs. For example, when a pen pattern resembling a brick wall is created, the pen that uses the pattern draws a brick wall, instead of a solid line, on the screen. Figure 8–5 is a pen pattern resembling a brick wall. On the left is what the pattern looks like in memory; on the right is what the pattern looks like when a pen draws it on a screen.

### Pen Masks

Another attribute of a QuickDraw pen is a mask. A *pen mask* is an 8-by-8 bit square that, like a pen pattern, defines a repeating design. See figure 8–6. As a line or an object is drawn, this design masks the pattern—only the pixels that "show through" the pen mask appear on the screen. In other words, only those pixels in the pattern aligned with a set bit in the pen mask are drawn.

A pen mask, then, is a special kind of pattern that a pen can draw through to create special effects on a screen. A pen mask is smaller than a pen pattern or a background pattern; a pen mask data structure is only 8 bytes long. In a data segment of a program, memory space for a pen mask is reserved in this manner:

```
Mask0           ds 8
```

The QuickDraw calls `GetPenMask` and `SetPenMask` transfer pen masks to and from GrafPorts. The effect of using a pen mask is illustrated in figure 8–7.

![Figure 8–5](image)

**Figure 8–5**

Pen pattern in memory and on the screen

![Figure 8–6](image)

**Figure 8–6**

Pen mask
Pen Modes

Still another attribute of a QuickDraw pen is its mode. The pen mode determines how the pen pattern will affect what is already in the pixel image when lines or shapes are drawn. When the pen draws, QuickDraw II first determines which pixels in the pixel image will be affected and finds their corresponding pixels in the pattern. QuickDraw II then does a pixel-by-pixel comparison based on the pen mode, which specifies one of eight Boolean operations to perform. The resulting pixel is stored in its proper place in the pixel image.

The QuickDraw calls GetPenMode and SetPenMode control the pen mode used in a GrafPort. The pen modes used in QuickDraw are listed in table 8-3.

A pen can be used for two kinds of drawing: normal drawing and erasing. In normal drawing, the pen mode determines what is drawn on the screen. Erasing just fills the affected pixels with the background pattern.

Pen State Structure

As mentioned, each QuickDraw GrafPort has its own drawing pen, and all the attributes of each pen are defined in a structure called a pen state structure. Listing 8-2 shows what a pen state structure looks like. For further details, refer to the Apple IIgs Toolbox Reference.

Listing 8-2
Pen State Structure

<table>
<thead>
<tr>
<th>PenState</th>
<th>anop</th>
</tr>
</thead>
<tbody>
<tr>
<td>PnLoc</td>
<td>ds 4</td>
</tr>
<tr>
<td>PnSize</td>
<td>ds 4</td>
</tr>
<tr>
<td>PnMode</td>
<td>ds 2</td>
</tr>
<tr>
<td>PnPAt</td>
<td>ds 32</td>
</tr>
<tr>
<td>PnMask</td>
<td>ds 8</td>
</tr>
</tbody>
</table>

bounds Rectangles

Two kinds of rectangles are very important in QuickDraw. One is a bounds rectangle, and the other is a port rectangle.

The bounds rectangle of a GrafPort, often abbreviated BoundsRect, is the rectangle defined by the LIBoundsRect field of a GrafPort's LocInfo data structure. When a GrafPort draws on the IIgs screen, the upper left corner of its bounds rectangle corresponds to the upper left corner of the screen, and the coordinates of its bounds rectangle and its pixel map are the same. If a
Table 8–3
QuickDraw II Pen Modes

<table>
<thead>
<tr>
<th>Number</th>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$0000</td>
<td>COPY</td>
<td>The default drawing mode. The source is copied into the destination, with source pixels replacing destination pixels.</td>
</tr>
<tr>
<td>$8000</td>
<td>notCOPY</td>
<td>The inverse of the source is copied into the destination, with the pixels being drawn replacing the destination pixels.</td>
</tr>
<tr>
<td>$0001</td>
<td>OR</td>
<td>Source pixels are overlaid nondestructively on top of destination pixels.</td>
</tr>
<tr>
<td>$8001</td>
<td>notOR</td>
<td>The inverse of the source pixels are overlaid nondestructively on top of the destination pixels.</td>
</tr>
<tr>
<td>$0002</td>
<td>XOR</td>
<td>Source pixels are exclusive-ORed (XOR) with destination pixels. If an image is drawn in XOR mode, the original appearance of the destination can be restored by drawing the image again in XOR mode.</td>
</tr>
<tr>
<td>$8002</td>
<td>notXOR</td>
<td>Source pixels are reversed, then exclusive-ORed with destination pixels.</td>
</tr>
<tr>
<td>$0003</td>
<td>BIC</td>
<td>Bit clear (BIC) pen with destination. This mode explicitly clears the pixels in the destination image before another image is copied in.</td>
</tr>
<tr>
<td>$8003</td>
<td>notBIC</td>
<td>Clears the pixels in a destination image, then copies the inverse of the source image pixels into the destination image.</td>
</tr>
</tbody>
</table>

GrafPort’s bounds rectangle is smaller than the pixel map that the GrafPort is using, however, the coordinates of the GrafPort’s bounds rectangle and the coordinates of its pixel map are not the same.

**Port Rectangles**

A *port rectangle*, or *PortRect*, outlines the section of a *BoundsRect* that is displayed on the super high-resolution screen. A port rectangle can be visualized as a window through which part of a bounds rectangle is viewed. A port rectangle can be the size of the screen or smaller. A good example of a *PortRect* is a window created and displayed by the Window Manager.

Regardless of the size of a port rectangle, the only part of a drawing that is displayed on the screen is the part that falls inside both the bounds rectangle and the port rectangle of the current GrafPort.

A newly created GrafPort has its pixel map initialized to include the entire screen. Its *BoundRect* and *PortRect* fields are set to rectangles enclosing the screen. Thus, coordinate 0,0 of the GrafPort’s bounds rectangle and port rectangle corresponds to the top left corner of the screen. But this situation can be changed—and often is changed—by application programs.
The JIGS Toolbox

Clip Regions

Two other attributes of a GrafPort are its clip region and its visible region. A clip region, or ClipRgn, is a structure that clips, or trims, pictures or drawings to a specified size. For a drawn object to be visible on the screen, it must be situated inside its GrafPort’s clip region, as well as inside its GrafPort’s bounds rectangle and port rectangle.

A clip region can be rectangular, or it can be drawn in any shape—even an irregular shape. Because of this feature, a clip region can create screens that are quite fancy. For example, if a GrafPort has a circle-shaped clip region, pictures displayed on the screen can be trimmed, or clipped, into round pictures.

A GrafPort’s clipping region is defined with the SetClip and ClipRect calls. The GetClip and SetClip calls save a GrafPort’s ClipRgn while other clipping functions are performed, for example, when you want to reset a ClipRgn so you can redraw a newly displayed portion of a document that’s been scrolled.

Visible Regions

A visible region, or VisRgn, is the part of a port rectangle visible on the screen at a given time. A VisRgn, like a ClipRgn, can be rectangular but it doesn’t have to be. When one window on a screen overlaps another, the Window Manager uses a VisRgn structure to determine which part of the partially hidden window should be displayed on the screen. Application programs can use visible regions for similar purposes. QuickDraw II contains a number of calls for manipulating visible regions.

QuickDraw Coordinates

When you define an object within QuickDraw’s conceptual drawing plane, or draw an object on a pixel map, you must use coordinates to tell QuickDraw where to place the object. That can be a problem because QuickDraw uses two kinds of coordinate systems: a global coordinate system and a local coordinate system.

When a pixel map is stored in the JIGS’s memory, its position within the conceptual drawing space is defined by a set of global coordinates. In the global coordinate system, coordinate 0,0 pinpoints where the upper left corner of a pixel map lies within the conceptual drawing plane.

In addition to QuickDraw’s global coordinate system, each GrafPort created under QuickDraw has its own local coordinate system. In a GrafPort’s local coordinate system, coordinate 0,0 defines the upper left coordinate of the GrafPort’s bounds rectangle.

Coordinate Conversion

As mentioned, a newly created GrafPort has its pixel map set to point to the entire screen, and its bounds rectangle and port rectangle are both set to rectangles enclosing the screen. So, when a GrafPort is initialized, coordinate
0,0 corresponds to the screen’s top left corner and also to the top left corners of its bounds rectangle and port rectangle.

But, as noted, a GrafPort does not have to use the screen as its pixel map, and its pixel map does not have to be the same size as its bounds rectangle. If a GrafPort’s pixel image is larger or smaller than its bounds rectangle, its local and global coordinate systems are not the same.

Sometimes an IIGs program needs to convert coordinates from one system to another—from global to local and vice versa. One reason this is necessary is that some tools in the Toolbox use global coordinates for their operations, and others use local coordinates. For example, when the Event Manager reports an event, it gives the mouse location in global coordinates. But when you call the Control Manager to find out if the user clicked in a control in one of your windows, you must pass the mouse location in local coordinates.

Another reason coordinate conversion is necessary is that sometimes—for example, when windows are used—one coordinate system calculates coordinates on the screen, while another system calculates coordinates in individual windows. You’ll see how and why this is done in chapter 10, which deals with the Window Manager.

Fortunately, there is an easy way to convert global coordinates to local coordinates and vice versa. The QuickDraw call GlobalToLocal converts any point expressed in global coordinates to a corresponding location expressed in local coordinates. Another QuickDraw call, LocalToGlobal, does the same job in reverse.

One call often used with onscreen rectangles is SetOrigin. The SetOrigin call allows a program to change the coordinates of a GrafPort’s port rectangle so that its coordinates correspond to those of the GrafPort’s bounds rectangle. When you use the SetOrigin call, the bounds and port rectangles remain the same size and in the same location relative to each other, but the upper left corner, or origin of the PortRect, is set to the point passed by SetOrigin. Details on the SetOrigin call are in the Apple IIGs Toolbox Reference.

If an application performs scrolling operations, it can use the ScrollRect call to shift the pixels of the image and then use SetOrigin to readjust the coordinate system after the shift. Details about the ScrollRect call are also in the Apple IIGs Toolbox Reference.

Strings and Text

QuickDraw recognizes three kinds of string and text structures:

- C-type strings. A C-type string ends with a null word (h’00’) and is not preceded by a length byte.
- Pascal-type strings. A Pascal-type string is preceded by a length byte and does not have to end with a null word.
- Text structures. You can define a QuickDraw text structure with the DrawText call. When you make a DrawText call, you must pass
QuickDraw an integer that defines the number of bytes you want to write. A QuickDraw text structure can therefore be up to 65,535 bytes long.

Two other kinds of text-related structures used by QuickDraw are the FontInfoRecord structure and the FontGlobalsRecord structure. These structures are used primarily by the Font Manager, but they are also available for use in application programs. Listing 8–3 shows how the FontInfoRecord and FontGlobalsRecord structures are defined in an assembly language program. If you’re interested in further details about these and other font-related and text-related structures, look in the *Apple IIgs Toolbox Reference*.

**Listing 8–3**

FontInfoRecord and FontGlobalsRecord Structures

<table>
<thead>
<tr>
<th>FontInfoRecord</th>
<th>anop</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ascent</td>
<td>ds 2</td>
</tr>
<tr>
<td>Descent</td>
<td>ds 2</td>
</tr>
<tr>
<td>WidMax</td>
<td>ds 2</td>
</tr>
<tr>
<td>Leading</td>
<td>ds 2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>FontGlobalsRec</th>
<th>anop</th>
</tr>
</thead>
<tbody>
<tr>
<td>FontID</td>
<td>ds 2</td>
</tr>
<tr>
<td>FStyle</td>
<td>dc 'TextStyle'</td>
</tr>
<tr>
<td>FSize</td>
<td>ds 2</td>
</tr>
<tr>
<td>FVersion</td>
<td>ds 2</td>
</tr>
<tr>
<td>FWidMax</td>
<td>ds 2</td>
</tr>
<tr>
<td>fbrExtent</td>
<td>ds 2</td>
</tr>
</tbody>
</table>

QuickDraw recognizes other kinds of structures that have special uses and are not described in detail here. QuickDraw uses BufSizeRecord to define the sizes and characteristics of buffers in which text is stored. Listing 8–4 shows how the structure of a BufSizeRecord is included in an assembly language program. BufSizeRecord is described in more detail in chapter 16 of the *Apple IIgs Toolbox Reference*.

**Listing 8–4**

BufSizeRecord Structure

<table>
<thead>
<tr>
<th>BufSizeRecord</th>
<th>anop</th>
</tr>
</thead>
<tbody>
<tr>
<td>MaxWidth</td>
<td>ds 2</td>
</tr>
<tr>
<td>TextBufHeight</td>
<td>ds 2</td>
</tr>
<tr>
<td>TextBufRowWrds</td>
<td>ds 2</td>
</tr>
<tr>
<td>FontWidth</td>
<td>ds 2</td>
</tr>
</tbody>
</table>
Cursor Records

The cursor on the super high-resolution screen is user-definable. The data structure to define a cursor is called, logically enough, a cursor record. Listing 8–5 shows a cursor record included in an assembly language program.

Listing 8–5

Cursor Record

<table>
<thead>
<tr>
<th>Field</th>
<th>Data Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cursor</td>
<td>anop</td>
</tr>
<tr>
<td>CursorHeight</td>
<td>ds 2</td>
</tr>
<tr>
<td>CursorWidth</td>
<td>ds 2</td>
</tr>
<tr>
<td>CursorImage</td>
<td>ds 32</td>
</tr>
<tr>
<td>CursorMask</td>
<td>ds 32</td>
</tr>
<tr>
<td>HotSpotY</td>
<td>ds 2</td>
</tr>
<tr>
<td>HotSpotX</td>
<td>ds 2</td>
</tr>
</tbody>
</table>

;where cursor points, y coord
;where cursor points, x coord

PaintParams Structure

QuickDraw has one special-purpose structure, called the PaintParams structure, which is used in just one call: PaintPixels. (This call is described in chapter 16 of the Apple IIgs Toolbox Reference.) Listing 8–6 shows the structure in an assembly language program.

Listing 8–6

PaintParams Structure

<table>
<thead>
<tr>
<th>Field</th>
<th>Data Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>PaintParams</td>
<td>anop</td>
</tr>
<tr>
<td>LocInfo1Ptr</td>
<td>ds 4</td>
</tr>
<tr>
<td>LocInfo2Ptr</td>
<td>ds 4</td>
</tr>
<tr>
<td>SrcRectPtr</td>
<td>ds 4</td>
</tr>
<tr>
<td>DestPtPtr</td>
<td>ds 4</td>
</tr>
<tr>
<td>ScreenMode</td>
<td>ds 2</td>
</tr>
<tr>
<td>MaskHandle</td>
<td>ds 4</td>
</tr>
</tbody>
</table>

Loading and Initializing QuickDraw

Before QuickDraw is started up, the following tool sets must be loaded and started up:

- Tool Locator (always loaded and active)
- Memory Manager
- Miscellaneous Tool Set

After these tool sets are loaded and initialized, you can initialize QuickDraw.
The PAINTBOX Program

Now that you know a little about how QuickDraw works, you’re ready to type, assemble, and run a few programs that use QuickDraw.

The first program is called PAINTBOX. This program draws a rectangle on the IIGS super high-resolution screen. The assembly language version of the program is PAINTBOX.S1 (listing 8–7). The C version is PAINTBOX.C (listing 8–8). Both program listings are at the end of this chapter.

Program

When the PAINTBOX.S1 program is executed, it first loads and initializes QuickDraw II and the other tool sets it depends upon. Before QuickDraw is initialized, the Memory Manager call NewHandle reserves the three direct pages QuickDraw needs, plus one direct page required by the Event Manager. When NewHandle reserves the requested space, it returns with a handle to the space pushed onto the stack. The PAINTBOX.S1 program then pulls the handle off the stack, stores it in a variable called DPHandle (for direct page handle), and uses it to provide the necessary direct page space to QuickDraw and the Event Manager.

Next, in a program segment called DrawRect, the screen is cleared to white (color code $F$) with the QuickDraw call ClearScreen. The call PenNormal is then used to set the pen color to black and the pen size to one pixel by one pixel.

When the pen state is set, the SetRect call defines a rectangle in QuickDraw’s conceptual drawing space. The PaintRect call paints the rectangle on the screen.

After the rectangle is drawn, an event loop begins. This loop, like the one used in the EVENT.S1 program in chapter 7, keeps checking for a key down event or a mouse down event. As soon as it receives a notification of either kind of event, the program ends.

Program

PAINTBOX.C is a C version of PAINTBOX.S1. It is designed to be used with the #include file INITQUIT.C, which appears in chapter 7.

From a program designer’s point of view, PAINTBOX.C is almost identical to EVENT.C—although you’d never know it by just running the two programs! The only real difference is that PAINTBOX.C, instead of displaying a message on a text screen, goes into super high-resolution graphics and draws a black rectangle on a white screen.

PAINTBOX.C illustrates the advantage of writing programs split into short procedures and functions. To transform EVENT.C into PAINTBOX.C, you just replace the PrintMessage function with one that draws a rectangle on a super high-resolution screen.

The SKETCHER Program

The next program we’ll look at, SKETCHER, is a little more complicated. With this program, you can use the IIGS mouse to draw sketches on a super high-resolution screen.
The assembly language version of the program is called SKETCHER.SI (listing 8–9). The C version is SKETCHER.C (listing 8–10). Both listings appear at the end of this chapter.

**SKETCHER.SI**  
SKETCHER.SI, like PAINTBOX.SI, starts off by loading and initializing QuickDraw and clearing the screen to white. But then it gets considerably fancier. It uses the ShowCursor call to display the arrow-shaped cursor on the screen. Then it goes into an event loop that allows the user to draw sketches on the screen with the Ilgs mouse. When the mouse moves, the cursor follows it. When the mouse button is pressed, the cursor starts drawing a line.

As long as the mouse button remains pressed, SKETCHER.SI draws on the screen. When the mouse button is released, the program stops drawing, but the cursor still follows the movements of the mouse. The event loop in SKETCHER.SI also looks for key down events. When it detects one, the program ends.

**SKETCHER.C**  
SKETCHER.C is a C language version of the SKETCHER.SI program. It is designed to be used with the #include file INITQUIT.C, which is listed in chapter 7.

SKETCHER.C is the first C language program you have encountered so far that has really justified the use of an event loop. It is the first one in which two or more different types of events require different responses. SKETCHER.C does more than just set a done flag to a value returned by a GetNextEvent call. It requires done to be true only when a key down event is detected. Mouse down events send the program to Sketch, a routine that sketches on the screen.

SKETCHER is the most ambitious program you have typed and run so far. You should be able to have some fun with it—particularly if you experiment with different pen colors, pen sizes, pen patterns, pen masks, background colors, and background patterns. You might want to add more event loop functions, such as a screen clearing function that doesn’t end the program and a function that erases lines. You’ll modify the SKETCHER program in some of these ways—and in other ways we haven’t discussed yet—in later chapters.

**PAINTBOX.SI and PAINTBOX.C Listings**

Listing 8–7
PAINTBOX.SI program

*  
* PAINTBOX.SI  
*  

*** A FEW ASSEMBLER DIRECTIVES ***

Title 'PaintBox'

195
ABSADDR on
LIST off
SYMBOL off
65816 on
mcopy paintbox.macros

KEEP PaintBox

*  * EXECUTABLE CODE STARTS HERE  *  *

Begin  START
Using QuitData

jmp MainProgram ; skip over data

END

*  * SOME DIRECT PAGE ADDRESSES AND A FEW EQUATES  *  *

DPData  START

DPPointer  gequ $10
DPHandle  gequ DPPointer+4

ScreenMode  gequ $00 ; 320 mode
MaxX  gequ 320 ; X clamp high

END

*  * MAIN PROGRAM LOOP  *  *

MainProgram  START

phk
plb
tdc
sta MyDP ; get current direct page
; and save it for the moment

jsr ToolInit ; start up all tools we'll need
jsr DrawRect ; paint rectangle on screen
jsr EventLoop ; check for key & mouse events
*** WHEN EVENT LOOP ENDS, WE'LL SHUT DOWN ***

    jsr Shutdown
    jmp Endit

MyDP  ds 2

END

*
*  THE ROUTINE THAT ENDS THE PROGRAM
*

EndIt  START

Using QuitData

   _Quit QuitParams

*** THIS ERROR SHOULD NEVER OCCURR ***

    ErrorDeath 'We have returned from a quit call!!!'

END

*
*  THIS IS WHERE WE INITIALIZE OUR TOOLS
*

ToolInit  START

   using MMData

*** START UP TOOL LOCATOR ***

   _TLStartup ; Tool Locator

*** INITIALIZE MEMORY MANAGER ***

    PushWord #0
    _MMStartup
    ErrorDeath 'Could not init Memory Manager.'
    pla
    sta MyID

*** INITIALIZE MISC. TOOLS SET ***

   _MTStartup
    ErrorDeath 'Could not init Misc Tools.'
*** GET SOME DIRECT PAGE MEMORY FOR TOOLS THAT NEED IT ***

PushLong #0 ; space for handle
PushLong #$400 ; four pages
PushWord MyID
PushWord #$C001 ; locked, fixed, fixed bank
PushLong #0
_NewHandle

ErrorDeath 'Could not get direct page.'

pla
sta DPHandle
pla
sta DPHandle+2

lda [DPHandle]
sta DPPPointer

*** INITIALIZE QUICKDRAW II ***

lda DPPPointer ; pointer to direct page
pha
PushWord #ScreenMode ; $00 for 320, $80 for 640 mode
PushWord #160 ; max size of scan line
PushWord MyID
_QDStartup
ErrorDeath 'Could not start QuickDraw.'

*** INITIALIZE EVENT MANAGER ***

lda DPPPointer ; pointer to direct page
clc
adc #$300 ; QD direct page + #$300
pha ; (QD needs 3 pages)
PushWord #20 ; queue size
PushWord #0 ; Xclamp low
PushWord #MaxX ; clamp high
PushWord #0 ; Y clamp low
PushWord #200 ; Y clamp high
PushWord MyID
_EMStartup
ErrorDeath 'Could not start Event Manager.'

rts

END
*  *  SHUT DOWN ALL THE TOOLS WE STARTED UP  *  *

ShutDown
START
Using MMData

_EMShutDown
_QDShutDown
_MTShutDown

PushLong DPHandle
_DisposeHandle

PushWord MyID
_MMShutDown
_TLShutDown

rts

END

*  *  EVENT LOOP  *  *

EventLoop
START
Using QuitData
Using EventTable
Using EventData

Again
PushWord #0  ; space for result
PushWord #$000A  ; key down & mouse down events
PushLong #EventRecord
_GetNextEvent
pla
beq Again
lda EventWhat
asl a
tax
jsr (EventTable,x)
lda QuitFlag
beq again

rts

END
* ROUTINE THAT DRAWS A RECTANGLE *

DrawRect START

*** CLEAR SCREEN AND SET PEN STATE ***

lda #$FFFF ; color code for white, typed four times (once for each byte)

pha ; push color code on the stack
_ClearScreen ; does what it says
_PenNormal ; make pen black & normal size

*** SET UP A RECTANGLE ***

PushLong #RectPtr ; pointer to a rectangle
PushWord #$30 ; upper x coordinate
PushWord #$30 ; upper y coordinate
PushWord #$110 ; lower x coordinate
PushWord #$98 ; lower y coordinate
_SetRect ; create a rectangle

*** PAINT RECTANGLE ON SCREEN ***

PushLong #RectPtr ; pointer to our rectangle
_PaintRect ; paint it on the screen

rts

RectPtr ds 8 ; our rectangle

END

* ROUTINE THAT SETS THE QUIT FLAG *

doQuit START

Using QuitData

lda #$8000

200
sta Quitflag
rts
END

*
*A USEFUL AND CONVENIENT WAY NOT TO DO ANYTHING*
*
Ignore START
rts
END

*
* DATA SEGMENTS *
*
EventTable DATA

 dc 'ignore' ; 0 null
 dc 'doQuit' ; 1 mouse down
 dc 'ignore' ; 2 mouse up
 dc 'doQuit' ; 3 key down
 dc 'ignore' ; 4 undefined
 dc 'ignore' ; 5 auto-key down
 dc 'ignore' ; 6 update event
 dc 'ignore' ; 7 undefined
 dc 'ignore' ; 8 activate
 dc 'ignore' ; 9 switch
 dc 'ignore' ; 10 desk acc
 dc 'ignore' ; 11 device driver
 dc 'ignore' ; 12 application
 dc 'ignore' ; 13 application
 dc 'ignore' ; 14 application
 dc 'ignore' ; 15 application
 dc 'ignore' ; 0 in desk

END

***
EventData DATA

 EventRecord anop ; table for Event Manager
 EventWhat ds 2
 EventMessage ds 4
The JIGS Toolbox

EventWhen ds 4
EventWhere ds 4
EventModifiers ds 2

END

***
QuitData DATA
QuitFlag ds 2
QuitParams dc i4'0'
dc i4'0'
dc i4'0'
dc i4'0'

END

***
MMData DATA
MyID dc i0'  ; program ID word

END

Listing 8-8
PAINTBOX.C program

#include "initquit.c"

#define SIMPLE_MASK (mDownMask + keyDownMask)

EventRecord myEvent;
Boolean done = false;

main()
{
  StartTools();
  DrawRect();
  EventLoop();
  ShutDown();
}

DrawRect() /* send message to stdout, then switch display */
{

202
Rect myRect;

    ClearScreen(OxFFFF);
    PenNormal();
    SetRect(&myRect,Ox30,Ox30,Ox110,Ox98);
    PaintRect(&myRect);

EventLoop()
{
    while(!done)
        done = getNextEvent(SIMPLE_MASK,&myEvent);
}

SKETCHER.S1 and SKETCHER.C Listings

    Listing 8–9
    SKETCHER.S1 program

*  
* SKETCHER.S1  
*  
*** A FEW ASSEMBLER DIRECTIVES ***

    Title 'Sketcher'

    ABSADDR on
    LIST off
    SYMBOL off
    65816 on
    mcopy sketcher.macros

    KEEP Sketcher

*  
* EXECUTABLE CODE STARTS HERE  
*  
Begin               START
    Using QuitData
    jmp MainProgram   ; skip over data

    END
The IIGS Toolbox

* * SOME DIRECT PAGE ADDRESSES AND A FEW EQUATES *

DPData START

DPPointer gequ $10
DPHandle gequ DPPointer+4

ScreenMode gequ $00 ; 320 mode
MaxX gequ 320 ; X clamp high

END

* *

** MAIN PROGRAM LOOP ** * *

MainProgram START

phk
plb
tdc ; get current direct page
sta MyDP ; and save it for the moment

jsr ToolInit ; start up all tools we'll need

*** CLEAR SCREEN AND SET PEN STATE ***

lda #$FFFF ; color code for white
pha ; push it on the stack
_ClearScreen ; does what it says

_PenNormal ; make pen black & normal size
_ShowCursor

jsr EventLoop ; check for key & mouse events

*** WHEN EVENT LOOP ENDS, WE'LL SHUT DOWN ***

jsr Shutdown
jmp Endit

MyDP ds 2

END

204
* * EVENT LOOP * *

EventLoop START
Using QuitData
Using EventTable
Using EventData

Again PushWord #0 ; space for result
PushWord #$000F ; key & mouse events
PushLong #EventRecord
_GetNextEvent pla
beq Again
lda EventWhat ; get event code
asl a ; code * 2 = table location
tax ; X is index register
jsr (EventTable,x) ; look up event's routine
lda QuitFlag
beq again

rts

END

* * ROUTINE TO DRAW SKETCHES ON THE SCREEN * *

MoveIt START
Using EventData

_ShowPen

lda EventWhere
sta MouseHouse
lda EventWhere+2
sta MouseHouse+2

PushLong MouseHouse
_MoveTo

Loop pea 0 ; space for return
pea 0 ; check button zero
_SStillDown pla
beq out
PushLong #MouseHouse
_GetMouse
PushLong MouseHouse
_LineTo

bra loop

out
   _HidePen
   rts

MouseHouse   ds 4

END

*  
*   THE ROUTINE THAT ENDS THE PROGRAM
*

EndIt    START

Using QuitData
   _Quit QuitParams

*** IF THIS COMES BACK, WE'RE DEAD ***
ErrorDeath 'We just came back from a quit call!!'

END

*  
*   THIS IS WHERE WE INITIALIZE OUR TOOLS
*

TooLInit    START
   using MMDdata

*** START UP TOOL LOCATOR ***
   _TLStartup ; Tool Locator

*** INITIALIZE MEMORY MANAGER ***
PushWord #0
   _MMStartup
   ErrorDeath 'Could not init Memory Manager.'
   pla
   sta MyID

206
*** INITIALIZE MISC. TOOLS SET ***

_MTStartup
ErrorDeath 'Could not init Misc Tools.'

*** GET SOME DIRECT PAGE MEMORY FOR TOOLS THAT NEED IT ***

PushLong #0 ; space for handle
PushLong #$800 ; eight pages
PushWord MyID
PushWord #$C001 ; locked, fixed, fixed bank
PushLong #0
_NewHandle

ErrorDeath 'Could not get direct page.'

pla
sta DPHandle
pla
sta DPHandle+2

lda [DPHandle]
sta DPPointer

*** INITIALIZE QUICKDRAW II ***

lda DPPointer ; pointer to direct page
pha
PushWord #ScreenMode ; either 320 or 640 mode
PushWord #160 ; max size of scan line
PushWord MyID
_QDStartup
ErrorDeath 'Could not start QuickDraw.'

*** INITIALIZE EVENT MANAGER ***

lda DPPointer ; pointer to direct page
clc
adc #$300 ; QD direct page + #$300
pha ; (QD needs 3 pages)
PushWord #20 ; queue size
PushWord #0 ; X clamp low
PushWord #MaxX ; X clamp high
PushWord #0 ; Y clamp low
PushWord #200 ; Y clamp high
PushWord MyID
_EMStartup
ErrorDeath 'Could not start Event Manager.'
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```assembly
rts

END

*
* SHUT DOWN ALL THE TOOLS WE STARTED UP
*

Shutdown START
Using MMData

_EMShutDown
_QDShutDown
_MTShutDown

PushLong DPHandle
_DisposeHandle

PushWord MyID
_MMShutDown
_TLShutDown

rts

END

*
* ROUTINE THAT SETS THE QUIT FLAG
*

doQuit START
Using QuitData

lda #$8000
sta QuitFlag
rts

END

*
* A USEFUL AND CONVENIENT WAY NOT TO DO ANYTHING
*

Ignore START

rts

END

208
* DATA SEGMENTS *

**EventTable** DATA

dc 'ignore'; 0 null

dc 'MoveIt'; 1 mouse down

dc 'ignore'; 2 mouse up

dc 'doQuit'; 3 key down

dc 'ignore'; 4 undefined

dc 'ignore'; 5 auto-key down

dc 'ignore'; 6 update event

dc 'ignore'; 7 undefined

dc 'ignore'; 8 activate

dc 'ignore'; 9 switch

dc 'ignore'; 10 desk acc

dc 'ignore'; 11 device driver

dc 'ignore'; 12 application

dc 'ignore'; 13 application

dc 'ignore'; 14 application

dc 'ignore'; 15 application

dc 'ignore'; 0 in desk

END

***

**EventData** DATA

EventData anop ; table for Event Manager

EventRecord ds 2
EventWhat ds 4
EventMessage ds 4
EventWhen ds 4
EventWhere ds 4
EventModifiers ds 2

END

***

**QuitData** DATA

QuitFlag ds 2

209
Listing 8-10
SKETCHER.C program

#include "initquit.c"

#define MY_MASK (mDownMask + mUpMask + keyDownMask)

EventRecord myEvent;
Boolean done = false;

main()
{
  StartTools();
  GrafPrep();
  EventLoop();
  ShutDown();
}

GrafPrep()
{
  ClearScreen(0xFFFF);
  PenNormal();
  ShowCursor();
}

EventLoop()
{
  while(!done)
  {
    if ( GetNextEvent(MY_MASK,&myEvent) )
      switch (myEvent.what) {
case mouseDownEvt:
    MoveIt();
    break;
case keyDownEvt:
    done = true;
    }
}

MoveIt()
{
    Point MouseHouse;
    ShowPen();
    MoveTo(myEvent.where);
    while (StillDown(O)) {
        GetMouse(&MouseHouse);
        LineTo(MouseHouse);
    }
    HidePen();
}
One of the most important features of the IIGS is its ability to display pull-down menus—menus that allow the user to select almost any function or application at almost any time, without going through confusing levels of menus and without remembering command words or special keys. Pull-down menus were introduced with the unveiling of the Apple Macintosh—and the IIos has windows almost identical to those that created such a sensation when they first appeared on the Mac.

**Menus and the IIGS User**

One reason why pull-down menus are so popular is that they are easy to use. To use a pull-down menu, you just place a cursor inside an onscreen bar called a menu bar, then click the button of the IIos mouse over a menu title that also appears inside the menu bar. An application can then call the Menu Manager, which highlights the selected title by redrawing it in inverted colors.

When a menu title is selected, you can drag the cursor into a series of menu items that appear below the menu title. As long as the mouse button is held down, the selected menu title is highlighted, and the menu items below it are displayed. Dragging the mouse cursor up and down through the list of
The IIGS Toolbox

menu items highlights each item or command while the cursor is positioned over it.

If the mouse button is released while an item is highlighted, the function or application that the item identifies is selected. The item blinks briefly to confirm the user’s choice, and the menu disappears.

When you choose a menu item, the Menu Manager tells the application which item was chosen, and the application can then perform the appropriate action. When the application completes the action, it can remove the highlighting from the menu title, indicating that the operation is complete.

If you hold down the mouse button and move the cursor out of the menu, the menu remains visible, though none of its items are highlighted. If you release the mouse button outside the menu, no choice is made. The menu simply disappears, and the application does not take any action. Thus, you can always look at a menu without changing the document or the screen.

The IIGS can display menus in both 640-pixel mode and 320-pixel mode. Figure 9–1 is a 640-mode menu, and figure 9–2 is a 320-mode menu.

Menu Bars

Before we go into more detail about how the IIGS Menu Manager works, it is helpful to review some of the terminology used so far in this chapter.

A menu bar is a rectangle that usually appears across the top of the IIGS screen. Several menu titles are usually visible inside the bar. Some of these titles may be dimmed, indicating they are disabled. A disabled menu can still

Figure 9–1
Menu in 640 mode
be pulled down, but all menu items under it will also be dimmed, and you usually cannot select them.

Underneath each menu title, an application can place the names of as many menu items as space allows. The items beneath a menu title, however, are not ordinarily visible unless you place the cursor over the menu title and pull the menu down.

A menu title and the items that appear beneath it make up a menu. Thus, several menus (as many as space allows) can appear inside a menu bar.

**System Menu Bar**

The Menu Manager has one special kind of menu bar called a system menu bar. Only one system menu bar can be on the screen at one time. The system menu bar is always positioned at the top of the screen, and only the cursor appears in front of it.

In applications that support desk accessories, the first menu on the menu bar—that is, the leftmost menu—should be a desk accessories menu. In programs written according to Apple's *Human Interface Guidelines*, the title of a desk accessories menu should always be a specially designed colored apple. In programs written for the Apple IIgs, a special Toolbox call, *FixAppleMenu*, sets up a desk accessories menu that has a colored apple as its title.
Desk accessories are special mini-applications that can be coresident in memory with other applications and thus can be executed at any time. A tutorial in writing desk accessory programs is beyond the scope of this book, but instructions for writing desk accessories are in the *Apple IIgs Toolbox Reference*.

**Window Menu Bars**

In addition to the system menu bar, an application can also use window menu bars. Because window menu bars can appear in individual windows, they can increase the number of menu titles visible on the screen. But they can also be confusing to the IIgs user, so they should be used in moderation, if at all.

**More About Menus**

A number of menu items make up a typical Apple IIgs menu. The items are listed vertically inside a shadowed rectangle, and each item may consist of the text of a command, an object or icon defined by an application, or just a line dividing groups of choices. Everything else on the screen, except the cursor, always appears behind menus.

**Keyboard Equivalents for Menu Commands**

An application program can set up a keyboard equivalent for any menu item so that you can issue a menu command from the keyboard, rather than the mouse. The character specified as a menu command equivalent is usually the first letter of a menu command. Typing the letter in either uppercase or lowercase is usually allowed. For example, typing either Q or q while holding down the Apple key can be used as an equivalent for a mouse selectable menu item titled Quit.

**Initializing the Menu Manager**

Before the Menu Manager is started, these tool sets must already be loaded and initialized:

- Tool Locator (always active)
- Memory Manager
- QuickDraw II
- Event Manager
- Window Manager
- Control Manager

The Menu Manager also requires one direct page. When one direct page is reserved, and the previous tool sets are started, the `MenuStartup` call initializes the Menu Manager. As soon as the Memory Manager is started, an empty menu bar appears at the top of the screen. The application that uses the menu bar must then finish drawing it by initializing a set of menus and printing their names in the bar.
Using the Menu Manager

An assembly language program titled MENU.S1 demonstrates how the Menu Manager is used in an assembly language program. There is also a C language version of the same program. (Both programs—listing 9–9 and listing 9–10—are at the end of this chapter.)

The MENU.S1 program prints a menu bar and a set of menus on the screen. Then it allows the user to place check marks in front of menu items by clicking the mouse. It also allows the user to quit the program by selecting a menu item titled Quit or by typing Q or q on the keyboard.

In the next few sections of this chapter, we divide the MENU.S1 program into parts and see how each part works. Then, at the end of the chapter, we put all the parts together and type and run the program.

Defining Menus and Items

The first step in creating a menu bar is to draw up a list of menus and menu items, and place the list in a data segment of a program. In the MENU.S1 program, menus and menu items are defined in the data segment titled MenuData.

Interpreting Menu Data

As the MenuData table shows, the MENU.S1 program has six menus, and there are several items under each menu title. In the data segment MenuData, the menus and menu items used in the program are listed in a special format required by the Menu Manager. For example, the menu titles in the listing are numbered consecutively beginning with 1, and the menu items in the listing are numbered consecutively beginning with 257. This numbering system is important because the Menu Manager uses it to distinguish between menu titles and menu items in a table of menu data. The number assigned to a menu title or a menu item is known as an ID number and is always preceded by the letter N in a table of menu data. Table 9–1 shows the ID numbers you can assign to menus and menu items and the uses for various ranges of ID numbers.

Special Characters in Menu Data Tables

In a menu data table, the title of each menu is preceded by the > symbol. The last item in each menu is followed by a line containing only a period. A number of other special characters also appear in the listing.

For example, the L that precedes the title of each menu and each menu item is merely a space filler required by the Menu Manager. If the > symbol appears in front of the L, the text string that follows the L is the title of a menu. If a space precedes the L, the string that follows the L is the title of a menu item.

Actually, L, >, the space character, and the period do not have to be used in the MENU.S1 program. You can substitute other characters as long as they are used consistently.
### Table 9-1
Menu and Menu Item ID Numbers

<table>
<thead>
<tr>
<th>Hex Number</th>
<th>Decimal Number</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>$0000</td>
<td>0</td>
<td>For internal use. Usually used for the front (first) menu in a menu bar.</td>
</tr>
<tr>
<td>$0001–$FFFF</td>
<td>1–65534</td>
<td>Reserved for application use.</td>
</tr>
<tr>
<td>$FFFF</td>
<td>65535</td>
<td>For internal use. Usually used for the last item in a menu bar.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Menu Item ID Numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td>$0000</td>
</tr>
<tr>
<td>$0001–$00F9</td>
</tr>
<tr>
<td>$00FA</td>
</tr>
<tr>
<td>$00FB</td>
</tr>
<tr>
<td>$00FC</td>
</tr>
<tr>
<td>$00FD</td>
</tr>
<tr>
<td>$00FE</td>
</tr>
<tr>
<td>$00FF</td>
</tr>
<tr>
<td>$0100–$FFFF</td>
</tr>
<tr>
<td>$FFFF</td>
</tr>
</tbody>
</table>

A number of reserved characters, however, always have the same meaning in tables of menu data. For example:

- The `@` character, preceded by the symbols used for a symbol title and followed immediately by a backslash (`\`) always represents the colored Apple logo that usually appears as the leftmost element on a menu bar. This symbol appears in the line labeled `Menu1` in the `MenuData` table.
- The backslash character (`\`) always marks the end of a string of text and the beginning of a series of special characters.
- The letter `N`, as noted, is a prefix for each ID number in a table of menu data.
- The `*` symbol is a prefix for letters that can be used as keyboard equivalents for menu selections. Usually this symbol is followed by two letters: an uppercase letter and its corresponding lowercase letter. When the prefix is used in this way, it means the keyboard equivalent for the menu choice is not case sensitive. This prefix is used in the second line following the label `Menu2` in the `MenuData` table.
- The ASCII character 13, a carriage return, is an end-of-line symbol in tables of menu data. A null character (00) has the same meaning.

All of the characters that have special meanings in menu data tables are...
listed in table 9–2. These characters can appear in any order following the backslash character that separates the text on each line from the special characters that follow it.

All of the characters in table 9–2 except the backslash character can be used in names of menu items, but the characters *, B, C, I, U, and V cannot be used in menu titles. There is no way to include a backslash character (\) in a text string because the Menu Manager always treats it as the beginning of a series of special characters.

**Building a Menu**

After a table of menu data is created and entered in a source code program, the Menu Manager calls `NewMenu` and `InsertMenu` can be used to build a menu. This is the syntax for issuing these two calls:

```plaintext
PushLong #0 ; space for return
PushLong #Menu6 ; ID number of menu
.NEWMenu
PushWord #0 ; make this menu
._InsertMenu ; the front menu
```

The `NewMenu` call takes two long parameters: a 0 to leave 2 words on the stack and a menu ID number. It returns one long parameter—a menu

---

**Table 9–2**

<table>
<thead>
<tr>
<th>Character</th>
<th>Meanings</th>
</tr>
</thead>
<tbody>
<tr>
<td>\</td>
<td>Marks the end of a text string and the beginning of a series of special characters.</td>
</tr>
<tr>
<td>*</td>
<td>Prefix for a character (or characters) that can be used as a keyboard equivalent for a menu choice. This prefix is usually followed by an uppercase letter and a corresponding lowercase letter, indicating that the keyboard equivalent is not case sensitive.</td>
</tr>
<tr>
<td>B</td>
<td>Print the text of the preceding line in boldface.</td>
</tr>
<tr>
<td>C</td>
<td>Prefix for a character that can be printed in front of a menu item to mark it. The character is identified by its ASCII code. For example, CI8 means use a check mark (ASCII code 18) to mark the preceding item.</td>
</tr>
<tr>
<td>D</td>
<td>Dim (disable) the preceding item.</td>
</tr>
<tr>
<td>H</td>
<td>A hexadecimal, non-ASCII ID number follows, in low-byte/high-byte order.</td>
</tr>
<tr>
<td>I</td>
<td>Italicize the text of the preceding item.</td>
</tr>
<tr>
<td>N</td>
<td>Prefix for the ID number of a menu title or a menu item.</td>
</tr>
<tr>
<td>U</td>
<td>Underscore the text of the preceding item.</td>
</tr>
<tr>
<td>V</td>
<td>Place an underline under the preceding item without requiring a separate item.</td>
</tr>
<tr>
<td>X</td>
<td>Color replacement, rather than an XOR operation, will be used for highlighting. This symbol is usually used with the colored Apple logo on a menu bar.</td>
</tr>
</tbody>
</table>
handle—which is left on the stack in the previous example. For the reason why, read on.

The InsertMenu call takes two parameters: a handle to a menu and the 1-word ID number after which the menu in question will be inserted. In the previous example, only the second parameter is passed because the first parameter—the menu handle just pushed onto the stack—is still there. If a 0 is passed as the second parameter, as it is in this example, the menu being inserted is placed in front of any other menus in the menu bar.

It's easy to use a 0 parameter to place an inserted menu on top of all the rest. So menus are usually built backwards, in back-to-front order, as you will see in the menu building segment of the MENU.S1 program.

After you build a menu, you can draw it with the FixAppleMenu, FixMenuBar, and DrawMenuBar calls.

Activating a Menu

After a menu is built, the next step in making it useful in a program is to write a routine that accepts input from the user. You can use an Event Manager loop, but it is much easier to use a tool called TaskMaster, which considerably expands the capabilities of the Event Manager call GetNextEvent.

Using TaskMaster

TaskMaster is a tool in the Window Manager tool set, but it also has capabilities designed to be used with the Menu Manager. When a program includes menus, windows, or both, it can call TaskMaster instead of making the Event Manager call GetNextEvent. When TaskMaster is called in a program, the first thing it does is call GetNextEvent. Then it checks for twelve events that GetNextEvent cannot handle, and it handles those events. Then it places some information on the stack and in a record called a task record. Finally, it returns to the calling program.

The following is a call to TaskMaster in an assembly language program:

```
PushWord #0          ; space for result
PushWord EventMask  ; standard GetNextEvent mask
PushLong TaskRecPtr ; pointer to a task record
_TaskMaster
PullWord TaskCode   ; a code returned by TaskMaster
```

As the example illustrates, a call to TaskMaster takes three parameters:

- A null word (a 0) to save space on the stack for the result of the call.
- An event mask. This 1-word parameter is the same as the EventMask parameter, which must be passed to the Event Manager call GetNextEvent.
- A pointer to a record called a task record. A task record, as you shall see, is just like an event record used by the Event Manager call GetNextEvent, except it has two extra fields.
Before a TaskMaster call returns, it places a word called a *task code* on the stack. If TaskMaster detects an event, the task code tells where on the desktop (that is, in what part of the screen) the event took place. The values returned as a task code can vary, depending upon what kind of item is detected by TaskMaster. For example, if TaskMaster detects any event that is not a key down or button down event, the task code that it returns is the same as the event code returned by the Event Manager. If TaskMaster detects a key down or button down event, however, the values that can be returned as a task code are the same as those returned by the Window Manager call `FindWindow`. These values, and their meanings, are listed in table 9–3.

One of the best ways to use TaskMaster is to set up a table including all tasks it can handle. One such table, labeled *TaskTable*, appears in the MENU.S1 program. The first seventeen items in the table are identical to the items in the event table used to make the `GetNextEvent` call in chapter 7. But at the end of the table there are twelve extra items: the events that TaskMaster looks for after it has called `GetNextEvent`.

When you call TaskMaster in a program, TaskMaster first makes the Event Manager call `GetNextEvent`. `GetNextEvent` handles all the events it can, then passes control back to TaskMaster.

Now TaskMaster goes to its expanded list of events and looks for events that `GetNextEvent` cannot handle. Specifically, TaskMaster looks to see if the mouse button has been clicked in

- the menu bar
- the system window (not an application window)
- the content region of any window
- the drag (title bar) region of any window

<table>
<thead>
<tr>
<th>Task Code</th>
<th>Code Name</th>
<th>Where Event Took Place</th>
</tr>
</thead>
<tbody>
<tr>
<td>0010</td>
<td>wNoHit</td>
<td>Not in a window or a menu</td>
</tr>
<tr>
<td>0011</td>
<td>wInDesk</td>
<td>On the desktop</td>
</tr>
<tr>
<td>0012</td>
<td>wInMenuBar</td>
<td>In the system menu bar</td>
</tr>
<tr>
<td>0013</td>
<td>wInContent</td>
<td>In a window's content region</td>
</tr>
<tr>
<td>0014</td>
<td>wInDrag</td>
<td>In a window's drag region</td>
</tr>
<tr>
<td>0015</td>
<td>wInGrow</td>
<td>In a window's grow box</td>
</tr>
<tr>
<td>0016</td>
<td>wInGoAway</td>
<td>In a window's close box</td>
</tr>
<tr>
<td>0017</td>
<td>wInZoom</td>
<td>In a window's zoom box</td>
</tr>
<tr>
<td>0018</td>
<td>wInInfo</td>
<td>In a window's information bar</td>
</tr>
<tr>
<td>0019</td>
<td>wInSpecial</td>
<td>In a special menu item bar</td>
</tr>
<tr>
<td>001A</td>
<td>wInDeskItem</td>
<td>Desk accessory selected from Apple menu</td>
</tr>
<tr>
<td>001B</td>
<td>wInFrame</td>
<td>In a window frame area</td>
</tr>
<tr>
<td>8XXX</td>
<td>wInSysWindow</td>
<td>In a system window</td>
</tr>
</tbody>
</table>
The JIGS Toolbox

- the grow box of a window
- a window’s go-away box
- a window’s zoom box
- a window’s information bar
- a window’s vertical scroll bar
- a window’s horizontal scroll bar
- a window’s frame
- a menu’s drop region

As you can see, most of the events TaskMaster looks for involve windows. We won’t go into detail about window events now; they are covered in chapter 10.

In addition to looking for window-related events, TaskMaster can detect when the mouse button is clicked over a menu title or over a menu item—that is, in a menu’s “drop region.” These two capabilities make TaskMaster a valuable tool in programs that use the Menu Manager.

Event Records

When TaskMaster calls \texttt{GetNextEvent}, the \texttt{GetNextEvent} routine returns information in the usual way: by placing it in an event record. But the event record TaskMaster uses, like the event table, is slightly expanded. An event record in a program that uses TaskMaster has to be two fields longer than an ordinary event record. Listing 9–1 shows an event record used by TaskMaster in an assembly language program.

\begin{verbatim}
Listing 9–1
An event record used by TaskMaster

EventData DATA
EventRecord anop
EventWhat ds 2
EventMessage ds 4
EventWhen ds 4
EventWhere ds 4
EventModifiers ds 2
TaskData ds 4
TaskMask dc i4\$OFFF
\end{verbatim}

The two extra fields used by TaskMaster are at the end of the event record in listing 9–1. In one of the extra fields, \texttt{TaskData}, TaskMaster returns information, in the same way that \texttt{GetNextEvent} returns data in the event record fields for which it is responsible.

The other extra field, \texttt{TaskMask}, can be used to tell TaskMaster what kinds of events to look for and what kinds of events to ignore. The \texttt{TaskMask} field is used much like the event mask passed to the \texttt{GetNextEvent} call as a parameter.
It is important to understand, however, that the event mask passed to TaskMaster as a parameter is different from the TaskMask passed to TaskMaster as part of a task record. The event mask passed to TaskMaster is the same kind of mask passed to the Event Manager in the GetNextEvent call. Table 9-4 shows the layout of an event mask.

The value TaskMaster returns in the TaskData field can vary, depending upon the kind of event TaskMaster has detected. For example, if TaskMaster detects a key down event, it makes the Menu Manager call MenuKey to determine if the key pressed is the keyboard equivalent of a mouse-controlled menu selection. If the key is a menu-related key, TaskMaster returns the ID number of the menu selected in the high word of the TaskData field and the ID number of the menu item selected in the low word. If the ID number ranges between 1 and 249 ($0000-$00F9), indicating a desk accessory item, TaskMaster makes the OpenNDA call to open a desk accessory. Then TaskMaster unhighlights the menu using the Hi l i t eMenu call and returns a task code of 0.

If TaskMaster detects any other kind of key event, it returns a key down event: an ASCII character code (with the high bit clear) in the low-order byte of the EventMessage field and the upper 3 bytes of the field undefined.

If a button down event in a menu item is detected, TaskMaster returns with the menu's ID number in the high word of the TaskData field, the item's ID number in the low word of the TaskData field, and a task code of $0011 (wInMenuBar).

If TaskMaster detects a button down event in the menu bar but no menu item is selected, it returns a task code of 0. TaskMaster can also detect and handle a number of window-related events. These are covered in chapter 10.

Table 9-4
Bits in an Event Mask

<table>
<thead>
<tr>
<th>Bit</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Not used</td>
</tr>
<tr>
<td>1</td>
<td>Mouse down mask</td>
</tr>
<tr>
<td>2</td>
<td>Mouse up mask</td>
</tr>
<tr>
<td>3</td>
<td>Key down mask</td>
</tr>
<tr>
<td>4</td>
<td>Auto-key mask</td>
</tr>
<tr>
<td>5</td>
<td>Update mask</td>
</tr>
<tr>
<td>6</td>
<td>Active mask</td>
</tr>
<tr>
<td>7</td>
<td>Switch mask</td>
</tr>
<tr>
<td>8</td>
<td>Desk accessory mask</td>
</tr>
<tr>
<td>9</td>
<td>Driver mask</td>
</tr>
<tr>
<td>10</td>
<td>Application 1</td>
</tr>
<tr>
<td>11</td>
<td>Application 2</td>
</tr>
<tr>
<td>12</td>
<td>Application 3</td>
</tr>
<tr>
<td>13</td>
<td>Not used</td>
</tr>
<tr>
<td>14</td>
<td>Not used</td>
</tr>
<tr>
<td>15</td>
<td>Not used</td>
</tr>
</tbody>
</table>
As mentioned, TaskMaster also returns a 1-word event code, which it pushes onto the stack. The task codes used by TaskMaster are listed in table 9–3.

**Task Masks**

A task mask is a 1-word parameter that must be passed to TaskMaster each time TaskMaster is called. An application uses a task mask to tell TaskMaster what events to look for or ignore.

In a task mask, bits 0 through 12 correspond to events TaskMaster can handle. Each bit corresponds to one type of event. If a bit is set, TaskMaster reports on the corresponding event. If a bit is clear, TaskMaster ignores the corresponding event. For TaskMaster to look for every type of event it can handle, the task mask should be $0000FFFF.

Bits 16 to 31 (the high word) in the task mask must always be clear. The bits in the task mask field and their functions are listed in table 9–5.

<table>
<thead>
<tr>
<th>Bit</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Menu key</td>
</tr>
<tr>
<td>1</td>
<td>Update handling</td>
</tr>
<tr>
<td>2</td>
<td>Find window</td>
</tr>
<tr>
<td>3</td>
<td>Menu select</td>
</tr>
<tr>
<td>4</td>
<td>Open NDA</td>
</tr>
<tr>
<td>5</td>
<td>System click</td>
</tr>
<tr>
<td>6</td>
<td>Drag window</td>
</tr>
<tr>
<td>7</td>
<td>Select window if event is wInContent</td>
</tr>
<tr>
<td>8</td>
<td>Track go-away</td>
</tr>
<tr>
<td>9</td>
<td>Track zoom</td>
</tr>
<tr>
<td>10</td>
<td>Grow window</td>
</tr>
<tr>
<td>11</td>
<td>Scroll window</td>
</tr>
<tr>
<td>12</td>
<td>Handle special menu items</td>
</tr>
<tr>
<td>13</td>
<td>Not used</td>
</tr>
<tr>
<td>14</td>
<td>Not used</td>
</tr>
<tr>
<td>15</td>
<td>Not used</td>
</tr>
<tr>
<td>16–31</td>
<td>Must be clear</td>
</tr>
</tbody>
</table>

**Accepting Input from the User**

When you create a task table and an event record for TaskMaster, you can write a routine to accept input from the IIgs user. The main event loop of MENU.S1, EventLoop in listing 9–2, is one such routine.

The event loop in listing 9–2 is straightforward. It calls TaskMaster, pulls TaskMaster’s event code off the stack, and then uses the code to jump to a subroutine listed in a jump table called TaskTable. This table is a standard event table of the type used by the Event Manager, with twelve additional events TaskMaster is designed to handle. The TaskMaster section of the event table used in MENU.S1 is in listing 9–3.
LISTING 9-2
Event loop in MENU.S1

EventLoop
START
Using QuitData
Using TaskTable
Using EventData

Again
PushWord #0 ; space for result
PushWord #$FFFF ; recognize all events
PushLong #EventRecord
(TaskMaster)
_pla
_asl a ; code * 2 = table location
tax ; X is index register
jsr (TaskTable,x) ; look up event’s routine
lda QuitFlag
beq again

rts
END

LISTING 9-3
TaskMaster section of MENU.S1 event table

* TaskMaster Events
*

dc i’DoMenu’ ; 1 in menu bar
dc i’ignore’ ; 2 in system window
dc i’ignore’ ; 3 in content of window (MoveIt)
dc i’ignore’ ; 4 in drag
dc i’ignore’ ; 5 in grow
dc i’ignore’ ; 6 in go-away
dc i’ignore’ ; 7 in zoom
dc i’ignore’ ; 8 in info bar
dc i’ignore’ ; 9 in ver scroll
dc i’ignore’ ; 10 in hor scroll
dc i’ignore’ ; 11 in frame
dc i’ignore’ ; in drop

END
As listing 9–3 shows, only the first item in the table—"in menu bar"—is activated. So each time TaskMaster loops through the table, it looks for only one kind of event: a button down event in the menu bar. If that event is detected, TaskMaster jumps to a subroutine labeled DoMenu, which appears in listing 9–4.

### Listing 9–4
A routine that uses TaskMaster

```
* *
* DoMenu *
* Called when TaskMaster tells us a new menu item is selected. *
*

DoMenu       START
Using TaskTable
Using EventData
Using MenuTable

Ida TaskData ; get TaskData value
cmp #256
bcc GiveUp ; this should never happen

and #$00FF ; mask off high byte
asl a ; double the value
tax ; for 2-byte addresses

jsr (MenuTable,x)

GiveUp       anop
PushWord #False ; false=unhighlight
PushWord TaskData+2 ; which menu?
_HiliteMenu ; unhighlight it

rts

END
```

The DoMenu routine is also straightforward. Each time it is called, it checks the TaskData field of the event record to see which item of which
menu (if any) the user selected. It then jumps to another table, labeled MenuTable, to determine what kind of action to perform. This table appears in listing 9–5.

### Listing 9–5
MenuTable segment from MENU.S1

<table>
<thead>
<tr>
<th>MenuTable</th>
<th>DATA</th>
</tr>
</thead>
<tbody>
<tr>
<td>*</td>
<td>Menu 1 (apple)</td>
</tr>
<tr>
<td></td>
<td>dc i'ignore' ; one for the NDAs</td>
</tr>
<tr>
<td></td>
<td>dc i'ignore'</td>
</tr>
<tr>
<td>*</td>
<td>Menu 2 (file)</td>
</tr>
<tr>
<td></td>
<td>dc i'doQuit' ; quit item selected</td>
</tr>
<tr>
<td>*</td>
<td>Menu 3 (appetizers)</td>
</tr>
<tr>
<td></td>
<td>dc i'CheckIt' ; 'salad'</td>
</tr>
<tr>
<td></td>
<td>dc i'CheckIt' ; 'jello'</td>
</tr>
<tr>
<td></td>
<td>dc i'CheckIt' ; 'slices'</td>
</tr>
<tr>
<td></td>
<td>dc i'CheckIt' ; 'juice'</td>
</tr>
<tr>
<td>*</td>
<td>Menu 4 (entrees)</td>
</tr>
<tr>
<td></td>
<td>dc i'CheckIt' ; 'duckling'</td>
</tr>
<tr>
<td></td>
<td>dc i'CheckIt' ; 'dumplings'</td>
</tr>
<tr>
<td>*</td>
<td>Menu 5 (beverages)</td>
</tr>
<tr>
<td></td>
<td>dc i'CheckIt' ; 'shake'</td>
</tr>
<tr>
<td></td>
<td>dc i'CheckIt' ; 'cola'</td>
</tr>
<tr>
<td></td>
<td>dc i'CheckIt' ; 'wine'</td>
</tr>
<tr>
<td>*</td>
<td>Menu 6 (desserts)</td>
</tr>
<tr>
<td></td>
<td>dc i'CheckIt' ; 'an apple'</td>
</tr>
<tr>
<td></td>
<td>dc i'CheckIt' ; 'pie'</td>
</tr>
<tr>
<td></td>
<td>dc i'CheckIt' ; 'turnover'</td>
</tr>
<tr>
<td>END</td>
<td></td>
</tr>
</tbody>
</table>

The data segment labeled MenuTable is a jump table version of the table of menu data in listing 9–6. Both tables are in the MENU.S1 program at the end of this chapter. The table in listing 9–5 sends the MENU.S1 program to the subroutine the user selects. The table in listing 9–6 provides the Menu Manager with the information it needs to create a menu that works with the jump table in listing 9–5.
### Listing 9–6
Data used to create a menu

<table>
<thead>
<tr>
<th>MenuData</th>
<th>DATA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Return</td>
<td>equ 13</td>
</tr>
<tr>
<td>Menu1</td>
<td>dc c'&quot;L@\XN1',i1'\RETURN'</td>
</tr>
<tr>
<td></td>
<td>dc c' LAn Apple Menu\N257',i1'\RETURN'</td>
</tr>
<tr>
<td></td>
<td>dc c'.</td>
</tr>
<tr>
<td>Menu2</td>
<td>dc c'\L File \N2',i1'\RETURN'</td>
</tr>
<tr>
<td></td>
<td>dc c' LQuit \N258**q',i1'\RETURN'</td>
</tr>
<tr>
<td></td>
<td>dc c'.</td>
</tr>
<tr>
<td>Menu3</td>
<td>dc c'\LA ppetizers \N3',i1'\RETURN'</td>
</tr>
<tr>
<td></td>
<td>dc c' LA pple Salad \N259',i1'\RETURN'</td>
</tr>
<tr>
<td></td>
<td>dc c' LApple Jello \N260',i1'\RETURN'</td>
</tr>
<tr>
<td></td>
<td>dc c' LApple Slices \N261',i1'\RETURN'</td>
</tr>
<tr>
<td></td>
<td>dc c' LApple Juice \N262',i1'\RETURN'</td>
</tr>
<tr>
<td></td>
<td>dc c'.</td>
</tr>
<tr>
<td>Menu4</td>
<td>dc c'\LA pple Duckling \N263',i1'\RETURN'</td>
</tr>
<tr>
<td></td>
<td>dc c' LApple Dumplings \N264',i1'\RETURN'</td>
</tr>
<tr>
<td></td>
<td>dc c'.</td>
</tr>
<tr>
<td>Menu5</td>
<td>dc c'\L Beverages \N5',i1'\RETURN'</td>
</tr>
<tr>
<td></td>
<td>dc c' LApple Shake \N265',i1'\RETURN'</td>
</tr>
<tr>
<td></td>
<td>dc c' LApple Cola \N266',i1'\RETURN'</td>
</tr>
<tr>
<td></td>
<td>dc c' LApple Wine \N267',i1'\RETURN'</td>
</tr>
<tr>
<td></td>
<td>dc c'.</td>
</tr>
<tr>
<td>Menu6</td>
<td>dc c'\LA pple Pie \N269',i1'\RETURN'</td>
</tr>
<tr>
<td></td>
<td>dc c' LApple Turnover \N270',i1'\RETURN'</td>
</tr>
<tr>
<td></td>
<td>dc c'.</td>
</tr>
</tbody>
</table>

END

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The MENU Program

Two programs that illustrate the use of the Ilcos Menu Manager are at the end of this chapter. One, an assembly language program titled MENU.SI, is in listing 9–9. The other, a C program titled MENU.C, appears in listing 9–10.

**MENU.SI Program**

MENU.SI is a simple program; its menu table contains the names of only two subroutines. One, *Quit*, ends the program. The other, *CheckIt*, uses the Menu Manager call *GetMItemMark* to see if there is a check mark in front of the menu item selected. If there is no check mark, the *CheckIt* routine puts one there. If there is a check mark, *CheckIt* removes it.

Listing 9–7 is a source code listing of the *CheckIt* routine—and that concludes our analysis of the MENU.SI program. When you have typed and run the program, be sure to save it. You'll use a similar menu, and add a windowing capability, in chapter 10.

**Listing 9–7**

*CheckIt* routine

```
CheckIt         START
Using EventData

PushWord #0     ; space for result
PushWord TaskData ; menu item number
_GetMItemMark
pla
beq putmark     ; no check mark, so make one

erasemark       PushWord #0     ; erase check mark
PushWord TaskData ; menu item number
_SetMItemMark
bra return

putmark         PushWord #18     ; ASCII for check mark
PushWord TaskData ; menu item number
_SetMItemMark

return          rts

END
```

**MENU.C Program**

MENU.C is the first program you have encountered so far that requires an expanded version of INITQUIT.C. In addition to the tool initialization in the original version of INITQUIT.C, the Menu Manager requires the use of the Window Manager and the Control Manager, so INITQUIT.C has grown. The revised version of INITQUIT.C appears in listing 9–8.
#include <TYPES.H>
#include <LOCATOR.H>
#include <MEMORY.H>
#include <MISCTOOL.H>
#include <QUICKDRAW.H>
#include <EVENT.H>
#include <CONTROL.H>
#include <WINDOW.H>
#include <MENU.H>

#define MODE mode640 /* 640 graphics mode def. from quickdraw.h */
#define MaxX 640      /* max X for cursor (for Event Mgr) */
#define dpAttr attrLocked+attrFixed+attrBank /* for allocating direct page space */

int MyID;         /* for Memory Manager */
Handle zp;        /* handle for page 0 space for tools */

int ToolTable[] = {5,
                   4, 0x0100, /* QD */
                   6, 0x0100, /* Event */
                   14, 0x0100, /* Window */
                   16, 0x0100, /* Control */
                   15, 0x0100, /* Menu */
               };

StartTools()      /* start up these tools: */
{
    TLStartUp();   /* Tool Locator */
    MyID = MMStartUp(); /* Mem Manager */
    MTStartUp();   /* Misc Tools */
    LoadTools(ToolTable); /* load tools from disk */
    ToolInit();    /* start up the rest */
}

ToolInit()        /* init the rest of needed tools */
{
    zp = NewHandle(0x600L, MyID, dpAttr, 0L); /* reserve 6 pages */
    QDStartUp((int) *zp, MODE, 160, MyID);   /* uses 3 pages */
    EMStartUp((int) (*zp + 0x300), 20, 0, MaxX, 0, 200, MyID);
    WindStartUp(MyID);
    RefreshDesktop(NULL);
    CtlStartUp(MyID, (int) (*zp + 0x400));
    MenuStartUp(MyID, (int) (*zp + 0x500));
    ShowCursor();
}
ShutDown() 
/* shut down all of the tools we started */
{
    GrafOff();
    MenuShutDown();
    CtlShutDown();
    WindShutDown();
    EMShutDown();
    QDShutDown();
    MTShutDown();
    DisposeHandle(zp); /* release our page 0 space */
    MMShutDown(MyID);
    TLShutDown();
}

Another significant difference between MENU.C and the event loop programs in previous chapters is that MENU.C uses the Window Manager call TaskMaster rather than the Event Manager call GetNextEvent. Because TaskMaster takes care of most of the event loop details in MENU.C, the rest of the event loop routine is interested in the answer to just one question: Was a menu item selected? If one was, you want to know whether it was the Quit item in the Files menu or simply an item that should be checked or unchecked.

The way in which the MENU.C program handles the checking of items is a little tricky. Because the Menu Manager call CheckMItem returns the ASCII value of a check mark when an item has been checked or a 0 if there is no check mark, you can treat the call’s result as a Boolean value; true if an item is marked and false if it is not. Similarly, the CheckMItem call takes a Boolean value as an input and uses the value to determine whether to check or uncheck a menu item.

In the MENU.C program, you want to send a value of true to CheckMItem if you want an item marked, and you want to send a value of false if you want an item unmarked. By prefixing the logical inverse operator ! (pronounced “not” or, by UNIX fans, “bang”) to GetMItemMark, you can pass the result returned by GetMItemMark directly to the CheckMItem routine.

Another trick used in the MENU.C program is the use of a pointer to refer to the contents of the wmTaskData field in TaskMaster’s task record. By typecasting the address of this long word field to a pointer to a word called data, you can reference the low word of the field (the item number) as *data and the high word of the field (the menu number) as *(data+1). Even though the contents of the wmTaskData field may change with each cycle through the event loop, the address of the information it contains always remains the same. Thus, you merely have to set the value of data to this address once before you begin the loop, and the value of *data and *(data+1) will always be equal to the latest results.
MENU.S1 and MENU.C Listings

Listing 9-9
MENU.S1 program

* *
* MENU.S1 *
* *

*** A FEW ASSEMBLER DIRECTIVES ***

Title 'Menu'

ABSADDR on
LIST off
SYMBOL off
65816 on
mcopy menu.macros

KEEP Menu

* *
* EXECUTABLE CODE STARTS HERE *
* *

Begin

START
Using QuitData

jmp MainProgram ; skip over data

END

* *
* SOME DIRECT PAGE ADDRESSES AND A FEW EQUATES *
* *

DPLstart

DPPPointer gequ $00
DPPHandle gequ DPPPointer+4
TabPtr gequ $00

ScreenMode gequ $80 ; 640 mode
MaxX gequ 640 ; X clamp high
False gequ $00

232
* * MAIN PROGRAM LOOP *
*

MainProgram START
Using GlobalData

phk
plb
tdc
sta MyDP ; get current direct page
; and save it for the moment

jsr ToolInit ; start up all tools we'll need
jsr BuildMenu ; create and draw menu bar
jsr EventLoop ; check for key & mouse events

*** WHEN EVENT LOOP ENDS, WE'LL SHUT DOWN ***

jsr Shutdown
jmp Endit

END

* * EVENT LOOP *
*

EventLoop START
Using QuitData
Using TaskTable
Using EventData

Again PushWord #0 ; space for result
PushWord #$FFFF ; recognize all events
PushLong #EventRecord
_TaskMaster
pl a
asl a ; code * 2 = table location
tax ; X is index register
jsr (TaskTable,x) ; look up event's routine
lda QuitFlag
beq again

rts

END
* CREATE AND DRAW MENU *

BuildMenu

START

using MenuData

; proceeding from back to front

PushLong #0
PushLong #Menu6
_NewMenu
PushWord #0
_InsertMenu

; space for return

PushLong #0
PushLong #Menu5
_NewMenu
PushWord #0
_InsertMenu

PushLong #0
PushLong #Menu4
_NewMenu
PushWord #0
_InsertMenu

; space for return

PushLong #0
PushLong #Menu3
_NewMenu
PushWord #0
_InsertMenu

; space for return

PushLong #0
PushLong #Menu2
_NewMenu
PushWord #0
_InsertMenu

; 'wait' screen menu bar

PushLong #0
PushLong #Menu1
_NewMenu
PushWord #0
_InsertMenu

; space for return

PushWord #1
_FixAppleMenu

; get NDAs for Apple Menu

PushWord #0
_FixMenuBar

; init & draw the menu bar
pla
 ; discard menu bar height

_DrawMenuBar

rts

END

* * DoMenu
* Called when TaskMaster tells us a new menu item is selected.
*

DoMenu
START
Using TaskTable
Using EventData
Using MenuTable

lda TaskData ; get TaskData value
cmp #256
bcc GiveUp ; this should never happen

and #$00FF ; mask off high byte
asl a ; double the value
tax ; for 2-byte addresses

jsr (MenuTable,x)

GiveUp
anop
PushWord #False ; draw normal
PushWord TaskData+2 ; which menu?
_HiliteMenu ; unhighlight it

rts

END

* * ROUTINE TO PRINT A CHECK MARK IN FRONT OF A MENU ITEM *
*

CheckIt
START
Using EventData

PushWord #0 ; space for result
PushWord TaskData ; menu item number
_GetMItemMark

pla
The Ilas Toolbox

beq putmark ; no check mark, so make one

erasemark PushWord #0 ; erase check mark
PushWord TaskData ; menu item number
_SetMItemMark
bra return

putmark PushWord #18 ; ascii for check mark
PushWord TaskData ; menu item number
_SetMItemMark

return rts

END

* * THIS IS WHERE WE INITIALIZE OUR TOOLS *

ToolInit START
Using GlobalData
Using ToolTable

*** START UP TOOL LOCATOR ***

_TLStartup ; Tool Locator

*** INITIALIZE MEMORY MANAGER ***

PushWord #0
_MMStartup

pla
sta MyID

*** INITIALIZE MISC. TOOLS SET ***

_MTStartup

*** GET SOME DIRECT PAGE MEMORY FOR TOOLS THAT NEED IT ***

PushLong #0 ; space for handle
PushLong #$800 ; eight pages
PushWord MyID
PushWord #$C001 ; locked, fixed, fixed bank
PushLong #0
_NewHandle
plas
sta DPHandle
plas
sta DPHandle+2

lda [DPHandle]
sta DPPPointer

*** INITIALIZE QUICKDRAW II ***

lda DPPPointer
pha
PushWord #ScreenMode
PushWord #160
PushWord MyID
_QDStartup

*** INITIALIZE EVENT MANAGER ***

lda DPPPointer
clc
adc #$300
pha
PushWord #20
PushWord #0
PushWord #MaxX
PushWord #0
PushWord #200
PushWord MyID
_EMStartup

*** LOAD SOME TOOLS FROM RAM ***

LoadEmUp
PushLong #ToolTable
_LoadTools

*** WINDOW MANAGER ***

PushWord MyID
_WindStartup

PushLong #$0000
_REFRESH

*** CONTROL MANAGER ***

PushWord MyID
lda DPPPointer
; DP to use = qd dp + $400
The IIGS Toolbox

clc
adc #$400
pha
CtlStartup

*** MENU MANAGER ***

PushWord MyID
lda DPPointer ; DP to use = qd dp + $600
clc
adc #$600
pha
MenuStartup

ShowCursor

rts

END

*
* THE ROUTINE THAT ENDS THE PROGRAM
*

EndIt

START

Using QuitData

Quit QuitParams

END

*
* SHUT DOWN ALL THE TOOLS WE STARTED UP
*

ShutDown

START

Using GlobalData

MenuShutDown
CtlShutDown
WindShutDown
EMShutDown
QDShutDown
MTShutDown

PushLong DPHandle
DisposeHandle
PushWord MyID
_MMShutDown
_TLShutDown

rts

END

*  
* ROUTINE THAT SETS THE QUIT FLAG  
*

doQuit START
        Using QuitData
        
        lda #$8000
        sta QuitFlag
        rts

        END

*  
* A USEFUL AND CONVENIENT WAY NOT TO DO ANYTHING  
*

Ignore START

  rts

  END

*  
* DATA SEGMENTS  
*

*  
* Menu Data  
*

MenuData DATA

Return equ 13

Menu1 dc c'>'L@\XN1',i1'\RETURN'
        dc c'>'LAn Apple Menu\N257',i1'\RETURN'
        dc c'>'

Menu2 dc c'>'L File \N2',i1'\RETURN'
dc c' LQuit \N258*Qq',i1'RETURN'
dc c'.'

Menu3

dc c'>L Appetizers \N3',i1'RETURN'
dc c' LApple Salad \N259',i1'RETURN'
dc c' LApple Jello \N260',i1'RETURN'
dc c' LApple Slices \N261',i1'RETURN'
dc c' LApple Juice \N262',i1'RETURN'
dc c'.'

Menu4

dc c'>L Entrees \N4',i1'RETURN'
dc c' LApple Duckling \N263',i1'RETURN'
dc c' LApple Dumplings \N264',i1'RETURN'
dc c'.'

Menu5

dc c'>L Beverages \N5',i1'RETURN'
dc c' LApple Shake \N265',i1'RETURN'
dc c' LApple Cola \N266',i1'RETURN'
dc c' LApple Wine \N267',i1'RETURN'
dc c'.'

Menu6

dc c'>L Desserts \N6',i1'RETURN'
dc c' LApples \N268',i1'RETURN'
dc c' LApple Pie \N269',i1'RETURN'
dc c' LApple Turnover \N270',i1'RETURN'
dc c'.'

END

***

MenuTable

DATA

* Menu 1 (apple)
dc 'ignore' ; one for the NDAs
dc 'ignore'

* Menu 2 (file)
dc 'doQuit' ; quit item selected

* Menu 3 (appetizers)
dc 'CheckIt' ; 'salad'
dc 'CheckIt' ; 'jello'
dc 'CheckIt' ; 'slices'
dc 'CheckIt' ; 'juice'

* Menu 4 (entrees)
dc 'CheckIt' ; 'duckling'

240
dc i'CheckIt' ; 'dumplings'

* Menu 5 (beverages)
dc i'CheckIt' ; 'shake'
dc i'CheckIt' ; 'cola'
dc i'CheckIt' ; 'wine'

* Menu 6 (desserts)
dc i'CheckIt' ; 'an apple'
dc i'CheckIt' ; 'pie'
dc i'CheckIt' ; 'turnover'

END

***
TaskTable DATA

dc i'ignore' ; 0 null
dc i'ignore' ; 1 mouse down
dc i'ignore' ; 2 mouse up
dc i'ignore' ; 3 key down
dc i'ignore' ; 4 undefined
dc i'ignore' ; 5 auto-key down
dc i'ignore' ; 6 update event
dc i'ignore' ; 7 undefined
dc i'ignore' ; 8 activate
dc i'ignore' ; 9 switch
dc i'ignore' ; 10 desk acc
dc i'ignore' ; 11 device driver
dc i'ignore' ; 12 application
dc i'ignore' ; 13 application
dc i'ignore' ; 14 application
dc i'ignore' ; 15 application
dc i'ignore' ; 0 in desk

* TaskMaster events
*

dc i'DoMenu' ; 1 in menu bar
dc i'ignore' ; 2 in system window
dc i'ignore' ; 3 in content of window (Move It)
dc i'ignore' ; 4 in drag
dc i'ignore' ; 5 in grow
dc i'ignore' ; 6 in go-away
dc i'ignore' ; 7 in zoom
dc i'ignore' ; 8 in info bar
dc i'ignore' ; 9 in ver scroll
dc i'ignore' ; 10 in hor scroll
dc i'ignore' ; 11 in frame
dc i'ignore' ; in drop

END

***

ToolTable DATA

dc i'5' ; number of tools in table
dc i'$04,$0100' ; QuickDraw
dc i'$06,$0100' ; Event Manager
dc i'$0E,$0000' ; Window Manager
dc i'$0F,$0100' ; Menu Manager
dc i'$10,$0100' ; Control Manager

END

***

EventData DATA

EventRecord anop ; table for Event Manager
EventWhat ds 2
EventMessage ds 4
EventWhen ds 4
EventWhere ds 4
EventModifiers ds 2
TaskData ds 4
TaskMask dc i4'$0FF'

END

***

QuitData DATA

QuitFlag ds 2
QuitParams dc i4'0'
dc i4'0'
dc i4'0'

END

***

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Listing 9–10
MENU.C program

/*****************************/
/* Data and routine to create menus */
/*****************************/

/* Set up menu strings. Because C uses \ as an escape character, we use two when we want a \ as an ordinary character. The \ at the end of each line tells C to ignore the carriage return. This lets us set up our items in an easy-to-read vertical alignment. */

char *menu1 = "\n >L@\XN1\r\n   LAn Apple Menu\N257\r\n .";
char *menu2 = "\n >L File \N2\r\n   LQuit \N258\*Qq\r\n .";
char *menu3 = "\n >L Appetizers \N3\r\n   LApple Salad \N259\r\n   LApple Jello \N260\r\n   LApple Slices \N261\r\n   LApple Juice \N262\r\n .";
char *menu4 = "\n >L Entrees \N4\r\n   LApple Duckling \N263\r\n   LApple Dumplings \N264\r\n .";
char *menu5 = "\n >L Beverages \N5\r\n   LApple Shake \N265\r\n   LApple Cola \N266\r\n   LApple Wine \N267\r\n .";

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char *menu6 = "
> Desserts \
> Apples \
> Apple Pie \
> Apple Turnover \\
.

#define QUIT_ITEM 258 /* these will help us check menu item numbers */
#define LAST_ITEM 270

BuildMenu()
{
    InsertMenu(NewMenu(menu6),0);
    InsertMenu(NewMenu(menu5),0);
    InsertMenu(NewMenu(menu4),0);
    InsertMenu(NewMenu(menu3),0);
    InsertMenu(NewMenu(menu2),0);
    InsertMenu(NewMenu(menu1),0);
    FixMenuBar();
    DrawMenuBar();
}

/**************************************************************************/
/* Main routine and event loop */
/**************************************************************************/

WmTaskRec myEvent;
Boolean done = false;

main()
{
    StartTools();
    BuildMenu();
    EventLoop();
    ShutDown();
}

/**************************************************************************/
/* When a menu bar event is returned, test the item number for a 
checkable item. Use the logical inverse of the value returned by 
GetMItemMark as a parameter to CheckMItem. This will toggle the check 
mark for each item. */
/**************************************************************************/

EventLoop()
{
    Word *data = (Word *)&myEvent.wmTaskData; /* address of item id */

    myEvent.wmTaskMask = 0xFF00;
    while (!done)
if ( TaskMaster(everyEvent,&myEvent) == wInMenuBar ) {
    if (*data == QUIT_ITEM)
        done = true;
    else if (((data > QUIT_ITEM) && (*data <= LAST_ITEM))
        CheckMItem (!GetMItemMark(*data), *data);
    HiliteMenu(false,*((data + 1)); /* data + 1 is address of menu id */
    }
es, the Apple IIGs does windows—and with real class, too! To make sure they’re done properly, the IIGs employs a Window Manager. The Window Manager—like the Event Manager, which was introduced in chapter 7—is a very important toolkit in the Apple IIGs Toolbox. It is the Window Manager’s job to handle all windows placed on the IIGs desktop. It can create, draw, shrink, expand, scroll, and move windows. When you’ve finished working with a window, the Window Manager can remove it from your screen. When you’re through with a window for good, the Window Manager can dispose it and deallocate its memory.

The Window Manager takes care of all kinds of windows, not just picture windows and document windows, but also dialog windows, alert windows, and windows custom-tailored for specific programs. Want a round window or a triangular window? The Window Manager can make one. How about a window that seems to explode when you click the mouse in its go-away box or a window with custom-designed controls? No problem for the Apple IIGs Window Manager. It’s a toolkit that can do just about any kind of window.

Kinds of Windows

The kinds of windows the Window Manager can manage are divided into three categories:
**Document windows.** Most of the windows used in IIgs programs are in this category. A window doesn’t have to contain text to be classified as a document window. Windows that contain pictures drawn with programs like PaintWorks Plus are also document windows.

**Dialog windows.** There are three kinds of dialog windows: modal dialogs, modeless dialogs, and alert windows. Although low-level operations for all three types of windows can be handled by the Window Manager, they are mostly the responsibility of the Dialog Manager. So we won’t go into detail about them until chapter 11, which is all about the Dialog Manager.

**Custom-designed windows.** You can design custom windows using the Window Manager, but that is beyond the scope of this book. If you’d like to design your own windows, you can find some tips on how to do it in the *Apple IIgs Toolbox Reference*.

### Window Frames

There are two kinds of predefined window frames: *alert window frames* and *document window frames*. An alert window frame is a double black line. A document frame is a single black line or includes controls.

A window does not have to be an alert window to have an alert window frame; document windows can have alert window frames, too. A standard document window frame and an alert window frame are illustrated in figure 10–1.

### Controls

The screen of the IIgs represents a working desktop. Various graphic objects appear on this desktop and are manipulated with a mouse. A window is a

---

**This window has a normal frame.**

**This window has an alert frame.**

*Figure 10–1*
Document frame and alert frame
10—Doing Windows

desktop object that presents information; it can contain a document, a picture, a message, or other items. Windows can be almost any size or shape, and one or more of them can be on the desktop at any time.

Windows owe their name to the fact that they can show you more information than the IIgs screen can display at one time. When a window is on the screen, you can look through it into a larger area. The information displayed through a window can be pictures, text, data, or all three. When you look at something through a window—for example, a picture—the window can be moved around over the picture with a control called a scroll bar.

Most document windows have two scroll bars: a horizontal scroll bar, which scrolls the window horizontally, and a vertical scroll bar, which scrolls the window vertically. You’ll learn how to use both kinds of scroll bars before you finish this chapter.

A document window can also have the following controls:

- A title bar, which is a horizontal bar that displays the window’s title, if there is one. A title bar can contain a close box, which makes the window disappear from the screen, and a zoom box, which changes the window’s size. A title bar can be used as a drag region for moving the window.

- A grow region, which is a small box in the lower right corner of a window that changes the window’s size.

- An information bar, another horizontal bar in which an application can display information that won’t be affected by the movements of scroll bars.

Information bars may have their uses, but they are not popular in programs written for the IIgs. A standard document window, without an information bar, is illustrated in figure 10—2. The controls in the title bar of a document window are used as follows:

- Clicking the mouse anywhere in an inactive window highlights its title bar and makes it the active window, the window in which drawing and other activities take place. The title bars of all other windows become unhighlighted. Although these windows remain on the screen, they become inactive windows. According to Apple’s Human Interface Guidelines, there should never be more than one active window on the screen.

- Clicking the mouse in the close box, or go-away region, closes the window. Usually, when you click the mouse in the close box, an application program calls the Window Manager routine HideWindow, which makes the window disappear from the screen.

- Pressing the mouse button in the window’s drag region (title bar) and then dragging the window pulls an outline of the window across the screen. Holding the mouse button down and releasing it in a new location moves the window there. Unless the Apple key is held
The IIGS Toolbox

It was a dark and stormy night: The rain fell in torrents except at occasional intervals, when it was checked by a violent gust of wind which swept up the streets (for it is in London that our scene lies), rattling along the housetops, and fiercely agitating the scanty flame of the lamps that struggled against the darkness.

is in London that our scene lies along the housetops, and fiercely agitating the scanty flame of the lamps that struggled against the darkness.

Figure 10-2
Standard document window

down when the mouse button is released, the moved window becomes the active window.

■ Clicking the mouse inside the grow box and then dragging the grow box changes the window’s size.

To keep windows from getting lost, the Window Manager prevents them from being dragged completely across the screen. The title bar can never be moved to a point where the visible area of the title bar is less than four pixels square.

Some windows are created by application programs and others are created by tools in the Toolbox. (For example, the Dialog Manager can create dialog windows.) Windows created by application programs and by tools in the Toolbox are known collectively as application windows. Another class of windows, called system windows, display desk accessories.

What the Window Manager Does

The Window Manager draws windows using QuickDraw II and the Control Manager, and it disposes them with the help of the Memory Manager. After a window is drawn on the screen, the Window Manager’s main function is
to keep track of overlapping windows. The Window Manager handles tasks so that you can draw in any window without running into windows in front of it. You can move a window to a different place on the screen, change its size, or change its plane (front-to-back order), and you don’t have to worry about details, such as how parts of various windows cover parts of other windows. The Window Manager redraws windows as needed and ensures that they overlap properly.

Window Regions

Every window is made up of two regions:

- A **content region**, which is the area that lies inside the window’s frame. An application can draw objects and text in this portion of a window.
- A **frame region**, which is the outline of the entire window, including its title bar and standard window controls.

A window’s content region and frame region make up what is known as the **structure region** of the window.

Every window also has a **data area**: a block of memory that includes all the data that can be viewed through the window. If the window has scroll bars, they can be used to move the window over its data area.

If a window has a grow box, a zoom box, or both, they can be used to increase or decrease the size of the window, causing more or less of its data area to be displayed. When the window is scrolled, it moves over the data area. But when the window is moved from one part of the screen to another, the data area is moved with it, so the view remains the same.

Initializing the Window Manager

Before the Window Manager can be started up, it must be loaded into memory, and QuickDraw and the Event Manager must be loaded and initialized. The Window Manager call `WindStartUp` can then be issued to initialize the Window Manager. Then you can use the Window Manager call `NewWindow` to create any windows needed in a program.

TaskMaster

In programs that use the Window Manager, there are two ways to handle user input. One way is to use the Event Manager call `GetNextEvent`. The other is to use the Window Manager call `TaskMaster`.

The easiest way to use the Window Manager is with TaskMaster. As you may recall from chapter 9, TaskMaster can handle events related to menus.
as well as events that involve windows. The interaction between TaskMaster and menus is covered in chapter 9. In this chapter, you see how to use TaskMaster in programs that make use of windows.

WINDOW.S1 shows how an assembly language program can handle windows using TaskMaster. WINDOW.C is a C language version of the same program. Both programs are at the end of this chapter.

When TaskMaster is used in a program, it does the following. First, TaskMaster makes the Event Manager call \texttt{GetNextEvent}. If an event isn’t ready, TaskMaster returns a task code of 0. If an event is ready, TaskMaster looks at it and tries to handle it. If TaskMaster can’t handle the event, it returns the event code to the application. The application can then handle the event as if its event code had been returned by \texttt{GetNextEvent}.

If TaskMaster can handle the event, it calls standard functions to try to complete the task. For example, if you press the mouse button in an active window’s zoom box, TaskMaster makes the Window Manager call \texttt{TrackZoom} until the mouse leaves the zoom box or the mouse button is released. If you release the mouse button while the mouse is in the zoom box, TaskMaster calls \texttt{ZoomWindow} to zoom the window either in or out, as appropriate. This takes care of the complete zoom operation selected by the user, so TaskMaster returns no event.

If TaskMaster can handle only part of an event, it does what it can and then returns control to the calling program. For example, if you press the mouse in the active window’s content region, TaskMaster can detect it, but it can’t do anything further. In this case, TaskMaster returns a task code of 0013 (\texttt{WinContent}). That lets an application program know that the mouse button has been pressed in the active window’s content region, but it is up to the application to determine what to do next.

The operation of TaskMaster is covered in detail in chapter 9, but here’s a brief review. A call to TaskMaster takes three parameters: a word to save a space on the stack, an event mask, and a pointer to a task record.

The event mask passed to TaskMaster is like an event mask used by the Event Manager. The task record used by TaskMaster is like an event record used by the Event Manager, but with two extra fields. Each time TaskMaster makes a \texttt{GetNextEvent} call, \texttt{GetNextEvent} fills in the first seventeen fields of the task record being used by TaskMaster. Then TaskMaster handles any events it can handle, fills in the last two fields of the task record, and returns.

Listing 10–1 is a task record used in this chapter’s example program, WINDOW.S1. The WINDOW.S1 program, listed in its entirety at the end of this chapter, is a sketcher program that allows the user to draw into a window with a mouse. When a sketch is drawn, each dot in it is actually drawn twice: once into the window on the screen and once into a pixel image that paints the window’s contents each time the window is updated. Thus, sketches drawn using the WINDOW.S1 program do not disappear from memory when a window is removed from the screen. They remain in memory and can show up in a window again when it is redrawn on the screen. In later chapters, the WINDOW.S1 program becomes even more sophisticated.
As you may recall from chapter 9, the event mask passed to TaskMaster as a parameter is different from the TaskMask passed to TaskMaster as part of a task record. The event mask passed to TaskMaster is the same kind of mask that is passed to the Event Manager in the GetNextEvent call.

A task mask is a word used by an application to tell TaskMaster what kinds of events it should look for and what kinds of events it should ignore. The high word of a task mask—bits 16 through 31—should always be clear. In the low word of a task mask, each bit corresponds to a task; a set bit causes TaskMaster to look for an event, and a cleared bit tells TaskMaster to ignore an event. For TaskMaster to look for every type of event it can handle, the task mask should be $0000FFFF. The bit layouts of an event mask and a task mask are listed in chapter 9.

Window Records

For each window used in an application program, the Window Manager maintains a window record. A window record contains a number of fields, but only the first seven are directly accessible to application programs. The rest of the fields in a window record can be accessed only through calls to the Window Manager. Table 10–1 shows the seven window record fields accessible to application programs.

When the Window Manager is active, it maintains a window list: a list of all windows currently open. It is important to note that a window can be open but hidden, and thus not visible on the screen.

As table 10–1 shows, the first field in a window record is a pointer to the Window Manager’s window list. The second field is the window’s GrafPort—the GrafPort itself, not a pointer to it. Thus, the length of the GrafPort field is the length of a GrafPort; the field is 186 bytes.

When a window is created using the Window Manager call NewWindow, the call returns a pointer to the new window’s GrafPort. Thus, the value returned by NewWindow is also a pointer to the second field of a window record.
Table 10–1

<table>
<thead>
<tr>
<th>Name</th>
<th>Length</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>wNext</td>
<td>Long</td>
<td>Pointer to next window in the window list</td>
</tr>
<tr>
<td>wport</td>
<td>186 bytes</td>
<td>Window’s port; returned window pointers point to here</td>
</tr>
<tr>
<td>wStrucRgn</td>
<td>Handle</td>
<td>Handle of window’s structural region (frame plus content)</td>
</tr>
<tr>
<td>wContRgn</td>
<td>Handle</td>
<td>Handle of window’s content region</td>
</tr>
<tr>
<td>wUpdateRgn</td>
<td>Handle</td>
<td>Handle of update regions (regions that need redrawing)</td>
</tr>
<tr>
<td>wControl</td>
<td>Handle</td>
<td>Handle of application’s first control in content region</td>
</tr>
<tr>
<td>wFrame</td>
<td>Word</td>
<td>Bit array that describes window’s frame</td>
</tr>
</tbody>
</table>

Every window used in an application program must be set up with a call to the Window Manager routine NewWindow. A call to NewWindow takes two parameters: 2 null words (zeros) to save spaces on the stack and a pointer to a parameter block. The call returns with a pointer to a window pushed onto the stack. Listing 10–2 is a NewWindow call used in the WINDOW.S1 program.

Listing 10–2

Call to NewWindow

```assembly
PushLong #0 ; space for result
PushLong #WinOParamBlock
_NewWindow

pla
sta WinOPtr
pla
sta WinOPtr+2
```
<table>
<thead>
<tr>
<th>Bit</th>
<th>Name of Field</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>F_HILITED</td>
<td>1 = Frame highlighted</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0 = Frame not highlighted</td>
</tr>
<tr>
<td>1</td>
<td>F_ZOOMED</td>
<td>1 = Currently zoomed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0 = Frame not zoomed</td>
</tr>
<tr>
<td>2</td>
<td>F_ALLOCATED</td>
<td>1 = Record was allocated</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0 = Record was provided by application</td>
</tr>
<tr>
<td>3</td>
<td>F_CTRL_TIE</td>
<td>1 = Control’s state is independent</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0 = Inactive window has inactive controls</td>
</tr>
<tr>
<td>4</td>
<td>F_INFO</td>
<td>1 = Information bar</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0 = No information bar</td>
</tr>
<tr>
<td>5</td>
<td>F_VIS</td>
<td>1 = Window is currently visible</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0 = Window is invisible</td>
</tr>
<tr>
<td>6</td>
<td>F_QCONTENT</td>
<td>1 = Return winContent even if window is inactive</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0 = Don’t return winContent if window is inactive</td>
</tr>
<tr>
<td>7</td>
<td>F_MOVE</td>
<td>1 = Title bar is a drag region</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0 = No drag region</td>
</tr>
<tr>
<td>8</td>
<td>F_ZOOM</td>
<td>1 = Zoom box on title bar</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0 = No zoom box (zoom box must have title bar)</td>
</tr>
<tr>
<td>9</td>
<td>F_FLEX</td>
<td>1 = GrowWindow and ZoomWindow won’t change the origin</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0 = GrowWindow and ZoomWindow will affect the origin</td>
</tr>
<tr>
<td>10</td>
<td>F_GROW</td>
<td>1 = Grow box</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0 = No grow box (grow box must have at least one scroll bar)</td>
</tr>
<tr>
<td>11</td>
<td>F_BSCRL</td>
<td>1 = Window frame horizontal scroll bar</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0 = No horizontal scroll bar</td>
</tr>
<tr>
<td>12</td>
<td>F_RSCRL</td>
<td>1 = Window frame vertical scroll bar</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0 = No vertical scroll bar</td>
</tr>
<tr>
<td>13</td>
<td>F_ALERT</td>
<td>1 = Alert type frame (don’t set grow box, close box, info bar, title bar, or scrolls)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0 = Standard frame</td>
</tr>
<tr>
<td>14</td>
<td>F_CLOSE</td>
<td>1 = Close box</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0 = No close box (close box must have title bar)</td>
</tr>
<tr>
<td>15</td>
<td>F_TITLE</td>
<td>1 = Title bar</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0 = No title bar</td>
</tr>
</tbody>
</table>
Parameter Blocks

Before an application makes a `NewWindow` call, it must set up a parameter block that spells out many details about the window. Listing 10–3 is a `NewWindow` parameter block used in the `WINDOW.SI` program. The fields in a window’s parameter block are described in table 10–3.

### Listing 10–3

Parameter block for a `NewWindow` call

```plaintext
WinOParamBlock anop
dc i'WinOEnd-WinOParamBlock'
dc i2'1101110110111000000' ; Bits describing frame
dc i4'WinOTitle' ; Pointer to title
dc i4'0' ; RefCon
dc i2'26,0,188,308' ; Full size (0=default)
dc i4'0' ; Color table pointer
dc i2'0' ; Vertical origin
dc i2'0' ; Horizontal origin
dc i2'200' ; Data area height
dc i2'320' ; Data area width
dc i2'200' ; Max cont height
dc i2'320' ; Max cont width
dc i2'2' ; No. of pixels to scroll vertically
dc i2'2' ; No. of pixels to scroll horizontally
dc i2'220' ; No. of pixels to page vertically
dc i2'32' ; No. of pixels to page horizontally
dc i4'0' ; Information bar text string
dc i2'0' ; Info bar height
dc i4'0' ; DefProc field
dc i4'0' ; Routine to draw info bar
dc i4'Paint0' ; Routine to draw content
dc i2'26,0,188,308' ; Size/position of content
dc i4'$FFFFFFF00' ; Plane to put window in
dc i4'0' ; Address for record (0=to allocate)
```

Before the `NewWindow` call returns, it creates a GrafPort for the window being set up and pushes a pointer to that GrafPort onto the stack. From that point, the application that created the window can treat it as a GrafPort. The application can draw into the window using QuickDraw II routines.

When the `NewWindow` call sets up a window, it uses the information passed in the window’s parameter block to create the window’s attributes. For example, the first field in the parameter block describes the window’s frame—using the bit layout illustrated in table 10–2—and the second field...
Table 10–3
Fields in a Window Parameter Block

<table>
<thead>
<tr>
<th>Field</th>
<th>Name</th>
<th>Length</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>paramLength</td>
<td>Word</td>
<td>Number of bytes in parameter table</td>
</tr>
<tr>
<td>2</td>
<td>wFrame</td>
<td>Word</td>
<td>Bit array describing window frame</td>
</tr>
<tr>
<td>3</td>
<td>wTitle</td>
<td>Pointer</td>
<td>Pointer to window’s title</td>
</tr>
<tr>
<td>4</td>
<td>wRefCon</td>
<td>Long</td>
<td>Reserved for application’s use</td>
</tr>
<tr>
<td>5</td>
<td>wZoom</td>
<td>Rect</td>
<td>Size and position of window when zoomed (0 = screen size)</td>
</tr>
<tr>
<td>6</td>
<td>wColor</td>
<td>Pointer</td>
<td>Pointer to window’s color table</td>
</tr>
<tr>
<td>7</td>
<td>wYOrigin</td>
<td>Word</td>
<td>Content’s vertical origin</td>
</tr>
<tr>
<td>8</td>
<td>wXOrigin</td>
<td>Word</td>
<td>Content’s horizontal origin</td>
</tr>
<tr>
<td>9</td>
<td>wDataH</td>
<td>Word</td>
<td>Height of entire document or pixel image</td>
</tr>
<tr>
<td>10</td>
<td>wDataW</td>
<td>Word</td>
<td>Width of entire document or pixel image</td>
</tr>
<tr>
<td>11</td>
<td>wMaxH</td>
<td>Word</td>
<td>Maximum height of content allowed by GrowWindow</td>
</tr>
<tr>
<td>12</td>
<td>wMaxW</td>
<td>Word</td>
<td>Maximum width of content allowed by GrowWindow</td>
</tr>
<tr>
<td>13</td>
<td>wScrollVer</td>
<td>Word</td>
<td>Number of pixels to scroll document vertically using scroll bar arrows</td>
</tr>
<tr>
<td>14</td>
<td>wScrollHor</td>
<td>Word</td>
<td>Number of pixels to scroll document horizontally using scroll bar arrows</td>
</tr>
<tr>
<td>15</td>
<td>wPageVer</td>
<td>Word</td>
<td>Number of pixels to scroll vertically using page control</td>
</tr>
<tr>
<td>16</td>
<td>wPageHor</td>
<td>Word</td>
<td>Number of pixels to scroll horizontally using page control</td>
</tr>
<tr>
<td>17</td>
<td>wInfoRefCon</td>
<td>Long</td>
<td>Value passed to information bar draw routine</td>
</tr>
<tr>
<td>18</td>
<td>wInfoHeight</td>
<td>Word</td>
<td>Height of information bar</td>
</tr>
<tr>
<td>19</td>
<td>wFrameDefProc</td>
<td>Pointer</td>
<td>Address of standard window definition procedure</td>
</tr>
<tr>
<td>20</td>
<td>wInfoDefProc</td>
<td>Pointer</td>
<td>Address of routine that draws information bar interior</td>
</tr>
<tr>
<td>21</td>
<td>wContDefProc</td>
<td>Pointer</td>
<td>Address of routine that draws content region interior</td>
</tr>
<tr>
<td>22</td>
<td>wPosition</td>
<td>Rect</td>
<td>Window’s starting position and size</td>
</tr>
<tr>
<td>23</td>
<td>wPlane</td>
<td>Long</td>
<td>Window’s starting plane (FFFFFFFF = frontmost)</td>
</tr>
<tr>
<td>24</td>
<td>wStorage</td>
<td>Pointer</td>
<td>Address of memory to use for window record (0 = don’t care)</td>
</tr>
<tr>
<td>25</td>
<td>paramLength</td>
<td>Word</td>
<td>Total number of bytes in parameter table, including this field</td>
</tr>
</tbody>
</table>
The IIGS Toolbox

contains the window’s title. In subsequent fields, the width and height of the window’s data areas and content areas are defined. A data area is a rectangle that encloses all the data a window can work with (for example, a pixel map). A content area is a rectangle enclosing the largest portion of the data area that may be displayed on the screen.

Some fields in a window’s parameter block duplicate fields in the window’s window record. When a window is created using a NewWindow call, the call uses information provided in the window’s parameter block to fill in the corresponding fields of the window’s window record.

One very important field in a window parameter block is the fourth field from the end of the block. This field contains a pointer to a routine that is used to draw the contents of the window each time the window is displayed on the screen. In the WINDOW.S1 program, the field looks like this:

\[
dc \quad i4'Paint0'; \quad \text{; Routine to draw content}
\]

The routine that paints a window must be written according to a specific format, and must end with the assembly language mnemonic rtl.

In the Paint0 segment of the WINDOW.S1 program, the QuickDraw call PPToPort copies the contents of a specific pixel map into the window used in the program. This pixel map is set up in a program segment called MakeWin0 and is accessed in the program by the pointer Pic0ptr.

The program segments MakeWin0 and Paint0 are in listing 10–5, the complete listing of the WINDOW.S1 program at the end of this chapter. Here is what happens in the segment of code labeled Paint0.

First, the Memory Manager call NewHandle reserves a 32K block of RAM—enough memory to hold a pixel map that is the size of one screen. The call returns with a handle to the requested block of data pushed onto the stack. This handle is then pulled off the stack and stored in a variable called Win0Handle. Later in the program, the Paint0 routine uses the block of data pointed to by Win0Handle to draw the contents of the program’s window on the screen.

When the handle called Win0Handle is assigned, a segment of code labeled Deref dereferences the handle (converts it into a pointer). The Deref routine also locks the handle being dereferenced so the Memory Manager can’t move the handle’s block of memory in the middle of an important operation, which could crash the program. Later, when the important operation is over, the Unlock routine unlocks the handle, enabling the Memory Manager to manage it again.

When Win0Handle is dereferenced, the pointer thus obtained is stored in a LocInfo data structure at the end of the WINDOW.S1 program in a field labeled Pic0Ptr. Then a NewWindow call creates a new window. To set the new window’s attributes, the NewWindow call uses the parameter block in listing 10–3.

As explained previously, the WINDOW.S1 program allows you to draw into a screen window and, at the same time, to draw into the pixel map that paints the window on the screen each time it is updated or redrawn. This is why sketches drawn with the WINDOW.S1 program do not vanish from
memory when a window is removed from the screen. Instead, they remain in RAM and can be redrawn into a window when it shows up again on the screen.

To make this technique possible, the WINDOW.S1 program creates a GrafPort that can be used to draw into the pixel map from which the program’s window is drawn. This GrafPort is set up in the NewPort program segment. For its LocInfo data, the new GrafPort uses the PicLocInfo data structure in the PortData data segment at the end of the program.

When the GrafPort that points to a pixel image is created, the WINDOW.S1 program clears the area of memory used for the pixel image with the BlkFill program segment. In this segment, the pen color is set to white and the QuickDraw call PaintRect clears the bit image to white. Later in the program, when the user asks for a new blank screen by making the menu choice New, the program uses the BlkFill routine to clear both the window port and the bit image port to white.

(Incidentally, the PaintRect call can be used to fill any block of RAM with any value, even in a nongraphics program. To “stuff” a block of memory, just pass to PaintRect the size of the area you want filled and the value you want it filled with. PaintRect does the rest—and you save the time and effort it would take to write a 65C816 block fill program.)

The WINDOW.S1 program, like every program that uses windows, has another GrafPort that is created by the Window Manager. When you use the Window Manager in a program, it always creates a special GrafPort that has the entire screen as its port rectangle. In all programs that use the Window Manager, this port is known as the Window Manager port. The Window Manager uses it to draw all windows, along with their scroll bars and other controls, on the IIGs screen.

The WINDOW.S1 program, like every program that uses windows, has another GrafPort that is created by the Window Manager. When you use the Window Manager in a program, it always creates a special GrafPort that has the entire screen as its port rectangle. In all programs that use the Window Manager, this port is known as the Window Manager port. The Window Manager uses it to draw all windows, along with their scroll bars and other controls, on the IIGs screen.

When the Window Manager draws or redraws a window, it always draws the window’s frame first. Then it draws the window’s contents.

During this process, the Window Manager manipulates regions of the Window Manager port as necessary to ensure that only what should be drawn is drawn. The Window Manager generates an update event to draw a window’s contents. But before an update event can take place, the Window Manager must accumulate, in the update region, the areas of the window’s content region that need updating.

In programs that use either TaskMaster or the Event Manager, the Event Manager periodically calls a routine called CheckUpdate to see if there is a window on the screen whose update region is not empty. If it finds one, it reports that an update event has occurred and passes a pointer to the window that needs updating in the event message field of its event record. If TaskMaster is used, it then updates the window as required. Programs that don’t use TaskMaster have to do the updating themselves. Obviously, it’s easier to use TaskMaster.

Some Window Manager routines can change the state of a window from inactive to active or from active to inactive. For each change, the Window Manager generates an activate event, passing along the window pointer in
the event message. The activeFlag bit in the modifiers field of the event record is set if the window becomes active and cleared if it becomes inactive.

When the Event Manager finds out from the Window Manager that an activate event has been generated, it passes the event to the application or TaskMaster through its getNextEvent routine. An activate event has the highest priority of any type of event, so when the Event Manager detects one it gets immediate action.

Usually, activate events are generated in pairs, because when one window becomes active another usually becomes inactive, and vice versa. Occasionally, however, a single activate event is generated, for example, when there is only one window in the window list or when an active window is closed permanently.

When a pair of activate events comes along, the Window Manager first generates the event for the window becoming inactive. It then generates the event for the window becoming active. In most applications, pairs of activate events are handled competently by TaskMaster. Rarely does an application program have to intervene.

Coordinates and the Window Manager

When NewWindow is called to create a window, it takes the window’s bounds rectangle from the LocInfo field of the window’s GrafPort. Thus, a window’s local coordinates begin in the upper left corner of the bounds rectangle specified in the LocInfo field of the window’s GrafPort. In a window’s global coordinate system, coordinate 0,0 is always assigned to the pixel in the upper left corner of the window’s bounds rectangle.

In the WINDOW.S1 program, the LocInfo record that defines the window’s bounds rectangle is titled PicOLocInfo. This record is in a data segment labeled PortData, which appears at the end of the program. The bounds rectangle defined in the PicOLocInfo record appears in the PicOFrame field. In the WINDOW.S1 program, therefore, the bounds rectangle assigned to the program’s window is the rectangle 0,0,200,320.

The global coordinates of a window are always based on a pixel image, specifically, the pixel image pointed to by the second field of the window’s LocInfo record. In a window’s global coordinate system, coordinate 0,0 is always assigned the pixel in the upper left corner of the window’s pixel image.

The pointer to the pixel image used in the WINDOW.S1 program is PicOPtr. This pointer is the second field in a LocInfo record called PicOLocInfo. The PicOLocInfo record is in a data segment called PortData, which appears at the end of the program.

The port rectangle of a window is a rectangle outlining the maximum portion of the window that can be displayed on the screen at any given time. If a window is partially hidden (for example, partly covered by another window or partly off the screen), the window’s visible region (VisRgn) is also used.
to determine how much of the window is visible on the screen. In the WINDOW.S1 program, the Window Manager takes care of VisRgnS automatically. But, as you shall see shortly, the program has to perform a few manipulations using port rectangles.

In programs like WINDOW.S1, coordinates often have to be converted from one system to another. Some QuickDraw and Window Manager routines use global coordinates, but others use local coordinates. For example, in the segment of the WINDOW.S1 program labeled MoveIt, TaskMaster returns mouse coordinates in global coordinates, and the Event Manager call GetMouse and the QuickDraw II call LineTo require local coordinates. For this reason, the QuickDraw call GlobalToLocal is used to convert the global coordinates returned by TaskMaster to the local coordinates required by other calls.

The MoveIt segment of the WINDOW.S1 program is the heart of the program. In this section, mouse movements are tracked and lines are drawn on the screen. TaskMaster detects the location of the IIGS mouse and returns it, in global coordinates, in the EventWhere field of its task record. The mouse location is then converted into local coordinates in these two lines:

```
PushLong #EventWhere
_GlobalToLocal
```

The GlobalToLocal call converts the global coordinates in the EventWhere record to local coordinates. After this conversion, the EventWhere field contains local coordinates, which can then be used by calls that require them. In the MoveIt segment, other conversions are taken care of by the StartDrawing and SetOrigin calls.

When a window is created, the upper left coordinate of its bounds rectangle are usually set to 0,0. Thus, in the local coordinate system used by a new window, the first pixel in its bounds rectangle is generally assigned the coordinate 0,0.

As you have seen, every window has both a port rectangle and a bounds rectangle. The intersection of a window’s bounds rectangle and port rectangle make up the largest possible area of the window that can be displayed on the screen.

Suppose a window has a bounds rectangle that starts at local coordinate 0,0 and is the same size as the screen. Let’s also suppose the window has a port rectangle that covers a smaller area in the middle of the screen. The coordinates of this port rectangle are 65,50 (the vertical coordinate is listed first). A bounds rectangle and a port rectangle that fit this description are illustrated in figure 10–3.

Now let’s assume you want to use the WINDOW.S1 program to draw a sketch in the window (that is, in the port rectangle) shown in figure 10–3. You first have to convert the mouse location returned by TaskMaster from global coordinates to local coordinates. But, because of the way the IIGS Window Manager works, you also have to reset the origin of the window’s
port rectangle; you have to change the value of the upper left corner of the port rectangle, as expressed in local coordinates.

This is why the port rectangle’s origin must be reset. When the Window Manager draws all the windows on a screen—complete with scroll bars, title bars, and all other necessary features—it uses a GrafPort that has the whole screen as its bounds rectangle. But before the Window Manager can draw the content region of a single window (for example, when the window has to be updated or redrawn), it has to switch to that window’s GrafPort and change the origin of the window’s port rectangle from its usual value of 0,0 to the value it had when it was a port rectangle in the Window Manager’s GrafPort, which uses the whole screen as its bounds rectangle.

The logic of this procedure is a little difficult to follow. After the origin of a window’s port rectangle is changed, the Window Manager can draw into the window, and the drawing ends up in the proper location on the screen.

When the Window Manager has finished drawing in a window, it must set the window’s origin back to 0,0 before it can leave the window’s port and return to its own GrafPort, so that it can regain the capability of drawing anywhere on the screen.

When the Window Manager has to draw in a window, it automatically carries out all the procedures just outlined. But when an application wants to draw in a window, it has to perform the same kinds of operations the Window Manager performs when it draws in a window.

To start drawing in a window, an application can use one of two approaches. It can either

- Make the QuickDraw call `SetPort` to make the window’s port the current port and then make the QuickDraw call `SetOrigin` with the proper parameters
- Make the Window Manager call `StartDrawing`, which carries out both of the previous steps automatically
The simpler approach is to use the `StartDrawing` call—and that is what is done in the WINDOW.S1 program.

After an application has finished drawing into a window, it must return the origin of the window’s port rectangle to its original state by making the QuickDraw call `SetOrigin` using parameters 0,0.

**Running the WINDOWS.S1 Program**

After the procedure for drawing into a window is understood, the operation of the WINDOW.S1 program becomes straightforward. The main part of the WINDOWS.S1 program is `MainProgram`. In this section, the tools used by the program are initialized, a menu is constructed, and the `MakeWindow` subroutine is called to create a window.

Next, the `NewPort` subroutine is called to set up a GrafPort used by the window’s pixel map. Then the `BlkFill` subroutine is called to clear the pixel map to white. (You could clear the screen to another color by simply replacing the color code $FF$ in the `BlkFill` routine with a different color code.)

When the window’s pixel image is cleared, the WINDOW.S1 program jumps to the `EventLoop` subroutine. This is the main event loop of the program. While the event loop is running, TaskMaster continuously looks for button down events. If TaskMaster detects a button down event, the program uses a jump table labeled `TaskTable` to determine what should be done.

If TaskMaster reports a menu event, the table called `TaskTable` sends the program to the `doMenu` subroutine. It is up to `doMenu` to carry out an appropriate response to the user’s menu selection. Depending upon the menu choice, the `doMenu` routine can either call the `Repaint` subroutine to draw a new window, call the `doWin0` subroutine to redraw a window, or jump to the `doQuit` subroutine to end the program.

If a window event is detected, TaskMaster takes care of all routine window-related operations, such as scrolling the window or changing its size. If TaskMaster detects a button down event in the window’s go-away box, the program jumps to a short subroutine titled `doGoAway`, which hides the window. If TaskMaster reports a button down event in the window’s content region, the program jumps to the `MoveIt` subroutine, which enables the user to draw in the window.

The `MoveIt` routine, as noted, is the heart of the WINDOW.S1 program. In this segment of code, as long as the mouse is inside a window and the mouse button is down, the QuickDraw call `LineTo` draws a line on the screen tracing the mouse’s movements. When the mouse button is released, the mouse’s movements are still followed, but the tracing is done using the `MoveTo` call rather than the `LineTo` call, so no line is drawn on the screen.

You can clear the window at any time by making the menu selection `New`. You can temporarily hide the window being drawn by clicking the mouse in the window’s go-away region. If a window is hidden, but is not erased with a click in the menu item `New`, you can bring the window back.
into view by making the menu selection Untitled (for now, the title of the window). After New is selected, however, the window is permanently erased and cannot be retrieved from memory.

Other Features of WINDOW.S1

The WINDOW.S1 program has some new features that should be mentioned before you conclude this chapter. One is the InsertSysDisk subroutine, which is called from the ToolInit program segment. The other new and noteworthy feature is a macro called ErrorCheck, which is also called from the ToolInit segment of the program.

The InsertSysDisk subroutine is called when the WINDOW.S1 program tries to load the tools it needs and finds that the IIgs system disk—on which some tools are stored—is not currently in the computer’s disk drive. When this condition is detected, InsertSysDisk is called and prints a message on the screen asking the user to insert the system disk in the disk drive.

The ErrorCheck macro is called following several critical routines, such as the loading of essential tools. If the calling of a vital routine is aborted by an error, the ErrorCheck macro ends the program. A system failure message—a rolling-Apple symbol accompanied by an error message and an error number—is displayed on the screen.

InsertSysDisk Routine

To see how the InsertSysDisk routine works, look through the ToolInit segment for the label LoadEmUp. Study the code that follows the labels LoadEmUp and DoInsertDisk, and you'll see that this section of code forms a loop. When the program comes to the LoadEmUp label, it makes the Tool Locator call LoadTools to load all the tools used in the program. The LoadTools call, like most Toolbox calls, uses a specific convention for detecting errors. If the call is completed successfully, without an error, it returns with the P register's carry flag clear and a value of 0 in the accumulator. If an error is encountered in making the call, however, the call returns with the carry bit set and an error number in the accumulator.

In the WINDOW.S1 program, if the LoadTools call returns without an error, the program jumps a few lines to a section of code labeled ToolsLoaded and the tools that have been loaded start up normally. If the call returns with the carry set and the number 45 in the accumulator, however, the program jumps to the DoInsertDisk subroutine, which prints a message on the screen asking the user to insert the IIgs system disk (which contains some of the tools used by the computer). If the user complies and the necessary tools are found, the program proceeds normally. If this doesn't solve the problem, the program ends and a system failure message is displayed.
To end programs and display system-death messages after fatal errors occur, the WINDOW.S1 program uses the **ErrorCheck** macro. Several calls to the **ErrorCheck** macro appear in the **ToolInit** segment of the WINDOW.S1 program.

The **ErrorCheck** macro appears in listing 10-4. To use it in your programs, type it into a macro file and add it to your library of macros using APW's **MACGEN** shell command.

```
Listing 10-4
ErrorCheck

MACRO
&lab ErrorCheck &msg
&lab bcc end&syscnt
pea x&syscnt|'-16
pea x&syscnt
ldx #$1503
jsl $E10000
x&syscnt str "&msg"
end&syscnt anop
MEND
```

**The WINDOW.S1 and INITQUIT.S1 Programs**

The WINDOW.S1 program, like the C language programs in the last few chapters, is divided into two parts: WINDOW.S1 and INITQUIT.S1. The WINDOW.S1 program, listing 10-5, and the INITQUIT.S1 program, listing 10-6, are at the end of this chapter.

Splitting a program into two or more parts can save a considerable amount of typing. For example, INITQUIT.S1—the portion of the program that loads, starts up, and shuts down tools—is also used in sample programs in chapters 11 and 12.

In programs written using the APW assembler-editor package, it’s easy to divide a program into sections and then put all the sections together again at assembly time. All you have to do is type each section, save it as a separate source code file, and then combine the files you have saved using the APW assembler directive **COPY**. Look at the end of the WINDOW.S1 program in listing 10-5, and you’ll see that the last line of the listing is

```
COPY INITQUIT.S1
```

When the APW assembler reaches that line, it starts assembling INITQUIT.S1 and adds it to WINDOW.S1, just as if the two listings were a single listing. Furthermore, any number of **COPY** directives can appear at the end of a source code listing. So you can add many modules to an APW program by using the **COPY** directive.
The WINDOW.C and INITQUIT.C Programs

The WINDOW.C program, listing 10–7, is a C language version of WIN-
DOW.S1. It is designed to be used with the INITQUIT.C program, listing
10–8, which performs the same functions as INITQUIT.S1 and was intro-
duced in chapter 9. The WINDOW.C and INITQUIT.C programs appear at
the end of this chapter.

WINDOW.C and INITQUIT.C are combined into one program with
the statement

```
#include "initquit.c"
```

This statement is in the first line of the WINDOW.C program.

There are significant differences between WINDOW.C and its assembly
language equivalent, WINDOW.S1. In WINDOW.C, for example, the
`SketchO` function, which draws on the screen, is simplified. It uses the
function `StartDrawingO` just once, then it uses `SetPortO` thereafter.
This is a more streamlined way to write the `SketchO` routine in C, but the
method used in WINDOW.S1 works better in assembly language. Experiment
and you'll see why.

In WINDOW.C, the `ErasePicO` function, which is called `repaint`
in WINDOW.S1, is also simplified. Instead of completely dismantling a win-
dow environment and then rebuilding it (the technique used in WINDOW.S1)
the `ErasePicO` function keeps the window’s environment, but simply
erases what is in it. Because of differences in the way in which WINDOW.S1
and WINDOW.C work, this is another approach that works well in C, but
the technique used in WINDOW.S1 works better in assembly language.

WINDOW.S1 and INITQUIT.S1 Listings

Listing 10–5
WINDOW.S1 program

```
*•
* WINDOW.S1
*

*** A FEW ASSEMBLER DIRECTIVES ***

Title 'Window'
ABSADDR on
LIST off
SYMBOL off
65816 on
`mcopy window.macros`

KEEP window
```
*  * EXECUTABLE CODE STARTS HERE  *
*  
Begin START
Using QuitData

jmp MainProgram ; skip over data

END

*  * SOME DIRECT PAGE ADDRESSES AND A FEW EQUATES  *
*

DPData START

DPTemp gequ $00
DPPPointer gequ DPTemp+4
DPHandle gequ DPPPointer+4

ScreenMode gequ $00 ; 320 mode
MaxX gequ 320 ; X clamp high

True gequ $8000
False gequ $00

END

*  * MAIN PROGRAM LOOP  *
*

MainProgram START
Using GlobalData
Using PortData

phk plb tdc ; get current direct page
sta MyDP ; and save it for the moment

jsr ToolInit ; start up all tools we'll need
jsr BuildMenu ; create and draw menu bar
jsr MakeWin0 ; create empty window
*** OPEN A PORT SO WE CAN DRAW IN WINDOW'S PIXEL MAP ***

```
jsr NewPort

lda #PicOPort
sta BlkToFill
lda #PicOPort
sta BlkToFill+2

jsr BlkFill
```

*** LINE THAT JUMPS TO THE EVENT LOOP ***

```
jsr EventLoop ; check for key & mouse events
```

*** WHEN EVENT LOOP ENDS, WE'LL SHUT DOWN ***

```
jsr Shutdown
jmp Endit

END
```

*  
* EVENT LOOP  
* 

```
EventLoop  START
Using QuitData
Using TaskTable
Using EventData

Again    anop
PushWord #0  ; space for result
PushWord #$FFFF  ; recognize all events
PushLong #EventRecord
_TaskMaster
pla
asl a  ; code * 2 = table location
tax  ; X is index register
jsr (TaskTable,x)  ; look up event's routine
lda QuitFlag
beq again

rts

END
```
* ROUTINE TO DRAW SKETCHES ON THE SCREEN *

MoveIt

START
Using EventData
Using GlobalData
Using PortData

PushLong TaskData
  _StartDrawing
PushLong #RectPtr
  _GetPortRect
PushLong #EventWhere  ; convert them to
  _GlobalToLocal  ; local coordinates
PushLong EventWhere  ; move cursor to mouse location
  _MoveTo

pea 0
pea 0
  _SetOrigin

PushLong #PicOPort
  _SetPort

PushLong #RectPtr
  _ClipRect

PushLong EventWhere
  _MoveTo

loop

  pea 0
  pea 0
  _StillDown
  pla
  beq out

  lda TaskData+2
  pha
  lda TaskData
  pha
  _StartDrawing

  lda #EventWhere
  pha
  lda #EventWhere
  pha
  _GetMouse
lda EventWhere+2
pha
lda EventWhere
pha
_LINETo
pea 0
pea 0
_SETOrigin
lda #PicOPort
pha
lda #PicOPort
pha
_SETPort
lda EventWhere+2
pha
lda EventWhere
pha
_LINETo
brl loop
out
anop
rts

RectPtr ds 8

END

* * REPAINT: MAKE NEW EMPTY WINDOW *

Repaint START
Using PortData
Using WindowData
Using GlobalData

PushLong #0
_SETPort
PullLong ThisPortPtr

PushLong #PicOPort
_SETPort

PushLong #ScreenRect
_ClipRect

lda #PicOPort
sta BlkToFill
lda #PicOPort
sta BlkToFill+2

jsr BlkFill

PushLong ThisPortPtr
_SetPort

PushLong WinOPtr
_HIDEWindow

PushLong WinOPtr
_CloseWindow

PushLong PicOHandle
_DisposeHandle

jsr MakeWin0
jsr doWin0

rts

ThisPortPtr   ds 4
ScreenRect    dc '0,0,200,320'

END

NewPort      START
Using GlobalData
Using PortData

PushLong #0   ; space for result
_GetPort
PullLong OrigPortPtr ; save pointer to current port

PushLong #PicOPort ; pointer to new port
_OpenPort       ; open a port for pixel map

PushLong #PicOPort ; make new port the current
_SetPort        ; port (temporarily)

PushLong #ScreenRect
_ClipRect
PushLong #PicOLocInfo ; set up loc info for new port
_SetPortLoc
PushLong OrigPortPtr ; make original port
_SetPort ; the current port again
rts

ScreenRect dc '0,0,200,320'
END

* * CREATE AND DRAW A WINDOW *
*

MakeWinO START
using GlobalData
using WindowData
using PortData

*** SET HANDLE FOR PIC 0 (new) ***

PushLong #$00
PushLong #$8000 ; 32K (one screen)
PushWord MyID
PushWord #$C000 ; locked and fixed
PushLong #0
_NewHandle

ErrorCheck 'Could not get handle.'
pla
sta PicOHandle
pla
sta PicOHandle+2

*** DEREF HANDLE, CLEAR MEMORY, AND CREATE POINTER ***

lda PicOHandle ; lock and deref PicOHandle
ldx PicOHandle+2 ; while we do our thing with it
jsr Deref
sta PicOPtr ; deref gives us a pointer
stx PicOPtr+2 ; to PicOHandle's pixel map
* ; so we'll save it
*** SET UP WINDOW 0 ***

```
PushLong #0 ; space for result
PushLong #WinOParamBlock
    _NewWindow

    pla
    sta WinOPtr
    pla
    sta WinOPtr+2

    rts

END
```

* DoWin0

* Selects and shows window 0 (blank) in response to menu selection.

```
DoWin0   START
    using GlobalData
    using WindowData

    PushLong WinOPtr
    _SelectWindow

    PushLong WinOPtr
    _ShowWindow

    rts

END
```

* PaintO

* Draws empty window when TaskMaster calls.

```
PaintO   START
    using GlobalData
    Using PortData
    using WindowData

    phb
    phk
    plb

    phd
    lda MyDP
```
The Ilgs Toolbox

tcd

PushLong #PicOLocInfo
PushLong #PicOFrame
PushWord #0
PushWord #0
PushWord #0
_PPToPort

pld
plb
rtl

END

*** BLOCK FILL ROUTINE ***

BlkFill

START
Using GlobalData
Using WindowData
Using PortData

PushLong #0
_GetPort
PullLong OrigPortPtr

PushLong BlkToFill
_SetPort

PushWord #$FF
_SetSolidPenPat

PushLong #ARect
_PaintRect

_PenNormal

PushLong OrigPortPtr
_SetPort

rts

OrigPortPtr  ds 4
ARect     dc '0,0,200,320'

END
* CREATE AND DRAW MENU *

**BuildMenu**

```plaintext
BuildMenu START
    using MenuData ; proceeding from back to front
    PushLong #0 ; space for return
    PushLong #Menu3
    _NewMenu
    PushWord #0
    _InsertMenu
    PushLong #0 ; space for return
    PushLong #Menu2 ; 'wait' screen menu bar
    _NewMenu
    PushWord #0
    _InsertMenu
    PushLong #0 ; space for return
    PushLong #Menu1
    _NewMenu
    PushWord #0
    _InsertMenu
    PushWord #0 ; init & draw the menu bar
    _FixMenuBar pla
    _DrawMenuBar
    rts
END
```

* DoMenu *

**Called when TaskMaster tells us a new menu item is selected.** *

**DoMenu**

```plaintext
DoMenu START
    Using TaskTable
    Using EventData
    Using MenuTable
    lda TaskData
    cmp #256
    bcc GiveUp ; this should never happen
```
and #$00FF
asl a
tax

jsr (MenuTable,x)

GiveUp anop
PushWord #False ; draw normal
PushWord TaskData+2 ; which menu
_HiliteMenu

rts

END

* * InsertSysDisk
* This routine is called when tools need to be loaded and the
* system disk is offline. Routine asks user to insert system disk.
*

InsertSysDisk START

_SetPrefix SetPrefixParams
_GetPrefix GetPrefixParams

PushWord #0 ; space for result
PushWord #195 ; x pos
PushWord #30 ; y pos
PushLong #PromptStr ; prompt string
PushLong #VolStr ; vol string
PushLong #OKStr
PushLong #CancelStr
_TLMountVolume

pla

rts

PromptStr str 'Please insert the disk'
VolStr ds 16
OKStr str 'OK'
CancelStr str 'Shutdown'

GetPrefixParams dc i'7'

276
dc i4'VolStr'

SetPrefixParams dc i'7'
dc i4'BootStr'

BootStr str '*/'

END

* * WINDOW GO-AWAY ROUTINE *
*

doGoaway START
Using EventData

PushLong TaskData
HideWindow
rts

END

* * A USEFUL AND CONVENIENT WAY NOT TO DO ANYTHING *
*

Ignore START

rts

END

* * Deref *
* Derefs the handle passed in a and x registers.
* Result passed back in a and x registers.
*

Deref START
sta DPTemp
stx DPTemp+2
ldy #2
lda [DPTemp],y
tax
lda [DPTemp]
rts

END
*  
  *  DATA SEGMENTS  
  *  
  
  *  Menu Data  
  *  

MenuData     DATA

Return           equ 13  

Menu1           dc c'"> L@\XN1',i'RETURN'  
                 dc c'"> LA Window Program \N257',i'RETURN'  
                 dc c'.

Menu2           dc c'"> L File \N2',i'RETURN'  
                 dc c'"> LNew \N258V',i'RETURN'  
                 dc c'"> LQuit \N259',i'RETURN'  
                 dc c'.

Menu3           dc c'"> L Windows \N3',i'RETURN'  
                 dc c'"> LUntitled \N260',i'RETURN'  
                 dc c'.

***

MenuTable     DATA

*  
  Menu 1 (apple)  
  dc i'ignore' ; one for the NDAs  
  dc i'ignore' ; 'a window program'

*  
  Menu 2 (file)  
  dc i'Repaint' ; 'doWinO' (new window)  
  dc i'Quit' ; quit item selected

*  
  Menu 3 (windows)  
  dc i'WinO' ; 'untitled'

END
***

TaskTable DATA

dc i'ignore' ; 0 null
dc i'ignore' ; 1 mouse down
dc i'ignore' ; 2 mouse up
dc i'ignore' ; 3 key down
dc i'ignore' ; 4 undefined
dc i'ignore' ; 5 auto-key down
dc i'ignore' ; 6 update event
dc i'ignore' ; 7 undefined
dc i'ignore' ; 8 activate
dc i'ignore' ; 9 switch
dc i'ignore' ; 10 desk acc
dc i'ignore' ; 11 device driver
dc i'ignore' ; 12 application
dc i'ignore' ; 13 application
dc i'ignore' ; 14 application
dc i'ignore' ; 15 application
dc i'ignore' ; 0 in desk

* TaskMaster events *

* 

dc i'DoMenu' ; 1 in menu bar
dc i'ignore' ; 2 in system window
dc i'MoveIt' ; 3 in content of window (MoveIt)
dc i'ignore' ; 4 in drag
dc i'ignore' ; 5 in grow
dc i'doGoAway' ; 6 in go-away
dc i'ignore' ; 7 in zoom
dc i'ignore' ; 8 in info bar

dc i'ignore' ; 9 in ver scroll
dc i'ignore' ; 10 in hor scroll
dc i'ignore' ; 11 in frame
dc i'ignore' ; in drop

END

***

ToolTable DATA

dc i'B' ; number of tools in table
dc i'$04,$0100' ; quickdraw
The IIGS Toolbox

dc i'$06,$0100' ; event manager
dc i'$0E,$0000' ; window manager
dc i'$0F,$0100' ; menu manager
dc i'$10,$0100' ; control manager
dc i'$14,$0000'
dc i'$15,$0000'
dc i'$17,$0000' ; std file manager
END

***
EventData DATA

EventRecord anop ; table for Event Manager
EventWhat ds 2
EventMessage ds 4
EventWhen ds 4
EventWhere ds 4
EventModifiers ds 2
TaskData ds 4
TaskMask dc i'$OFFF'
END

***
QuitData DATA

QuitFlag ds 2
QuitParams dc i'$0'
dc i'$0'
dc i'$0'
dc i'$0'
END

***
WindowData DATA

PicOHandle ds 4
WinOPtr ds 4
WinOTitle str 'Untitled'

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WinOParamBlock anop

    dc  i'WinOEnd-WinOParamBlock'
    dc  i2'1101110111000000'
    ; Bits describing frame
    dc  i4'WinOTitle'
    ; Pointer to title
    dc  i4'0'
    ; RefCon
    dc  i2'26,0,188,308'
    ; Full Size (0= default)
    dc  i4'0'
    ; Color Table Pointer
    dc  i2'0'
    ; Vertical origin
    dc  i2'0'
    ; Horizontal origin
    dc  i2'200'
    ; Data Area Height
    dc  i2'320'
    ; Data Area Width
    dc  i2'200'
    ; Max Cont Height
    dc  i2'320'
    ; Max Cont Width
    dc  i2'2'
    ; No. of pixels to scroll vertically
    dc  i2'2'
    ; No. of pixels to scroll horizontally
    dc  i2'20'
    ; No. of pixels to page vertically
    dc  i2'32'
    ; No. of pixels to page horizontally
    dc  i4'0'
    ; Information bar text string
    dc  i2'0'
    ; Info bar height
    dc  i4'0'
    ; DefProc
    dc  i4'0'
    ; Routine to draw info bar
    dc  i4'Paint0'
    ; Routine to draw content
    dc  i2'26,0,188,308'
    ; Size/position of content
    dc  i4'$FFFFFFFF'
    ; Plane to put window in
    dc  i4'0'
    ; Address for window record (0 to allocate)

* WinOEnd  anop

END

***

GlobalData DATA

BlkToFill ds 4

MyID    dc  i'0'
; program ID word
MyDP    ds 2

BlockSize ds 4
FilVal ds 2

END
***
PortData DATA

OrigPortPtr ds 4 ; pointer to original port
PicOPort ds $AA
PicOLocInfo dc i'00' ; 320 mode
PicOPtr ds 4 ; MakeWinO fills this in
dc i'160' ; width
PicOFrame dc i'0,0,200,320' ; pic image frame rect

* *  IOData *
* IOData DATA

ReplyRecord anop
GoodFlag ds 2
FType dc i'193' ; $c1
AuxFType dc i'0' ; #0
FName ds 15
FullPathName ds 128

CreateParams anop
NameC dc i'40'
dc i2'$00C3' ; DRNWR
CTYPE dc i2'$00C1' ; super high-res graphics
CAux dc i4'$00000000'

dc i2'$0001' ; type
dc i2'$0000' ; create date
dc i2'$0000' ; create time

DestParams anop
NameD dc i'40'

OpenParams anop
OpenID ds 2
NamePtr ds 4
ds 4

ReadParams anop
ReadID ds 2
PicDestIN ds 4
dc i4'$8000' ; this many bytes
ds 4 ; how many xferred

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COPY INITQUIT.S1

Listing 10–6
INITQUIT.S1 program

*  
* INITQUIT.S1: WHERE WE INITIALIZE OUR TOOLS  
*  
ToolInit  
START  
Using GlobalData  
Using ToolTable  

*** START UP TOOL LOCATOR ***

_TOStartup ; Tool Locator  

*** INITIALIZE MEMORY MANAGER ***

PushWord #0  
_MMStartup  
ErrorCheck 'Could not init Memory Manager.'  

pla  
sta MyID  

*** INITIALIZE MISC. TOOL SET ***

_MTStartup  
ErrorCheck 'Could not init Misc Tools.'  

*** GET SOME DIRECT PAGE MEMORY FOR TOOLS THAT NEED IT ***

PushLong #0 ; space for handle  
PushLong #$800 ; eight pages
PushWord MyID
PushWord #$C001 ; locked, fixed, fixed bank
PushLong #0

NewLabel

ErrorCheck 'Could not get direct page.'

pla
sta DPHandle
pla
sta DPHandle+2

lda [DPHandle]
sta DPPointer

*** INITIAlize QuickDraw ii ***

lda DPPointer ; pointer to direct page
pha
PushWord #ScreenMode ; either 320 or 640 mode
PushWord #160 ; max size of scan line
PushWord MyID

_QDStartup

ErrorCheck 'Could not start QuickDraw.'

*** INITIAlize Event Manager ***

lda DPPointer ; pointer to direct page

clc
adc #$300 ; QD direct page + #$300
pha ; (QD needs 3 pages)
PushWord #20 ; queue size
PushWord #0 ; X clamp low
PushWord #MaxX ; X clamp high
PushWord #0 ; Y clamp low
PushWord #200 ; Y clamp high
PushWord MyID

_EMStartup

ErrorCheck 'Could not start Event Manager.'

*** Load SOME TOOLS from RAM ***

LoadEmUp

PushLong #ToolTable
_LoadTools
bcc ToolsLoaded

 cmp #$45 ; prodos error: vol not found
beq doInsertDisk
DoInsertDisk

    anop
    jsr InsertSysDisk
    cmp #1
    beq LoadEmUp
    sec
    ErrorCheck 'Could not load tools.'

*** WINDOW MANAGER ***

ToolsLoaded

    PushWord MyID
    _WindStartup
    ErrorCheck 'Could not Start Window Manager.'

    PushLong #$0000
    _Refresh

*** CONTROL MANAGER ***

    PushWord MyID
    lda DPPointer ; DP to use = qd dp + $400
    clc
    adc #$400
    pha
    _CtlStartup
    ErrorCheck 'Could not start Control Manager.'

*** MENU MANAGER ***

    PushWord MyID
    lda DPPointer ; DP to use = qd dp + $500
    clc
    adc #$500
    pha
    _MenuStartup
    ErrorCheck 'Could not start Menu Manager.'

    _ShowCursor

*** LINE EDIT ***

    PushWord MyID
    lda DPPointer
    clc
    adc #$600 ; qd dp + $600
    pha
The Ilgs Toolbox

_LEStartup
  errorcheck 'Could not start up Line Edit.'

*** DIALOG MANAGER ***

  PushWord MyID
  _DialogStartup
  errorcheck 'Could not start Dialog Manager.'

*** STANDARD FILE MANAGER ***

  PushWord MyID
  lda DPPPointer
  clc
  adc #$700 ; qd dp + $700
  pha
  _SFStartup
  errorcheck 'Could not start up SF Manager.'

  rts

END

* *
* THE ROUTINE THAT ENDS THE PROGRAM *
*

EndIt START

  Using QuitData

  _Quit QuitParams

*** A QUIT CALL SHOULDN'T RETURN; IF IT DOES, WE'RE FINI ***

  ErrorCheck 'We returned from a quit call!'

END

* *
* SHUT DOWN ALL THE TOOLS WE STARTED UP *
*

ShutDown START

  Using GlobalData
  Using WindowData

  _SFShutdown
DialogShutdown
_LENGTHUTDOWN
_MENUShutDown
_CTLShutDown
_WINDShutDown
_EMShutDown
_QDShutDown
_MTShutDown

PushLong DPHandle
_DisposeHandle

PushLong PicOHANDLE
_DisposeHandle

PushWord MyID
_MMShutDown
_TLShutDown

rts

END

*  ROUTINE THAT SETS THE QUIT FLAG
*

doQuit

START
Using QuitData

lda #$8000
sta QuitFlag
rts

END

WINDOW.C and INITQUIT.C Listings

Listing 10–7
WINDOW.C program

#include "initquit.c"

**********************************************************
/* Data and routine to create menus */
/* *************************************************************/

287
/* Set up menu strings. Because C uses \ as an escape character, we use two when we want a \ as an ordinary character. The \ at the end of each line tells C to ignore the carriage return. This lets us set up our items in an easy-to-read vertical alignment. */

char *menu1 = "\n>LA Window Program \n\n\n",
char *menu2 = "\n>File \nLNew \nLQuit \n",
char *menu3 = "\n>Windows \nLUntitled \n",

#define QUIT_ITEM 259 /* these will help us check menu item numbers */
#define QUIT_ITEM 259 /* these will help us check menu item numbers */
#define NEW_ITEM 258
#define UNTIT_ITEM 260

BuildMenu()
{
    InsertMenu(NewMenu(menu3),0);
    InsertMenu(NewMenu(menu2),0);
    InsertMenu(NewMenu(menu1),0);
    FixMenuBar();
    DrawMenuBar();
}

/* Data structures and routine to set up offscreen drawing environment */
LocInfo picOLocInfo = {
    mode320,
    NULL, /* space for pointer to pixel image */
    160, /* width of image in bytes = 320 pixels */
    0,0,200,320 /* frame rect */
};
Rect screenRect = {0,0,200,320};
GrafPort picOPort;
#define IMAGE_ATTR attrLocked+attrFixed+attrNoCross+attrNoSpec+attrPage

PicOSetup() /* called once by MakeWindow at start of program */
{
    GrafPortPtr thePortPtr;

    picOLocInfo.ptrToPixImage = *(NewHandle(0x8000L,myID,IMAGE_ATTR,NULL));
    thePortPtr = GetPort();
    OpenPort(&picOPort);
    SetPort(&picOPort);
    SetPortLoc(&picOLocInfo);
    ClipRect(&screenRect);
    EraseRect(&screenRect);
    SetPort(thePortPtr);
}

/**************************************************************/
/* Data structures and routine to create window */
/**************************************************************/

/* Initialize template for NewWindow */

#define FRAME fQContent+fMove+fZoom+fGrow+fBSscroll+fRSscroll +fClose+fTitle

ParamList template = { sizeof (ParamList),
    FRAME,
    "\pUntitled", /* pointer to title */
    0L, /* RefCon */
    26,0,188,308, /* full size (O=default) */
    NULL, /* use default ColorTable */
    0,0, /* origin */
    200,320, /* data area height & width */
    200,320, /* max cont height & width */
    2,2, /* ver & hor scroll increment */
    20,32, /* ver & hor page increment */
    NULL, /* no info bar text string */
    0, /* info bar height = none */
    NULL, /* default def proc */
    NULL, /* no info bar draw routine */
    NULL, /* draw content must be filled in */
    at run time */
    26,0,188,308, /* starting content rect */
    -1L, /* topmost plane */
    NULL /* let window manager allocate record */
}
The Ilas Toolbox

/* Window's draw content routine */
pascal void DrawContent()
{
    PPToPort(&picOLocInfo,(picOLocInfo.boundsRect),O,O,modeCopy);
}

GrafPortPtr winOPtr;

MakeWindow() /* complete template, make (the window,
and setup offscreen port */
{
    template.wContDefProc = DrawContent;
    winOPtr = NewWindow(&template);
    PicOSetup(); /* create offscreen image for use by DrawContent */
}

********************************************************************************
/* Main routine. Set up environment, call eventloop, and shut down */
********************************************************************************
main()
{
    StartTools();
    BuildMenu();
    MakeWindow();
    EventLoop();
    DisposeHandle(FindHandle(picOLocInfo.ptrToPixImage));
    ShutDown();
}

********************************************************************************
/* Event loop and supporting routines */
********************************************************************************
WmTaskRec myEvent;
Boolean done = false;

EventLoop()
{
    myEvent.wmTaskMask = 0xFFF;
    while(!done)
    {
        switch ( TaskMaster(everyEvent,&myEvent)) {
            case wInMenuBar:
                DoMenus();
                break;
            case wInGoAway:
                HideWindow(winOPtr);
                break;
            case wInContent:
                Sketch();
        }
    }
}
DoMenus()
{
    Word *data = (Word *)&myEvent.wmTaskData; /* address of item id */

    switch(*data) {
        case QUIT_ITEM:
            done = true;
            break;
        case NEW_ITEM:
            ErasePicO();
            HideWindow(winOPtr);
            CloseWindow(winOPtr);
            winOPtr = NewWindow(&tempLate);
        case UNTIL_ITEM:
            SelectWindow(winOPtr);
            ShowWindow(winOPtr);
            break;
    }
    HiliteMenu(false,(data + 1)); /* data + 1 is address of menu id */
}
ErasePicO()
{
    GrafPortPtr oldPortPtr;

    oldPortPtr = GetPort();
    SetPort(&picOPort);
    ClipRect(&screenRect);
    EraseRect(&screenRect);
    SetPort(oldPortPtr);
}
Sketch() /* sketch into current port and into offscreen port */
{
    Point mouseLoc;
    GrafPortPtr thePortPtr = (GrafPortPtr)myEvent.wmTaskData;
    Rect theRect;

    mouseLoc = myEvent.wmWhere;

    StartDrawing(thePortPtr); /* set up correct drawing coordinate system */
    GetPortRect(&theRect); /* copy current Port Rect */
    GlobalToLocal(&mouseLoc); /* get cursor pos in local coordinates */
The JIGS Toolbox

MoveTo(mouseLoc);        /* set pen position to mouse loc */
SetPort(&picOPort);       /* switch to offscreen port */
ClipRect(&theRect);       /* clip offscreen drawing to window's
port rect */
MoveTo(mouseLoc);         /* set offscreen pen to same location */
SetPort(thePortPtr);      /* switch back to window's port */

while (StillDown(O)) {
    GetMouse(&mouseLoc);   /* get new mouse coordinates */

    LineTo(mouseLoc);      /* draw line in both ports */
    SetPort(&picOPort);
    LineTo(mouseLoc);
    SetPort(thePortPtr);
}

SetOrigin(0,0);           /* restore normal coordinates */

Listing 10-8
INITQUIT.C program

#include <TYPES.H>
#include <LOCATOR.H>
#include <MEMORY.H>
#include <MISCTOOL.H>
#include <QUICKDRAW.H>
#include <EVENT.H>
#include <CONTROL.H>
#include <WINDOW.H>
#include <MENU.H>
#include <LINEEDIT.H>
#include <DIALOG.H>

#define MODE mode320      /* 640 graphics mode def. from quickdraw.h */
#define MaxX 320           /* max X for cursor (for Event Mgr) */
#define dpAttr attrLocked+attrFixed+attrBank /* for allocating direct page
space */

int myID;                /* for Memory Manager */
int Handle zp;           /* handle for page 0 space for tools */

int ToolTable[] = {7,
    4, 0x0100, /* QD */
    6, 0x0100, /* Event */
    14, 0x0100, /* Window */
    16, 0x0100, /* Control */
    15, 0x0100, /* Menu */
};
20, 0x0100, /* Line Edit */
21, 0x0100, /* Dialog */
};

StartTools() /* start up these tools: */
{
    TLStartUp(); /* Tool Locator */
    myID = MMStartUp(); /* Mem Manager */
    MTStartUp(); /* Misc Tools */
    LoadTools(ToolTable); /* load tools from disk */
    ToolInit(); /* start up the rest */
}

ToolInit() /* init the rest of needed tools */
{
   zp = NewHandle(0x700L, myID, dpAttr, OL); /* reserve 6 pages */

    QDStartUp((int) *zp, MODE, 160, myID); /* uses 3 pages */
    EMStartUp((int) (*zp + 0x300), 20, 0, MaxX, 0, 200, myID);
    WindStartUp(myID);
    RefreshDesktop(NULL);
    CtlStartUp(myID, (int) (*zp + 0x400));
    MenuStartUp(myID, (int) (*zp + 0x500));
    LEStartUp(myID, (int) (*zp + 0x600));
    DialogStartUp(myID);
    ShowCursor();
}

ShutDown() /* shut down all of the tools we started */
{
    GrafOff();
    DialogShutDown();
    LEShutDown();
    MenuShutDown();
    CtlShutDown();
    WindShutDown();
    EMShutDown();
    QDShutDown();
    MTShutDown();
}
DisposeHandle(zp); /* release our page 0 space */
MMSHutDown(myID);
TLMShutDown();
The main channel of communication between the Apple IIgs and its user is handled by a tool set known as the Dialog Manager. When a program needs to inform the user of something important or give the user guidance—or when a program needs to obtain information from the user—the Dialog Manager provides the interface between computer and user.

The Dialog Manager communicates with the IIgs user through dialog windows—boxes that are usually programmed to appear on the screen when they are needed. Dialog windows can display messages, obtain user input, or both. They can contain icons, pictures, text, and user-operated controls. Some icons can stay on the screen for a long time and can be moved around. Others remain in one spot until they are deactivated and then go away as quickly as they appeared.

In this chapter, you'll take a look at various kinds of dialog windows, and you'll see how dialogs can be used in IIgs programs.

What Dialog Windows Look Like

Dialog windows resemble ordinary document windows, but they have controls that ordinary windows usually do not have. A dialog window usually appears near the top of the screen, in the center of the screen and slightly below the
menu bar, and is somewhat narrower than the screen. Figure 11–1 shows a
typical dialog window.

As figure 11–1 shows, a dialog window looks something like a printed
form. Like a paper form, a dialog can contain messages, illustrations, and
blanks to be filled in by the user. These features can be presented in many
formats, such as

- Messages designed to provide the user with information,
  instructions, or alerts.
- Controls such as buttons, scroll bars, and squares that can be
  checked off by the user. Text messages may or may not be supplied
  along with these controls.
- Rectangles in which the user may type in text. These rectangles,
called edit lines, may be blank when they appear on the screen or
they may contain default text that can be edited by the user.
- Graphic symbols: either icons or pictures drawn using QuickDraw.
  Icons are easier to manage than QuickDraw pictures and are thus
  more commonly used. But there is no reason why a QuickDraw
  picture can’t appear in a dialog window.
- Any other types of items an application can define.
Dialog I/O

The simplest kind of dialog window is one that requires no response at all. Such a noninteractive dialog might be created to print a message on the screen while an application is performing a time-consuming process. When the operation is finished, the dialog could be removed from the screen.

Another simple type of dialog is one that contains just two items: a printed message and one button, often labeled OK, that the user can press after reading the message. In most cases, the dialog in which the message appears then disappears from the screen.

The button that makes the dialog disappear does not have to be labeled OK. It could be labeled Start or Proceed, or it could have another name. But, for simplicity, we call this button the OK button throughout this chapter.

Many kinds of dialog windows can be used in IIgs programs. Some dialog windows display more than one message on the screen, some display different messages at different times, and some accept input from the user. For example, if a dialog window appears on the screen as the result of some action by the user, it might contain a button labeled Cancel that is clicked to cancel the action that caused the dialog to appear. Or there could be a button labeled Help that is used to request additional information.

Dialog Items

In Dialog Manager jargon, buttons with labels like OK, Cancel, and Help are known as dialog items. There are many kinds of dialog items, and each is designed to be used in a slightly different way. Some dialog items provide information to the user, some obtain information from the user, and some do both. The items that can be used in dialog windows can be divided into the following categories:

- Button items. A button item is a simulated pushbutton that contains a label such as OK, Help, or Cancel. A button item usually has round corners and usually contains a label displayed in the standard IIgs type font, or system font. When the user clicks the IIgs mouse inside a button item, an application program can carry out whatever response is appropriate.

- Check items. A check item is a small square box that is empty or contains an X. When the user clicks the mouse in an empty check item, an X appears. When the user clicks the mouse in a check item that contains an X, the X disappears.

A dialog box can contain any number of check items. When a dialog with a user ends, the application using the dialog can check to see which boxes have been checked and which have been left unchecked, and take the appropriate actions.
Radio items. A radio item is a small circle that is empty or contains a still smaller circle. The inner circle in a radio item is usually black. When the user clicks the mouse in an empty radio item, an inner circle appears. When the user clicks the mouse in a radio item that contains an inner circle, the inner circle disappears.

Scroll bar items. A scroll bar item is a special scroll bar used only in dialogs. A scroll bar item can be used to display the progress of an operation. For example, the white square, or "thumb" of a scroll bar, can move down the bar as files are printed to show the user how the operation is progressing.

Static text items. A static text item, usually abbreviated StatText item, consists only of a Pascal-type string (a length byte followed by a string of ASCII characters). StatText items only display information; they cannot accept input from the user. Text in a StatText item does not have to be enclosed in a visible rectangle, and it cannot be edited.

Long static text items. A long static text item, abbreviated LongStatText item, consists only of a block of text. The text in a LongStatText item is not preceded by a length byte, so its length must be passed to the Dialog Manager as a parameter when the item is created with a NewDItem call. More about this call is provided later in this chapter. LongStatText items only display messages; they cannot accept input from the user. Text in a LongStatText item does not have to be enclosed in a visible rectangle, and it cannot be edited.

Edit line items. An edit line item contains space for one line of text that is entered or edited by the user. The text usually appears inside a visible rectangle. When an edit line item appears on the screen, it is empty or contains default text. If it is empty, you can fill it in by typing information, and you can edit the information after it has been typed. If the item contains default text when it appears on the screen, that text can be edited by the user.

Icon items. An icon item contains an icon. Icons used in dialog windows are stored in memory in a specific format and appear in the dialog window when it is displayed on the screen. When the user clicks the mouse in an icon item, the application using the dialog can take whatever action is appropriate.

Picture items. A picture item contains a picture drawn with QuickDraw II. When the user clicks the mouse in a picture item, the application using the dialog can take whatever action is appropriate.

User items. Any item that is not in any of the previous categories is called a user item. User items are defined by application programs.
Types of Dialog Windows

There are three kinds of dialog windows: modal dialogs, modeless dialogs, and alert dialogs. Let’s take a closer look at each of these types of dialog windows.

Modal Dialogs

Modal dialogs require the user to respond to a dialog message before taking any other action. Modal dialogs derive their name from the fact that they put a program in a state, or mode, of being unable to take any action outside a dialog window. A modal dialog usually has at least one button item that is clicked to perform some action and a Cancel button that is clicked to make the dialog box go away. Normally, clicking the mouse anywhere outside the dialog window only makes the IIgs speaker beep.

In programs written according to Apple’s Human Interface Guidelines, one button item in a dialog window may be outlined in bold; that is, it may have a double outline. If such a button appears in a dialog box, it is usually the OK button, the button that ends the dialog by initiating some action and making the dialog window go away. When a button has a double outline, the Return key on the keyboard can always be pressed as an alternative to clicking the outlined button. In short, a button with a double outline is the dialog’s default button—the safest button to use in the current situation.

If there is no boldly outlined button, pressing the Return key will have no effect on the dialog. A typical modal dialog window is illustrated in figure 11–2.

Modeless Dialogs

A dialog cannot be modal and modeless at the same time; different routines create these two types of dialogs. When a program is running, however, it can be difficult to distinguish between a modal dialog and a modeless dialog because they often look alike.

A modeless dialog, like a modal dialog, usually has an OK button (often doubly outlined) and a Cancel button. And, just like a modal dialog, a modeless dialog can contain other controls that do not erase the dialog window and do not result in any change in a program until an OK button is pressed to make the dialog go away.

But modeless dialogs do not put a program into any special state, or mode, and thus do not require the user to respond to a dialog before taking any other action. When a modeless dialog is on the screen, it can stay there while the user performs actions unrelated to the dialog. For example, the user might be permitted to work in various windows on the desktop before clicking a button in the dialog window.

Because a modeless dialog can remain on the screen while document windows (or even other dialog windows) are in use, you can create a modeless dialog window that has a title bar and thus can be moved on the screen. Because of this feature—and because they can stay on the screen while various operations take place—modeless dialogs are used as desk accessories. Clocks, calculators, notepads, and other desk accessory items are often incorporated into programs in the form of modeless dialogs.
Figure 11–2
Modal dialog window

Figure 11–3 shows a modeless dialog box that is similar to a document window. Like a standard document window, it has both a title bar and a close box. So it can be moved, hidden, closed, and opened again, like any other similarly equipped window.

Alert Dialogs

An alert dialog looks much like a modal dialog (or a modeless dialog without a title bar). But an alert dialog has a special function. It appears only when something has gone wrong or when something important must be brought to the user’s attention. Alert dialogs can provide a program with a convenient method for reporting errors or issuing warnings.

An alert window is usually placed slightly farther below the menu bar than a modal or modeless dialog. And an alert dialog often contains an icon that gives the user a visual clue about the nature of the alert. There are three standard types of alert icons: Stop, Note, and Caution. You can also design other kinds of icons. An alert dialog can also be programmed to beep or make other sounds when it is activated.

To help the user who isn’t sure how to proceed when an alert box appears, the button used most often in the current situation is displayed with a double outline. This button is also the alert’s default button. If the user presses the Return key, the effect is the same as clicking the alert’s default button.

One special feature of an alert dialog is that it can behave in a different way each time it is activated. This feature can give the user increasingly
severe warnings each time an error is made or a dangerous situation becomes more dangerous. For example, the first time an error is made, the error might beep the speaker but generate no alert box. Thereafter, each successive error might cause an alert dialog to be displayed, and each alert might carry an increasingly severe warning.

Furthermore, the sound produced by an alert dialog does not have to be a beep. It can be any sequence of tones, which may occur either by themselves or with an alert dialog. Figure 11–4 is an illustration of a typical alert dialog window.

Manipulating Dialog Windows

After a modal or modeless dialog is created, it can be manipulated like any other window. With the help of routines provided by the Window Manager and QuickDraw, an application can do just about anything to a dialog window: show, hide, or move it, change its size or plane, or close and discard it when it is no longer needed. The Dialog Manager even recognizes the ClipRgn field of the dialog window’s GrafPort, so the QuickDraw II SetClipRgn and ClipRect routines can keep portions of a window from being displayed on the screen.

When an alert window is designed, however, the Dialog Manager takes care of most details, so that all alert windows have a standard appearance and behavior. The size and location of the box are supplied as part of the definition of the alert and are not changed easily. You do not have to specify an alert window’s plane because an alert always appears in front of all other windows. After an alert window is on the screen, the application that uses it never has to manipulate it. That’s because an alert window requires the user to respond before doing anything else, and the user’s response makes the box disappear.
Initializing the Dialog Manager

Before the dialog is started, the following tool sets must be loaded and started:

- Tool Locator (always loaded and active)
- Memory Manager
- Miscellaneous Tool Set
- QuickDraw II
- Event Manager
- Window Manager
- Control Manager
- LineEdit Tool Set

After these tools are loaded and initialized, the DialogStartUp call can be made to start up the Dialog Manager. If you want the type font used in your dialog and alert windows to be something other than the system font, you can make the Dialog Manager call SetDAFont.

When the Dialog Manager is loaded and started up, the NewModalDialog, NewModelessDialog, and GetNewModalDialog calls can be used to create dialog windows. NewModelessDialog creates a dialog using a special kind of dialog record, and GetNewModelessDialog creates a dialog using a template that can be accessed by more than one dialog window.
After a dialog is set up, the NewDItem and GetNewDItem calls can be used to create the items that appear in each dialog. The CloseDialog call can be used to close and dispose of any dialogs.

Creating a Dialog Window

The Dialog Manager requires the same kind of information to create a dialog that the Window Manager requires to create a document window. These are the steps that are usually used to set up a dialog window:

1. The application calls NewModalDialog, GetNewModalDialog, or NewModelessDialog. In addition to creating a dialog window, these calls determine how the window looks and behaves.
2. The Dialog Manager must be supplied with a rectangle that becomes the port rectangle of the window's GrafPort.
3. The Dialog Manager must be told whether the window will be visible or invisible when it is created. If it is created as a visible window, it appears on the screen immediately. If it is created as an invisible window, the Window Manager calls SelectWindow and ShowWindow must be made each time the window appears on the screen.

If a modeless dialog is created, the plane in which it appears in relation to other windows must also be specified. By convention, a newly created window always appears in the frontmost plane.

The example program in this chapter, DIALOG.S1, uses the call NewModalDialog to create a modal dialog window. Listing 11–1 shows how NewModalDialog is used in the program. Instructions for typing and compiling the DIALOG.S1 program in both assembly language and C are at the end of this chapter.

Listing 11–1
Calling the NewModalDialog routine

PushLong #0 ; output
PushLong #DRect
PushWord #True ; visible
PushLong #0 ; refcon
-NewModalDialog

pla
sta MDiaLogPtr
pla
sta MDiaLogPtr+2
As listing 11-1 shows, the NewModalDialog call takes four parameters:

- 2 null words (zeros), which provide a space on the stack for a 2-word result.
- A pointer to a rectangle that defines the location of the dialog window on the screen.
- A 1-word space for a Boolean value. If the value is nonzero, or true, the dialog is displayed on the screen as soon as it is created. If the value is zero, the window is not displayed until a specific command, such as ShowWindow, is called to display it on the screen.

When a NewModalDialog call returns, a pointer to the dialog window which it created is on the stack. In the DIALOG.SI program, this pointer is stored in the MDiaLogPtr variable.

Creating an Item List

Before a dialog window can be displayed on the screen, the NewDItem call must be used to create each item that will appear in the window. The dialog window in the DIALOG.SI program contains three buttons: Start, Quit, and Help. Listing 11-2 shows how the NewDItem call creates the Start button.

Listing 11-2
NewDItem call

<table>
<thead>
<tr>
<th>Instruction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>PushLong MDiaLogPtr</td>
<td>item belongs to this window</td>
</tr>
<tr>
<td>PushWord #1</td>
<td>item ID number</td>
</tr>
<tr>
<td>PushLong #ButtonRect1</td>
<td>pointer to button's rect</td>
</tr>
<tr>
<td>PushWord #ButtonItem</td>
<td>item type</td>
</tr>
<tr>
<td>PushLong #ButtonText1</td>
<td>item descriptor</td>
</tr>
<tr>
<td>PushWord #0</td>
<td>item's initial value</td>
</tr>
<tr>
<td>PushWord #0</td>
<td>visible/invis flag</td>
</tr>
<tr>
<td>PushLong #0</td>
<td>color table pointer</td>
</tr>
</tbody>
</table>

As listing 11-2 shows, the NewDItem call takes eight parameters:

- A pointer to the window to which the item belongs.
- A 1-word identification number that will be used in all dialog-related items to identify the item being created.
- A pointer to a rectangle that defines where the item will appear inside its dialog window. Note that this rectangle is expressed not in screen coordinates, but in local coordinates that treat the dialog window as a bounds rectangle.
A 1-word parameter identifying the type of item being created. This parameter is a constant that can be found in APW's LIBRARIES/AINCLUDE file, under the filename EI6.DIALOG. In the DIALOG.S1 program, the constants for item types are listed in the DialogData data segment.

By convention, the OK button in an alert's item list is always assigned an ID of 1, and the Cancel button should always have an ID of 2. The Dialog Manager provides predefined constants equal to the item ID for OK and Cancel as follows:

```
OK equ 1
Cancel equ 2
```

In a modal dialog's item list, the item whose ID is 1 is generally assumed to be the dialog's default button. If the user presses the Return key, the Dialog Manager normally returns the ID of the default button, just as when that item is actually clicked.

To conform with Apple's Human Interface Guidelines, the Dialog Manager automatically prints a double outline in bold around the default button, unless there is no default button—that is, no button item with an ID number of 1. So, if you don't want a dialog to have a default button, you should not assign any button an ID number of 1. The item types listed in the DIALOG.S1 program are shown in listing 11–3.

A two-word parameter called a dialog item descriptor. The function of this parameter can vary, depending upon the type of item being created. Table 11–1 shows the functions the item descriptor parameter can have when used with different kinds of items.

A one-word parameter setting the initial value of the item descriptor, if applicable.

A flag determining whether the item being created should be visible or invisible when the window is first displayed. This parameter can also include item-specific information, for example, the family number of a radio button or whether a scroll bar is horizontal or vertical. Further information on item-specific data in this parameter is in the Apple Ilgs Toolbox Reference.

A pointer to a color table, which can be used to change the standard colors used to draw items in a dialog. Custom color tables can be used for standard or custom-designed controls. But make sure your use of color conforms to Apple's Human Interface Guidelines.

**Listing 11–3**

<table>
<thead>
<tr>
<th>DialogData</th>
<th>DATA</th>
</tr>
</thead>
<tbody>
<tr>
<td>ButtonItem</td>
<td>equ 10</td>
</tr>
<tr>
<td>CheckItem</td>
<td>equ 11</td>
</tr>
<tr>
<td>RadioItem</td>
<td>equ 12</td>
</tr>
</tbody>
</table>
The JIGS Toolbox

ScrollBarItem equ 13
UserCtlItem equ 14
StatText equ 15
EditText equ 16
EditLine equ 17
IconItem equ 18
PicItem equ 19
UserItem equ 20

END

Table 11–1
Item Descriptor Parameter in a NewDItem Call

<table>
<thead>
<tr>
<th>Type</th>
<th>Function of Descriptor</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>ButtonItem</td>
<td>Pointer to a string containing item's label</td>
<td>N/A</td>
</tr>
<tr>
<td>CheckItem</td>
<td>N/A</td>
<td>0 = not checked</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 = checked</td>
</tr>
<tr>
<td>RadioItem</td>
<td>N/A</td>
<td>0 = not checked</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 = checked</td>
</tr>
<tr>
<td>ScrollBarItem</td>
<td>Pointer to dialog scroll bar action procedure</td>
<td>0 or default value</td>
</tr>
<tr>
<td></td>
<td></td>
<td>if ItemDescr = 0</td>
</tr>
<tr>
<td>UserCtlItem</td>
<td>Pointer to control definition procedure</td>
<td>Initial value of control</td>
</tr>
<tr>
<td>UserCtlItem2</td>
<td>Pointer to parameter block</td>
<td>Initial value of control</td>
</tr>
<tr>
<td>StatText</td>
<td>Pointer to static string</td>
<td>Application use</td>
</tr>
<tr>
<td>LongStatText</td>
<td>Pointer to the beginning of text</td>
<td>Length of text (0 to 32,767)</td>
</tr>
<tr>
<td>EditLine</td>
<td>Pointer to default string</td>
<td>Maximum length allowed (0 to 255)</td>
</tr>
<tr>
<td>IconItem</td>
<td>Handle to the icon</td>
<td>Application use</td>
</tr>
<tr>
<td>PicItem</td>
<td>Handle to the picture</td>
<td>Application use</td>
</tr>
<tr>
<td>UserItem</td>
<td>Pointer to item definition procedure</td>
<td>Application use</td>
</tr>
</tbody>
</table>

Using a Dialog Window in a Program

When a modal dialog is created, the ModalDialog call can be used to accept user input. Listing 11–4 shows how the ModalDialog call is used in the DIALOG.S1 program. Let's take a look now at how the routine in listing 11–4 works. Then we'll see how the routine is used in the DIALOG.S1 program.
The **ModalDialog** call takes two parameters: a 1-word null (zero) value that saves a space on the stack and a pointer to a user-written filter procedure, if there is one. A filter procedure, usually abbreviated **FilterProc**, is a routine that an application can call to filter out unwanted responses by the user (for example, to ignore non-numeric characters typed in an **EditLine** item that calls for numeric characters only). If a 0 is passed to **ModalDialog** in the **FilterProc** parameter, it means no filter process is set up by the application using the dialog. In that case, **ModalDialog** will not look for one.

In the **DIALOG.S1** program, **ModalDialog** is called with two 0 parameters: a null word to save a space on the stack and a null pointer because there is no filter procedure in the program.

When a **ModalDialog** call returns, a 1-word value—the ID number of the item selected by the user—is pushed on the stack. In the **DIALOG.S1** program, this value is pulled off the stack and compared with the literal values 3 and 1. If the value is 3—the item ID number for the Help button—the program loops back to the line labeled **Again**. That’s because no help function is written for the **DIALOG.S1** program. If you expand the program, you may want to write a help function.

If the **ModalDialog** call returns a value of 1—the item ID number of the Start button—the dialog is erased from the screen with a **CloseDialog** call and the **DIALOG.S1** program continues, as though there had never been a dialog window on the screen.

If the routine in listing 11–4 discovers that the user has clicked a button that is neither item 1 nor item 3, it is smart enough to determine that the user

<table>
<thead>
<tr>
<th>Again</th>
<th>PushWord #0</th>
<th>; space for result</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PushLong #0</td>
<td>; filter procedure pointer</td>
</tr>
<tr>
<td></td>
<td>_ModalDialog</td>
<td>pla</td>
</tr>
<tr>
<td>next</td>
<td>cmp #3</td>
<td>beq Again</td>
</tr>
<tr>
<td></td>
<td>cmp #1</td>
<td>beq noquit</td>
</tr>
<tr>
<td>button2</td>
<td>lda #$FFFF</td>
<td>; button 2 was pressed</td>
</tr>
<tr>
<td></td>
<td>sta QuitFlag</td>
<td></td>
</tr>
<tr>
<td>noquit</td>
<td>PushLong MDiaLogPtr</td>
<td>; use this exit for #1 or #3</td>
</tr>
<tr>
<td></td>
<td>_CloseDialog</td>
<td></td>
</tr>
<tr>
<td></td>
<td>rts</td>
<td></td>
</tr>
</tbody>
</table>

---

**Listing 11–4**

**ModalDialog** call

<table>
<thead>
<tr>
<th>Again</th>
<th>PushWord #0</th>
<th>; space for result</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PushLong #0</td>
<td>; filter procedure pointer</td>
</tr>
<tr>
<td></td>
<td>_ModalDialog</td>
<td>pla</td>
</tr>
<tr>
<td>next</td>
<td>cmp #3</td>
<td>beq Again</td>
</tr>
<tr>
<td></td>
<td>cmp #1</td>
<td>beq noquit</td>
</tr>
<tr>
<td>button2</td>
<td>lda #$FFFF</td>
<td>; button 2 was pressed</td>
</tr>
<tr>
<td></td>
<td>sta QuitFlag</td>
<td></td>
</tr>
<tr>
<td>noquit</td>
<td>PushLong MDiaLogPtr</td>
<td>; use this exit for #1 or #3</td>
</tr>
<tr>
<td></td>
<td>_CloseDialog</td>
<td></td>
</tr>
<tr>
<td></td>
<td>rts</td>
<td></td>
</tr>
</tbody>
</table>
If the routine in listing 11-4 discovers that the user has clicked a button that is neither item 1 nor item 3, it is smart enough to determine that the user has made the only other choice, item 2. This is the Quit button, which ends the program by storing a nonzero value in the program's quit flag before returning.

The DIALOG.S1 Program

DIALOG.S1 is an expanded version of the WINDOW.S1 program in chapter 10, so you can save yourself a lot of work by modifying WINDOW.S1 instead of typing the entire DIALOG.S1 program. To convert WINDOW.S1 into DIALOG.S1, the following modifications are necessary:

1. Replace the heading of the WINDOW.S1 program with the heading shown in listing 11-5.
2. Add three lines to the main program segment of the WINDOW.S1 program so that the segment looks like the one in listing 11-6.
3. Following the program segment labeled EventLoop, insert the segment that appears in listing 11-7. This segment displays a dialog window on the screen.
4. In the data segment labeled MenuData, change the line

   dc c' LA Window Program \N257",i1'\RETURN'

   to

   dc c' LA Dialog Program \N257",i1'\RETURN'

5. At the end of the program, add the data segment that appears in listing 11-8. This segment provides the item codes used in the DIALOG.S1 program.
6. Before you assemble DIALOG.S1, make sure you have the latest version of INITQUIT.S1 saved on the same disk that holds your DIALOG.S1 source code. Then the COPY directive at the end of DIALOG.S1 will combine the DIALOG.S1 and INITQUIT.S1 programs.

When you've typed, assembled, and executed DIALOG.S1, you'll be ready to examine the portion that creates a dialog on the screen. Starting from the beginning of the DIALOG.S1 program, move down the listing until you see the label Main Program. Below that label look for this line:

   jsr doDialog1

If you have typed and run the program, you should have no trouble figuring out what this line does. After all tools are initialized and an empty menu bar appears on the screen, the line jsr doDialog1 simply places a
modal dialog on the screen and waits for the user's input. The user can do one of three things: click Start, which erases the dialog box and resumes execution of the DIALOG.S1 program, click Help, which won't do anything because there is no help routine, or click Quit, which ends the program.

Listing 11-5
Heading segment

* DIALOG.S1
*

*** A FEW ASSEMBLER DIRECTIVES ***

Title 'Dialog'
ABSADDR on
LIST off
SYMBOL off
65816 on
mcopy dialog.macros

KEEP dialog

Listing 11-6
Main loop segment

* MAIN PROGRAM LOOP

MainProgram START
Using GlobalData
Using PortData

phk
plb

; get current direct page

; and save it for the moment

jsr ToolInit ; start up all tools we'll need

*** PUT DIALOG NO. 1 ON THE SCREEN ***

jsr doDialog1

jsr BuildMenu ; create and draw menu bar
jsr MakeWin0 ; create empty window
The Ilas Toolbox

*** OPEN A PORT SO WE CAN DRAW IN WINDOW'S PIXEL MAP ***

jsr NewPort

lda #PicOPort
sta BlkToFill
lda #PicOPort
sta BlkToFill+2

jsr BlkFill

*** LINE THAT JUMPS TO THE EVENT LOOP ***

jsr EventLoop ; check for key & mouse events

*** WHEN EVENT LOOP ENDS, WE'LL SHUT DOWN ***

jsr Shutdown
jmp Endit

END

Listing 11–7
Dialog window segment

* * DODIALOG1: PRINT DIALOG NO. 1 ON THE SCREEN *

doDialog1

START

using GlobalData
using WindowData
using DialogData
using QuitData

PushLong #0 ; output
PushLong #DRect
PushWord #True ; visible
PushLong #0 ; refcon
NewLabelModalDialog

pla
sta MDialogPtr
pla
sta MDialogPtr+2

PushLong MDialogPtr ; item belongs to this window
PushWord #1 ; item ID number
pushlong #buttonrect1 ; pointer to button’s rect
pushword #buttonitem ; item’s id number
pushlong #buttonrect1 ; item descriptor
pushword #0          ; item’s initial value
pushword #0          ; visible/invis flag
pushlong #0          ; color table pointer
_newditem

pushlong mdialogptr
pushword #2
pushlong #buttonrect2
pushword #buttonitem
pushlong #buttonrect2
pushword #0
pushword #0
pushlong #0
_newditem

pushlong mdialogptr
pushword #3
pushlong #buttonrect3
pushword #buttonitem
pushlong #buttonrect3
pushword #0
pushword #0
pushlong #0
_newditem

again
pushword #0          ; space for result
pushlong #0          ; filter procedure pointer
_modaldialog
pla

next
    cmp #3
    beq again

    cmp #1
    beq noquit

button2
    lda #$fff
    sta quitflag

noquit
    pushlong mdialogptr ; use this exit for #1 or #3
    _closedialog

rts

drect
    dc i'84,63,114,252' ; screen coordinates
The IIGS Toolbox

ButtonRect1   dc i'8,129,22,179' ; local coordinates using
ButtonRect2   dc i'8,8,22,58'    ; dialog window's frame
ButtonRect3   dc i'8,67,22,117' ; as a bounds rectangle

ButtonText1   str 'Start'
ButtonText2   str 'Quit'
ButtonText3   str 'Help'

MDialogPtr    ds 4

END

Listing 11-8
DialogData segment

DialogData     DATA

ButtonItem      equ 10
CheckItem      equ 11
RadioItem      equ 12
ScrollBarItem  equ 13
UserCtlItem    equ 14
StatText       equ 15
EditText       equ 16
EditLine       equ 17
IconItem       equ 18
PicItem        equ 19
UserItem       equ 20

End

The DIALOG.C Program

Listing 11-9, DIALOG.C, is a C language version of the DIALOG.S1 program. It is designed to be used with the include file INITQUIT.C, and it works just like DIALOG.S1.

Listing 11-9
DIALOG.C program

#include "initquit.c"

Boolean done = false;
WmTaskRec my Event;
/******************************/
/* Data and routine to create menus */
******************************/
/* Set up menu strings. Because C uses \ as an escape character, we use
two when we want a \ as an ordinary character. The \ at the end of each
line tells C to ignore the carriage return. This lets us set up our items
in an easy-to-read vertical alignment. */

char *menu1 = "\n@\rn\nLA Window Program \n577\n."
char *menu2 = "\nL File \n2\nLNew \n58\rLQuit \n59\n."
char *menu3 = "\nL Windows \n3\nLUntitled \n60\n."
#define QUIT_ITEM 259 /* these will help us check menu item numbers */
#define NEW_ITEM 258
#define UNTIT_ITEM 260
BuildMenu()
{
    InsertMenu(NewMenu(menu3),0);
    InsertMenu(NewMenu(menu2),0);
    InsertMenu(NewMenu(menu1),0);
    FixMenuBar();
    DrawMenuBar();
}

/******************************/
/* Data structures and routine to set up offscreen drawing environment */
******************************/
LocInfo picOLocInfo = { mode320,
                        NULL, /* space for pointer to pixel image */
                        160, /* width of image in bytes = 320 pixels */
                        0,0,200,320 /* frame rect */
};

Rect screenRect = {0,0,200,320};
GrafPort picOPort;
#define IMAGE_ATTR attrLocked+attrFixed+attrNoCross+attrNoSpec+attrPage

PicOSetup() /* called once by MakeWindow at start of program */
{
GrafPortPtr thePortPtr;

picOLocInfo.ptrToPixImage = *(NewHandle(0x8000L,myID,IMAGE_ATTR,NULL));
thePortPtr = GetPort();
OpenPort(&picOPort);
SetPort(&picOPort);
SetPortLoc(&picOLocInfo);
ClipRect(&screenRect);
EraseRect(&screenRect);
SetPort(thePortPtr);
}

/*****************************************************/
/* Data structures and routine to create window */
/*****************************************************/

/* Initialize template for NewWindow */

#define FRAME fQContent+fMove+fZoom+fGrow+fBScroll+fRScroll+fClose+fTitle

ParamList template = {
sizeof (ParamList),
FRAME,
"\"Untitled\", /* pointer to title */
0L, /* RefCon */
26,0,188,308, /* full size (0=default) */
NULL, /* use default ColorTable */
0,0, /* origin */
200,320, /* data area height & width */
200,320, /* max cont height & width */
2,2, /* vertical & horizontal scroll increment */
20,32, /* vertical & horizontal page increment */
NULL, /* no info bar text string */
0, /* info bar height = none */
NULL, /* default def proc */
NULL, /* no info bar draw routine */
NULL, /* draw content must be filled in at run time */
26,0,188,308, /* starting content rect */
-1L, /* topmost plane */
NULL /* let Window Manager allocate record */
};
11-Dialog with a IIGs

/* Window's draw content routine */

pascal void DrawContent()
{
    PPToPort(&picOLocInfo,&(picOLocInfo.boundsRect),0,0,modeCopy);
}

GrafPortPtr winOPtr;

MakeWindow() /* complete template, make window, and set up offscreen port */
{
    template.wContDefProc = DrawContent;
    winOPtr = NewWindow(&template);
    PicOSetup(); /* create offscreen image for use by DrawContent */
}

******************************************************************************
/* Data and routine to set up and display dialog */
******************************************************************************

ItemTemplate item1 = {1,[8,129,22,179],buttonltem, "\pStart\r",0,0,NULL };
ItemTemplate item2 = {2,[8,8,22,58],buttonltem, "\pQuit\r",0,0,NULL };
ItemTemplate item3 = {3,[8,67,22,117],buttonltem, "\pHelp\r",0,0,NULL };

DialogTemplate dtemp = {{84,63,114,252},true,OL,&item1,&item2,&item3,NULL };

DoDialog() /* Create and display an opening dialog box */
{
    GrafPortPtr dlgPtr;
    Word hit;

    dlgPtr = GetNewModalDialog(&dtemp);

    while ((hit = ModalDialog(NULL)) == 3);
    done = (hit == 2);
    CloseDialog(dlgPtr);
}

******************************************************************************
/* Main routine. Set up environment, call event loop, and shut down */
******************************************************************************

main()
{
    StartTools();
    DoDialog();
    BuildMenu();
}
The Ilgs Toolbox

MakeWindow();
EventLoop();
DisposeHandle(FindHandle(picOLocInfo.ptrToPixImage));
ShutDown();

/**************************************************
/∗ Event loop and supporting routines ∗/
**************************************************/

EventLoop()
{
    myEvent.wmTaskMask = OxOFFF;
    while(!done)
        switch ( TaskMaster(everyEvent,&myEvent)) {
            case wInMenuBar:
                DoMenus();
                break;
            case wInGoAway:
                HideWindow(winOPtr);
                break;
            case wInContent:
                Sketch();
        }
    }

DoMenus()
{
    Word *data = (Word *)&myEvent.wmTaskData; /*address of item id */

    switch(*data) {
        case QUIT_ITEM:
            done = true;
            break;
        case NEW_ITEM:
            ErasePicO();
            HideWindow(winOPtr);
            CloseWindow(winOPtr);
            winOPtr = NewWindow(&template);
            case UNTIT_ITEM:
                SelectWindow(winOPtr);
                ShowWindow(winOPtr);
                break;
    }
    HilitMenu(false,*(data + 1)); /* data + 1 is address of menu id */
}
ErasePicO()
{
    GrafPortPtr oldPortPtr;
    oldPortPtr = GetPort();
    SetPort(&picOPort);
    ClipRect(&screenRect);
    EraseRect(&screenRect);
    SetPort(oldPortPtr);
}

Sketch() /* sketch into current port and into offscreen port */
{
    Point mouseLoc;
    GrafPortPtr thePortPtr = (GrafPortPtr)myEvent.wmTaskData;
    Rect theRect;

    mouseLoc = myEvent.wmWhere;

    StartDrawing(thePortPtr); /* set up correct drawing coordinate system */
    GetPortRect(&theRect); /* copy current Port Rect */
    GlobalToLocal(&mouseLoc); /* get cursor pos in local coordinates */
    MoveTo(mouseLoc); /* set pen position to mouse loc */
    SetPort(&picOPort); /* switch to offscreen port */
    ClipRect(&theRect); /* clip offscreen drawing to window's Port Rect */
    MoveTo(mouseLoc); /* set offscreen pen to same location */
    SetPort(thePortPtr); /* switch back to window's port */

    while (StillDown(0)) {
        GetMouse(&mouseLoc); /* get new mouse coordinates */
        LineTo(mouseLoc); /* draw line in both ports */
        SetPort(&picOPort);
        LineTo(mouseLoc);
        SetPort(thePortPtr);
    }
    SetOrigin(0,0); /* restore normal coordinates */
}
Until the advent of the Apple IIgs, it could be difficult to incorporate disk drive operations into assembly language programs. Today, in programs written for the IIgs, the job is much easier. Here are four major reasons.

The Apple IIgs has new features that earlier Apple II computers do not have. For example, the Memory Manager tool set relieves the programmer of the responsibility of dealing with absolute addresses. It also has a new kind of I/O port, a SmartPort, which keeps track of the locations of disk drives and supports named devices and multiple, user-defined file prefixes.

The disk operating system in the IIgs is ProDOS 16—a 16-bit descendant of ProDOS 8, which was designed for the Apple Ile and the Apple IIc. ProDOS 16 is faster, more powerful, and easier to use than its 8-bit predecessor. And, unlike ProDOS 8, ProDOS 16 makes use of several new features of the IIgs.

The APW assembler-editor has a library of ProDOS macros that simplify the job of making ProDOS calls. In this chapter, you’ll see how those macros are used.

The Standard File Operations Tool Set, which is included in the IIgs Toolbox, makes the task of working with ProDOS 16 even easier. When the Standard File Operations Tool Set is used in a program, a special dialog box is created every time a file is loaded or saved. You can load or save the file by either clicking the mouse inside a button item or typing the name of the file in a line edit control. You can also search through directories using the
Standard File Tool Set’s dialog boxes, and you can even switch disks and change directories. The tool set gives the programmer the option of using predesigned dialog boxes or creating custom-designed boxes. Application programs can select the types of files that will or will not be listed on the screen.

In this chapter, you’ll see how easy it is to create, load, save, and edit files using ProDOS 16, the ProDOS macros in the APW assembler-editor package, and the Ilgs Standard File Operations Tool Set. These techniques are demonstrated using a sample program called SF.S1, which is listed at the end of this chapter. A C language version, SF.C, is also listed at the end of this chapter. Figure 12–1 shows the Standard File Tool Set screen display.

**Introducing ProDOS 16**

If you have written Apple II programs using ProDOS 8, you probably won’t have any trouble understanding ProDOS 16. ProDOS 16 calls are made in the same way as ProDOS 8 calls: by filling in a block of parameters, pushing the address of the parameter block onto the stack, and jumping to a fixed entry point.

There are two important differences in the way calls are made in ProDOS 8 and ProDOS 16. In ProDOS 16, a program must jump to the ProDOS entry point with a jsr instruction rather than a jsr instruction, and the entry point is in bank $E1 rather than bank $00. In programs written using the APW
library of ProDOS macros, neither of these details makes any difference; the macros take care of them.

The kernel (or central part) of the Apple IIgs operating system is ProDOS 16, which is covered in detail in the *Apple IIgs ProDOS 16 Reference*. ProDOS accesses the disk drive or disk devices on which files are stored and retrieved and manages the creation and modification of files. ProDOS 16 also controls certain features of the IIgs operating environment, such as pathname prefixes and procedures for quitting programs and starting new ones.

ProDOS 16 can communicate with various disk drives, including hard disk drives, 5.25-inch floppy disk drives, and 3.5-inch disk drives. Because the IIgs has an intelligent disk port called a SmartPort, programs that use ProDOS 16 do not have to specify a disk’s slot number or drive number to access the disk. Under ProDOS 16, a disk can also be accessed by its volume name or device name.

In ProDOS 16, just as in ProDOS 8, disks are also known as volumes, and information on a volume is divided into files. A file is an ordered sequence of bytes that has several attributes, including a name and a file type.

There are two primary types of files in ProDOS 16: standard files and directory files. Directory files contain the names and disk locations of other files. When a volume is formatted, a volume directory file is placed on it. The volume directory has the same name as the volume and usually contains the names and disk locations of other directory files.

ProDOS 16 supports a hierarchical file system. In a hierarchical file structure, volume directories can contain the names of other directories, called subdirectories, and subdirectories can, in turn, contain the names of other files or subdirectories.

In ProDOS 16, a file is identified by its pathname: a sequence of filenames starting with the name of the volume directory and ending with the name of the file. A pathname that begins with the name of a volume is a full pathname and is always preceded by a slash (/). If the name of the volume in which a file is stored is known, the file can be referenced by a partial pathname: a pathname that is not preceded by a slash and does not include a volume name.

Whether a pathname is preceded by a slash or not, the names of the directories, subdirectories, and files in the pathname are all separated by slashes. More details about pathnames are in the *Apple IIgs ProDOS 16 Reference*.

### Loading a File with ProDOS 16

The SF.SL program contains three code segments that make calls to ProDOS 16: *EndIt*, *LoadOne*, and *SaveOne*. *EndIt* makes the ProDOS call *Quit* to end the program. *LoadOne* appears in listing 12–1. *SaveOne* is explained shortly.
**Listing 12–1**

### Loading a file using ProDOS 16

<table>
<thead>
<tr>
<th>LoadOne</th>
<th>START using IOData</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>_Open OpenParams</td>
</tr>
<tr>
<td></td>
<td>bcc cont1</td>
</tr>
<tr>
<td></td>
<td>ErrorCheck 'Could not open picture file.'</td>
</tr>
<tr>
<td>cont1</td>
<td>anop</td>
</tr>
<tr>
<td></td>
<td>lda OpenID</td>
</tr>
<tr>
<td></td>
<td>sta ReadID</td>
</tr>
<tr>
<td></td>
<td>sta CloseID</td>
</tr>
<tr>
<td></td>
<td>_Read ReadParams</td>
</tr>
<tr>
<td></td>
<td>bcc cont2</td>
</tr>
<tr>
<td></td>
<td>ErrorCheck 'Could not read picture file.'</td>
</tr>
<tr>
<td>cont2</td>
<td>anop</td>
</tr>
<tr>
<td></td>
<td>_Close CloseParams</td>
</tr>
<tr>
<td></td>
<td>clc</td>
</tr>
<tr>
<td></td>
<td>rts</td>
</tr>
<tr>
<td>OpenParams</td>
<td>anop</td>
</tr>
<tr>
<td>OpenID</td>
<td>ds 2</td>
</tr>
<tr>
<td>NamePtr</td>
<td>ds 4</td>
</tr>
<tr>
<td>IOBuffer</td>
<td>ds 4</td>
</tr>
<tr>
<td>ReadParams</td>
<td>anop</td>
</tr>
<tr>
<td>ReadID</td>
<td>ds 2</td>
</tr>
<tr>
<td>PicDestIN</td>
<td>ds 4</td>
</tr>
<tr>
<td></td>
<td>_i4'$8000'         ; this many bytes</td>
</tr>
<tr>
<td></td>
<td>ds 4               ; how many xfered</td>
</tr>
<tr>
<td>CloseParams</td>
<td>anop</td>
</tr>
<tr>
<td>CloseID</td>
<td>ds 2</td>
</tr>
</tbody>
</table>

In listing 12–1, the APW macro *Open* opens a file, the *Read* macro copies it into memory, and the *Close* macro closes it. In each of these calls, a label that identifies a parameter block is used as an operand. The parameter blocks used in the program appear at the end of the listing.

In the source code listing of the SF.S1 program, only one parameter—the number of bytes to be read into RAM—is filled in. When you run the
The Standard File Operations Tool Set

The program, a segment of code called ReadIt fills in the other parameters. You'll examine the ReadIt segment later in this chapter.

As listing 12-1 shows, the ProDOS call Open takes three parameters:

- A 1-word file identification number that ProDOS assigns to the file being called when the Open call is made.
- A pointer to a string that contains the name of the file to be loaded. The string must be provided by the program using the Open call.
- A pointer to a 1,024-byte I/O buffer that ProDOS allocates when the call is made.

The ProDOS Read call takes four parameters:

- A 1-word file identification number. This is the ID number ProDOS assigns to the file when it is opened using an Open call.
- A pointer to a block of memory in which the file is stored. This block of memory must be provided by the application program making the Read call. In the SF.S1 program, the block is allocated using the Memory Manager call NewHandle in the segment of code labeled MakeWin0.
- A long word containing the number of bytes read into memory. In the SF.S1 program, $8000 bytes (or 32K) of memory are loaded into memory. This number was chosen because it is the length of the IIGS screen buffer and is thus the number of bytes required by one screenful of data.
- A long word that ProDOS fills in with the number of bytes actually transferred after the Read call is made.

When the file is read, a Close call should be issued to close the file. A Close call takes one parameter: the 1-word ID number assigned to the file when it is opened.

Saving a File with ProDOS 16

In the SF.S1 program, the code segment labeled SaveOne also makes a call to ProDOS 16. Listing 12-2 shows how ProDOS 16 can be used to save a program.

Listing 12-2
Saving a file using ProDOS 16

```
SaveOne START
    using IOData
    _Destroy DestParams
    _Create CreateParams
    bcc cont0
    ErrorCheck 'Could not create pic file.'
```
cont0
  _Open OpenParams
  bcc cont1
  ErrorCheck 'Could not open pic file.'

cont1
  anop
  lda OpenID
  sta WriteID
  sta CloseID

  _Write WriteParams
  bcc cont2
  ErrorCheck 'Could not write to pic file.'

cont2
  anop
  _Close CloseParams

  clc
  rts

DestParams anop
NameD   dc i4'0'

CreateParams anop
NameC   dc i4'0'
  dc i2'$00C3'
  ; DRNWR
CTYPE   dc i2'$00C1'
  ; super high-res graphics
CAux    dc i4'$00000000'
  ; Aux
  dc i2'$0001'
  ; type
  dc i2'$0000'
  ; create date
  dc i2'$0000'
  ; create time

OpenParams anop
OpenID   ds 2
NamePtr  ds 4
  ds 4

WriteParams anop
WriteID  ds 2
PicDestOUT ds 4
  dc i4'$8000'
  ; this many bytes
  ds 4
  ; how many xfered

CloseParams anop
CloseID  ds 2

END
Five ProDOS 16 calls appear in listing 12–2. Destroy, Create, Open, Write, and Close. Let’s take a closer look at each of these calls.

The Destroy call deletes a file. It is used in the SF.SI program to delete one file so that another file can be created and placed in the RAM space left by the first one. The Destroy call takes just one parameter: the name of the file being deleted.

The Create call takes seven parameters:

- A pointer to a string that contains the name of the file being created. The string must be provided by the program using the Create call.
- A word whose bits contain information about how the file can be accessed. Only the low-order byte of this word is significant, and bits 2 through 4 are not used. The meanings of the other five bits are listed in table 12–1.
- A word identifying the file’s file type. ProDOS 16 file types are listed in table 12–2.
- A long word identifying the file’s auxiliary file type. Many applications use this field. For example, APW source files (file type $80) use the auxiliary file type parameter to identify the language of a file—that is, whether it is a 65C816 assembly language file, a C file, an exec file, and so on. ProDOS 16 applies no restrictions to this parameter, however, and user-written applications may use it to distinguish between subtypes of files.
- A word identifying the file’s storage type. This parameter identifies the level in the ProDOS hierarchy in which a file falls. Values that can be stored in this parameter, and their meanings, are listed in table 12–3. The values most commonly used in this parameter are $01 and $0D. More information on file storage types can be found in the Apple IIgs ProDOS 16 Reference.
- Create date: a word specifying the date on which a file was created. Bits 0 through 4 hold the day of the month, bits 5 through 8 hold the number of the month, and bits 9 through 15 hold the year. If no date is specified when a file is created, ProDOS 16 supplies the date from the system clock.
- Create time: a word specifying the time a file was created. Bits 0 through 5 hold the minute and bits 8 through 12 hold the hour. Bits 6, 7, and 13 through 15 are not used. If no date is specified when a file is created, ProDOS 16 supplies the date from the system clock.

An Open call must be issued before a file can be saved on a disk. You saw the parameters of an Open call previously, when you examined listing 12–1.

The ProDOS 16 call Write takes four parameters:

- A l-word file ID number assigned when the file is opened.
- A pointer to the memory address of the information to be saved as a file.
Table 12–1  
Access Byte in the Create Call

<table>
<thead>
<tr>
<th>Bit</th>
<th>Name</th>
<th>Function</th>
<th>Value</th>
</tr>
</thead>
</table>
| 7   | D    | Destroy enable bit | 0 = File can't be destroyed  
|     |      |           | 1 = File can be destroyed |
| 6   | RN   | Rename enable bit | 0 = File can't be renamed  
|     |      |           | 1 = File can be renamed |
| 5   | B    | Backup needed bit | 0 = File backup is required  
|     |      |           | 1 = Backup not required |
| 4   |      | Reserved   |       |
| 3   |      | Reserved   |       |
| 2   |      | Reserved   |       |
| 1   | W    | Write enable bit | 0 = File can't be written to  
|     |      |           | 1 = File can be written to |
| 0   | R    | Read enable bit | 0 = File can't be read  
|     |      |           | 1 = File can be read |

- A long word holding the number of bytes to be saved.
- A long word in which ProDOS stores the number of bytes that have actually been transferred after the call is completed.

When you have finished saving a file, a close call should be issued to close the file. A close call takes one parameter: the I-word ID number assigned to the file when it is opened.

Using the Standard File Tool Set

The Standard File Operations Tool Set, as noted, offers the Ilgs user an easy and convenient method for loading and saving files—a collection of dialog boxes that can be programmed to appear on the screen when needed. These dialog boxes make loading and saving files as easy as clicking the mouse button. The Standard File Tool Set is even more of a timesaver for the Ilgs programmer than it is for the Ilgs user!

Before the Standard File Operations Tool Set is started up, the following tool sets must be loaded and initialized:

- Tool Locator (always loaded and active)
- Window Manager
- Control Manager
- Menu Manager
- LineEdit Tool Set
- Dialog Manager

When these tool sets are loaded and started up, the Standard File Tool Set can be initialized with the SfStartup call. Before a program that uses the tool set ends, SfShutdown should be called.
### Table 12–2
ProDOS 16 File Types

<table>
<thead>
<tr>
<th>Type</th>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$00</td>
<td>Uncategorized file</td>
<td></td>
</tr>
<tr>
<td>$01</td>
<td>BAD</td>
<td>Bad block file</td>
</tr>
<tr>
<td>$02–$03</td>
<td>Used by SOS (Apple III)</td>
<td></td>
</tr>
<tr>
<td>$04</td>
<td>TXT</td>
<td>ASCII text file</td>
</tr>
<tr>
<td>$05</td>
<td>Used by SOS (Apple III)</td>
<td></td>
</tr>
<tr>
<td>$06</td>
<td>BIN</td>
<td>Binary file</td>
</tr>
<tr>
<td>$07</td>
<td>Used by SOS (Apple III)</td>
<td></td>
</tr>
<tr>
<td>$08</td>
<td>FOT</td>
<td>Apple II graphics screen file</td>
</tr>
<tr>
<td>$09–$0E</td>
<td>SOS (Apple III) reserved</td>
<td></td>
</tr>
<tr>
<td>$0F</td>
<td>DIR</td>
<td>Directory file</td>
</tr>
<tr>
<td>$10–$18</td>
<td>Used by SOS (Apple III)</td>
<td></td>
</tr>
<tr>
<td>$19</td>
<td>ADB</td>
<td>AppleWorks database file</td>
</tr>
<tr>
<td>$1A</td>
<td>AWP</td>
<td>AppleWorks word-processor file</td>
</tr>
<tr>
<td>$1B</td>
<td>ASP</td>
<td>AppleWorks spreadsheet file</td>
</tr>
<tr>
<td>$1C–$1F</td>
<td>Reserved</td>
<td></td>
</tr>
<tr>
<td>$20</td>
<td>SRC</td>
<td>APW source file</td>
</tr>
<tr>
<td>$21</td>
<td>OBJ</td>
<td>APW object file</td>
</tr>
<tr>
<td>$22</td>
<td>LIB</td>
<td>APW library file</td>
</tr>
<tr>
<td>$23</td>
<td>S16</td>
<td>ProDOS 16 application program file</td>
</tr>
<tr>
<td>$24</td>
<td>RTL</td>
<td>Run-time library</td>
</tr>
<tr>
<td>$25</td>
<td>EXE</td>
<td>ProDOS 16 shell application file</td>
</tr>
<tr>
<td>$26</td>
<td>ProDOS 16 permanent initialization file</td>
<td></td>
</tr>
<tr>
<td>$27</td>
<td>ProDOS 16 temporary initialization file</td>
<td></td>
</tr>
<tr>
<td>$28</td>
<td>New desk accessory (NDA)</td>
<td></td>
</tr>
<tr>
<td>$29</td>
<td>Classic desk accessory (CDA)</td>
<td></td>
</tr>
<tr>
<td>$2A</td>
<td>Tool set file</td>
<td></td>
</tr>
<tr>
<td>$2B–$2E</td>
<td>Reserved for ProDOS 16 load files</td>
<td></td>
</tr>
<tr>
<td>$2F</td>
<td>ProDOS 16 document file</td>
<td></td>
</tr>
<tr>
<td>$30–$3F</td>
<td>Reserved</td>
<td></td>
</tr>
<tr>
<td>$3F</td>
<td>PAS</td>
<td>Pascal area on a partitioned disk</td>
</tr>
<tr>
<td>$40</td>
<td>CMD</td>
<td>ProDOS 8 CI added command file</td>
</tr>
<tr>
<td>$41–$48</td>
<td>ProDOS 8 user-defined files 1–8</td>
<td></td>
</tr>
<tr>
<td>$49</td>
<td>ProDOS 8 reserved</td>
<td></td>
</tr>
<tr>
<td>$50</td>
<td>INT</td>
<td>Integer BASIC program file</td>
</tr>
<tr>
<td>$51</td>
<td>INV</td>
<td>Integer BASIC variable file</td>
</tr>
<tr>
<td>$52</td>
<td>BAS</td>
<td>AppleSoft BASIC program file</td>
</tr>
<tr>
<td>$53</td>
<td>VAR</td>
<td>AppleSoft BASIC variables file</td>
</tr>
<tr>
<td>$54</td>
<td>REL</td>
<td>Relocatable code file (EDASM)</td>
</tr>
<tr>
<td>$55</td>
<td>SYS</td>
<td>ProDOS 8 system program file</td>
</tr>
</tbody>
</table>
Loading a File with the Standard File Tool Set

The easiest way to load a file using the Standard File Tool Set is with the $GetFile call. The $GetFile routine displays a standard, predesigned dialog box and allows the IIGS operator to use the dialog to open and load the selected file. With $GetFile, the calling program can specify where the dialog box will be placed on the screen and the prompt that appears at the top of the box. The calling program can also filter the types of files to be displayed in the box. But the routine does not allow an application program to modify the appearance of the box. Programs that use a custom-designed dialog box must use another Standard File routine, $GetFile.

In the SF.S1 program, the $GetFile call loads files into memory. Listing 12-3 shows the section of the program that uses the $GetFile call.

The $GetFile Call

As listing 12-3 illustrates, the $GetFile call takes five parameters:

- A 1-word integer that specifies the horizontal screen coordinate of the upper left corner of the dialog box.
- Another 1-word integer that specifies the vertical screen coordinate of the upper left corner of the dialog box.
- A pointer to a Pascal-style string that is printed as a prompt inside the dialog box.
- A pointer to a "filter process" that can provide special instructions to the Dialog Manager about the handling of files. If such a process is used, it must be defined by the calling program. Instructions for designing a filter process are in the Apple IIgs Toolbox Reference. No filter process is used in the SF.S1 program.
- A pointer to a reply record, a specially designed record that the $GetFile call fills with information before it returns. Listing 12-4 shows the reply record used in the SF.S1 program.
LoadIt
START
using WindowData
using IOData

jsr Repaint

PushWord #20 ; upper x coordinate
PushWord #20 ; upper y coordinate
PushLong #PromptPtr
PushLong #0 ; no filter process
PushLong #TypeListPtr ; file types to display
PushLong #ReplyRecord ; defined in iodata
_SFGetFile

lda GoodFlag
bne cont
jmp return ; user canceled operation

cont
lda #FName
sta NamePtr
lda #$FName
sta NamePtr+2

lda WinOHandle
ldx WinOHandle+2
jsr Deref
sta PicDestIn
stx PicDestIn+2
jsr LoadOne

PushLong NamePtr
PushLong WinOPtr
_SetWTitle ; update window title

lda WinOHandle
ldx WinOHandle+2
jsr Unlock

PushLong NamePtr ; update 'title' menu item
PushWord #262 ; menu item number
_SetMItemName ; update name of item
PushWord #0
PushWord #0
PushWord #3 ; menu number
_CalcMenuSize ; update width of items
return        rts  
PromptPtr   str 'Load Picture:
TypeListPtr anop
NumEntries  dc i'1'
FileType1   dc h'c1'

END

Listing 12-4
Reply record used by SFGetFile call

<table>
<thead>
<tr>
<th>ReplyRecord</th>
<th>anop</th>
</tr>
</thead>
<tbody>
<tr>
<td>GoodFlag</td>
<td>ds 2</td>
</tr>
<tr>
<td>FType</td>
<td>dc ds 2 ; in SF.S1, will always be $C1</td>
</tr>
<tr>
<td>AuxFType</td>
<td>dc i'0' ; #0</td>
</tr>
<tr>
<td>FName</td>
<td>ds 15</td>
</tr>
<tr>
<td>FullPathName</td>
<td>ds 128</td>
</tr>
</tbody>
</table>

An SFGetFile reply record has five fields:

- A 1-word flag, called GoodFlag in the SF.S1 program, that holds a Boolean value. The flag is cleared to 0 if the user aborts the SFGetFile operation by pressing a Cancel button inside the dialog box. If the user does not press the Cancel button, the flag is set.

- A 1-word parameter that contains the type of file selected by the user. This parameter, like all other parameters in a reply record, is filled in by the SFGetFile call.

- A 1-word parameter that contains the auxiliary file type of the file selected by the user.

- A Pascal-style string that contains the name of the file selected by the user. The length of this parameter can be set by the application that calls SFGetFile. The most common length for this parameter is 15 bytes.

- Another Pascal-style string that contains the full pathname of the file selected by the user. The length of this parameter must be set by the application that calls SFGetFile. The recommended length for the parameter is 128 bytes.

All the information returned by the SFGetFile call is placed in its reply record; it does not push any values onto the stack.

In the SF.S1 program, a pointer to the file name returned by SFGetFile is loaded into the NamePtr variable. The handle of the screen buffer used in the program is then dereferenced (converted into a pointer), and the LoadOne subroutine loads the file chosen by the user into the screen buffer.
Next, the program makes the Window Manager call SetWTi tle to update the name of the window being displayed on the screen. Then the Menu Manager routines SetMItemName and CalcMenuSi ze replace the menu item Untitled with a menu item that displays the name of the selected window.

The SFPutFile Call

The simplest way to save a file using the Standard File Tool Set is with the call SFPutFILE. The SFPutFile routine, like the SFGetFile routine, displays a standard, predesigned dialog box. The Iko operator can then use the dialog to save the selected file on a disk. With SFPutFile, like SFGetFile, the calling program can specify the location of the dialog box on the screen, the prompt that appears at the top of the box, and the types of files to be displayed in the box. But it does not permit an application program to modify the design of the box. Programs that use a custom-tailored dialog box must use another Standard File routine, SFPPutFILE.

In the SF.S1 program, files are saved using the SFPutFILE call. Listing 12–5 shows how the call is used in the program.

Listing 12–5
SFPutFile call in SF.S1

```
SaveIt START
Using WindowData
Using IOData

PushWord #20 ; upper X coordinate
PushWord #20 ; upper Y coordinate
PushLong #TopMsg
PushLong #Win0Title
PushWord #15 ; max length of filename
PushLong #ReplyRecord ; defined in iodata
_SFPPutFile

lda GoodFlag
bne cont
jmp return ; user canceled operation

cont lda FName
sta NamePtr
lda # FName
sta NamePtr+2

lda WinOHan dle
ldx WinOHan dle+2
jsr Dere
sta PicDestOut
stx PicDestOut+2
```
The IIGS Toolbox

```
jsr SaveOne
PushLong NamePtr
PushLong WinOPtr
_SetWTitLe ; update window title

lda WinOHandle
ldx WinOHandle+2
jsr Unlock
PushLong NamePtr ; update 'title'menu item
PushWord #262 ; menu item number
_SetMItemName ; update name of item
PushWord #0
PushWord #0
PushWord #3 ; menu number
_CalcMenuSize ; update width of items

return rts
TopMsg str 'Type name of picture:'

END
```

SFPutFile, like SFGetFile, takes five parameters. There are some differences, however, between the parameter sequences used by the two calls. The parameters that must be passed to the SFPutFile call are

- A 2-byte integer that specifies the horizontal screen coordinate of the upper left corner of the dialog box.
- Another 2-byte integer that specifies the vertical screen coordinate of the upper left corner of the dialog box.
- A pointer to a Pascal-style string that is printed as a prompt inside the dialog box.
- A pointer to a Pascal-type string that can be used to specify a default file name. If a pointer is specified, the string that is pointed to is printed in a line edit item inside the default box. You can then save that file by clicking the mouse button inside an OK box or pressing the Return key. If you want to save another file, the default string can be erased or edited using standard line edit techniques. If a 0 is passed in this parameter, a default string is not printed on the screen.
- A pointer to the same kind of five-field reply record used by the SFGetFile call.
After the SFPutFile routine is called in the SF.S1 program, the LoadOne subroutine loads the file selected by the user into the program’s window buffer. The name of the window is updated, and the menu is modified so that it displays the new window’s name.

The SF.S1 Program

The sample program in this chapter, SF.S1, is an expanded version of the DIALOG.S1 program created in chapter 11. To convert DIALOG.S1 into SF.S1, the following modifications are necessary:

1. Edit the heading of the program so that it looks like the one shown in listing 12–6.
2. Following the program segment labeled EventLoop, insert the segments shown in listing 12–7. These segments are the heart of the SF.S1 program. They load and save files and control the Standard File Tool Set.
3. Replace the data segment labeled MenuData with the segment shown in listing 12–8.
4. At the end of the program, add the data segment shown in listing 12–9.
5. Make sure that the latest version of INITQUIT.S1 is on the same disk that holds your SF.S1 source code. The COPY directive at the end of the SF.S1 combines the SF.S1 program and the INITQUIT.S1 program.

Listing 12–6
SF.S1 heading segment

* SF.S1 *

*** A FEW ASSEMBLER DIRECTIVES ***

Title 'SF'

ABSADDR on
LIST off
SYMBOL off
65816 on
mcopy SF.macros

KEEP SF
The IIgs Toolbox

Listing 12-7
SF.S1 new segments

* LOADIT: ROUTINE TO LOAD A PICTURE FROM DISK *

LoadIt

START
using WindowData
using IOData

jsr Repaint

PushWord #20 ; upper x coordinate
PushWord #20 ; upper y coordinate
PushLong #PromptPtr
PushLong #0 ; no filter process
PushLong #TypeListPtr ; file types to display
PushLong #ReplyRecord ; defined in iodata
_SFGetFile

lda GoodFlag
bne cont
jmp return ; user canceled operation

cont

lda #FName
sta NamePtr
lda #'FName
sta NamePtr+2

lda WinHandle
ldx WinHandle+2
jsr Deref
sta PicDestIn
stx PicDestIn+2
jsr LoadOne

PushLong NamePtr
PushLong WinOPtr
_setWTitle ; update window title

lda WinHandle
ldx WinHandle+2
jsr Unlock

PushLong NamePtr ; update 'title' menu item
PushWord #262 ; menu item number
_setMItemName ; update name of item
PushWord #0
PushWord #0
PushWord #3 ; menu number
_CalcMenuSize ; update width of items
return rts

PromptPtr str 'Load Picture:

TypeListPtr anop
NumEntries dc i'1'
Filetype1 dc h'c1'

END

*      *
*      SAVEIT: ROUTINE TO SAVE A PICTURE TO DISK      *
*

SaveIt START
Using WindowData
Using IOData

PushWord #20 ; upper X coordinate
PushWord #20 ; upper Y coordinate
PushLong #TopMsg
PushLong #WinOTitle
PushWord #15 ; max length of file name
PushLong #ReplyRecord ; defined in iodata
_SFPutFile

 lda GoodFlag 
bne cont
 jmp return ; user canceled operation

cont
 lda #FName 
sta NamePtr
 lda `FName
 sta NamePtr+2

 lda WinOHandle
ldx WinOHandle+2
jsr Deref
sta PicDestOut
stx PicDestOut+2
jsr SaveOne

PushLong NamePtr
PushLong WinOPtr
_SetWTitles ; update window title

lda WinOHandle
ldx WinOHandle+2
jsr Unlock

PushLong NamePtr ; update 'title' menu item
PushWord #262 ; menu item number
_SetMItemName ; update name of item

PushWord #0
PushWord #0
PushWord #3 ; menu number
_CalcMenuSize ; update width of items

return rts

TopMsg str 'Type name of picture:'

END

* * LoadOne
* Loads the picture whose pathname is passed in NamePtr to address
* passed in PicDestIN
*

LoadOne START using IOData

_Open OpenParams
bcc cont1
ErrorCheck 'Could not open picture file.'

cont1 anop
lda OpenID
sta ReadID
sta CloseID

_Read ReadParams
bcc cont2
ErrorCheck 'Could not read picture file.'
12—The Standard File Operations Tool Set

cont2

anop

_Close CloseParams

clc

rts

END

* *
* SaveOne
* Saves the picture whose pathname is passed in NamePtr from address
* passed in PicDestOUT
*

SaveOne START
using IOData

lda NamePtr
sta NameC
sta NameD
lda NamePtr+2
sta NameC+2
sta NameD+2

_Destroy DestParams

lda #$c1 ; SuperHiRes picture type
sta CType
lda #$0 ; standard type = 0
sta CAux

_Create CreateParams
bcc cont0
ErrorCheck 'Could not create pic file.'

cont0

_Open OpenParams
bcc cont1
ErrorCheck 'Could not open pic file.'

cont1
anop
lda OpenID
sta WriteID
sta CloseID

_Write WriteParams
bcc cont2
ErrorCheck 'Could not write to pic file.'
The I Gas Toolbox

cont2
    anop
    _Close CloseParams
    clc
    rts

    END

Listing 12–8
SF.S1 new MenuData segment

* Menu Data *

MenuData   DATA
Return     equ 13
Menu1      dc c’>L@\XN1’,i1’RETURN’
dc c’ LA Window Program \N257’,i1’RETURN’
dc c’.
Menu2      dc c’>L File \N2’,i1’RETURN’
dc c’ LNew \N258V’,i1’RETURN’
dc c’ LLoad \N259’,i1’RETURN’
dc c’ LSave \N260V’,i1’RETURN’
dc c’ LQuit\N261’,i1’RETURN’
dc c’.
Menu3      dc c’>L Windows \N3’,i1’RETURN’
dc c’ LUntitled \N262’,i1’RETURN’
dc c’.

   END

MenuTable  DATA

* Menu 1 (apple)
dc i’ignore’ ; one for the NDAs
dc i’ignore’ ; ’a window program’

* Menu 2 (file)
dc i’Repaint’ ; ’doWinO’ (new window)
dc i’LoadIt’
dc i’SaveIt’
dc i’doQuit’ ; quit item selected
Menu 3 (windows)
dc 'doWin0'
; 'untitled'

END

Listing 12-9
SF.S1 IOData segment

IOData DATA

ReplyRecord anop
Goodflag ds 2
FType dc i'193' ; $c1
AuxFType dc i'0' ; #0
FName ds 15
FullPathName ds 128

CreateParams anop
NameC dc i'40'
dc i2'$00C3' ; DRNWR
 CType dc i2'$00C1' ; super high-res graphics
CAux dc i4'$00000000'
; Aux
dc i2'$0001' ; type
dc i2'$0000' ; create date
dc i2'$0000' ; create time

DestParams anop
NameD dc i'40'

OpenParams anop
OpenID ds 2
NamePtr ds 4
ds 4

ReadParams anop
ReadID ds 2
PicDestIN ds 4
dc i4'$8000' ; this many bytes
ds 4 ; how many xfered
The SF.C Program

Listing 12–10 is a C language version of the SF.SI program. Designed to be used with the include file INITQUIT.C, it works almost exactly like the SF.SI program.

In the C version of the SF program, files are not loaded and saved using ProDOS calls, as they are in the assembly language version. Instead, SF.C uses four C library routines: Open, Close, Read, and Write. These routines are called in the LoadIt and SaveIt segments of the program.

The Open function returns an integer, known as a file descriptor, for each file successfully opened. If the call fails, it returns -1. In the SF.C program, you test the value returned by Open. If the value is -1, a dialog window appears on the screen and tells the user an I/O error has occurred. Then the user can try to continue or quit. This dialog is created and displayed in the BadIO segment of the program.

The event loop of the program is the same as the one that appeared in the DIALOG.C program in chapter 11. The DoMenus section is expanded to accommodate some new menu choices, but the changes need little explanation.

There are also changes in the way window titles are selected and displayed. These modifications are necessary because window titles can change in the SF.SI program. Although there may be a more elegant way to accommodate the shifting of window titles, calling HideWindow and then ShowWindow does the job.

Also, the File menu selection in SF.SI does not conform strictly to the usual conventions for saving and loading files. For example, in the SF.SI program, you can use the menu selections New, Load, or Quit without saving first—and you can thus wipe out the picture currently on the screen without warning. Because SF.SI is a tutorial program, we decided to forego fixing that bug to avoid adding more complexity to the program.

One feature we did add was to disable the menu selection Save when no window is open. Disabling an item lets the user know “that can’t be done right now,” and ensures that TaskMaster does not return the constant that represents the disabled item in the wmTaskData field.
Listing 12-10
SF.C program

#include "initquit.c"
#include <prodos.h>
#include <string.h>
#include <fcntl.h>

Boolean done = false;
WmTaskRec myEvent;

/******************************************
/* Data and routine to create menus */
******************************************/

/*! Set up menu strings. Because C uses \ as an escape character, we use two when we want a \ as an ordinary character. The \ at the end of each line tells C to ignore the carriage return. This lets us set up our items in an easy-to-read vertical alignment. */

char *menu1 = "\n>Standard File Program \n257\r
.",

char *menu2 = "\n>File \n2\r
 LNew \n258\r
 LOpen #\n259\r
 LSave \n260\r
 LQuit #\n261\r
.",

char *menu3 = "\n>Windows \n\n Untitled \n262\r
.",

#define NEW_ITEM 258
#define OPEN_ITEM 259
#define SAVE_ITEM 260
#define QUIT_ITEM 261 /* these will help us check menu item numbers */
#define TITLE_ITEM 262

BuildMenu()
{
    InsertMenu(NewMenu(menu3),0);
    InsertMenu(NewMenu(menu2),0);
The JIGS Toolbox

InsertMenu(NewMenu(menu1),0);
FixMenuBar();
DrawMenuBar();
DisableMItem(SAVE_ITEM); /* save is disabled until a window is drawn */

ToString

%%%%%%%%%%%%%%%
/* Data structures and routines to set up and refresh */
/* offscreen drawing environment */
%%%%%%%%%%%%%%%

LocInfo picOLocInfo = {mode320,
    NULL, /* space for pointer to pixel image */
    160, /* width of image in bytes = 320 pixels */
    0,0,200,320 /* frame rect */};

Rect screenRect = {0,0,200,320};
GrafPort picOPort;

#define IMAGE_ATTR attrLocked+attrFixed+attrNoCross+attrNoSpec+attrPage

PicOSetup() /* called once by MakeWindow at start of program */
{
    GrafPortPtr thePortPtr;
    picOLocInfo.ptrToPixImage = *(NewHandle(0x8000L,myID,IMAGE_ATTR,NULL));
    thePortPtr = GetPort();
    OpenPort(&picOPort);
    SetPort(&picOPort);
    SetPortLoc(&picOLocInfo);
    ClipRect(&screenRect);
    EraseRect(&screenRect);
    SetPort(thePortPtr);
}

ErasePicO()
{
    GrafPortPtr oldPortPtr;

    oldPortPtr = GetPort();
    SetPort(&picOPort);
    ClipRect(&screenRect);
    EraseRect(&screenRect);
    SetPort(oldPortPtr);
}
/* Data and routines for handling Open and Save calls */

#define O_PICLOAD O_RDONLY+O_BINARY
#define O_PICSAVE O_WRONLY+O_CREAT+O_BINARY+O_TRUNC

SFReplyRec file = {0,193}; /* int 2 fields, rest are 0'd */
char curpath[130]; /* place for C string version of pathname */
Byte typelist[2] = {1,193}; /* we only want to open hi-res pictures */
FileRec fileInfo = {file.fullPathname}; /* initialize first field */

LoadIt()
{
    int filedes;
    char oldTitle[16];

    strncpy(oldTitle,file.filename,16); /* save title in case load fails */

    SFGetFile(20,20,"pLoad Picture:")NULL,typelist,&file);
    if(file.good) {
        p2cstr(strncpy(curpath,file.fullPathname,(int)*file.fullPathname+1));
        if((filedes = open(curpath,O_PICLOAD)) != -1) {
            read(filedes,picOLocInfo.ptrToPixImage,Ox8000);
            close(filedes);
            SetMItemName(file.filename,262);
            CalcMenuSize(0,0,3);
            RenewWind();
        } else {
            BadIO(); /* load failed, put up message and restore title */
            strncpy(file.filename,oldTitle,16);
        }
    }
}

SaveIt(winPtr)
GrafPortPtr winPtr;
{
    int filedes;
    char oldTitle[16];

    strncpy(oldTitle,file.filename,16); /* save title in case save fails */

    SFPutFile(20,20,"pType name of picture:"file.filename,15,&file);
if(file.good){
    p2cstr(strncpy(curpath,file.fullPathname,(int)*file.fullPathname+1));
    if((filedes = open(curpath,O_PICSAVE)) ! = -1){
        write(filedes,picOLocInfo.ptrToPixImage,0x8000);
        close(filedes);
        GET_FILE_INFO(&fileInfo); /* make file's type a hires picture */
        fileInfo.fileType = 0xC1;
        SET_FILE_INFO(&fileInfo);
        SetMItemName(file.filename,TITLE_ITEM);
        CalcMenuSize(0,0,3);
    } else { /* save failed, put up message and restore title */
        BadIO();
        strncpy(file.filename,oldTitle,16);
    }
} else strncpy(file.filename,oldTitle,16);
}

/**************************************************************************/
/* Data structures and routines to create window */
/**************************************************************************/

/* Initialize template for NewWindow */
#define FRAME fQContent+fMove+fZoom+fGrow+fBScroll+fRScroll+fClose+fTitle
ParamList template = { sizeof(ParamList),
    FRAME,
    file.filename, /* Pointer to title in SFReplyRec */
    0L, /* RefCon */
    26,0,188,308, /* Full size (O=default) */
    NULL, /* use default ColorTable */
    0,0, /* origin */
    200,320, /* data area height & width */
    200,320, /* max cont height & width */
    2,2, /* vertical & horizontal scroll increment */
    20,32, /* vertical & horizontal page increment */
    NULL, /* no info bar text string */
    0, /* info bar height = none */
    NULL, /* default def proc */
    NULL, /* no info bar draw routine */
    NULL, /* draw content must be filled in at run time */
    26,0,188,308, /* starting content rect */
}
-1L, /* topmost plane */
NULL /* let window manager allocate record */

/* Window's draw content routine */

doctor void DrawContent()
{
    PPToPort(&pic0Location,&(pic0Location.boundsRect),0,0,modeCopy);
}

GrafPortPtr winOPtr;

MakeWindow() /* Set default title str, complete template, make the window */
{
    strncpy(file.filename;"pUntitled",9); /* default name for new window */
    template.wContDefProc = DrawContent;
    winOPtr = NewWindow(&template);
}

RenewWind() /* a way to restore a window to its default size and position */
{ /* will not affect the contents unless ErasePicO is called first */
    EnableMItem(SAVE_ITEM);
    HideWindow(winOPtr);
    CloseWindow(winOPtr);
    winOPtr = NewWindow(&template);
    SelectWindow(winOPtr);
    ShowWindow(winOPtr);
}

******************************************************************************
/* Data and routines to set up and display dialogs */
******************************************************************************

char prompt[40] = "pUnable to load or save ";

ItemTemplate item1 = { 1,[8,129,22,179],buttonltem,"pStart\r",0,0,NULL ];
ItemTemplate item2 = { 2,[8,8,22,58],buttonItem,"pQuit\r",0,0,NULL };;
ItemTemplate item3 = { 3,[8,67,22,117],buttonltem,"pHelp\r",0,0,NULL };;
ItemTemplate item4 = { 4,[30,8,55,259],statText,prompt,0,0,NULL };;
ItemTemplate item5 = { 1,[8,129,22,179],buttonltem,"pOK",0,0,NULL };;

DialogTemplate dtemp = {{84,63,114,252],true,OL;&item1;&item2;&item3,NULL};
DialogTemplate iotemp = {{84,23,144,292],true,OL;&item5;&item2;&item4,NULL};

DoDialog() /* Create and display an opening dialog box */
{
GrafPortPtr dlgPtr;
Word hit;

dlgPtr = GetNewModalDialog(&dtemp);

while ((hit = ModalDialog(NULL) == 3);
done = (hit == 2); 
CloseDialog(dlgPtr);
}

BadIO()
{
GrafPortPtr dlgPtr;

strncat(prompt, file.filename + 1, *file.filename);
*prompt = 23 + *file.filename;

dlgPtr = GetNewModalDialog(&iotemp);

done = (ModalDialog(NULL) == 2);
CloseDialog(dlgPtr);
}

/*********************************************************************/
/* Main routine. Set up environment, call eventloop, and shut down */
/*********************************************************************/

main()
{
StartTools(); 
DoDialog(); 
BuildMenu(); 
MakeWindow(); 
PicOSetup();
EventLoop(); 
DisposeHandle(FindHandle(picOLocInfo.ptrToPixImage));
ShutDown();
}

/*********************************************************************/
/* Event loop and supporting routines */
/*********************************************************************/

EventLoop()
{
myEvent.wmTaskMask = OxOFFF;
while(!done)

switch ( TaskMaster(everyEvent,&myEvent)) {
case wInMenuBar:
DoMenus();
break;
case wInGoAway:
    DisableMItem(SAVE_ITEM);
    HideWindow(winOPtr);
    break;
case wInContent:
    Sketch();
}
}

DoMenus()
{
Word *data = (Word *)&myEvent.wmTaskData; /* address of item id */

switch(*data) {
    case QUIT_ITEM:
        done = true;
        break;
    case OPEN_ITEM:
        LoadIt();
        break;
    case SAVE_ITEM:
        SaveIt();
        HideWindow(winOPtr); /* Make sure the title gets updated */
        ShowWindow(winOPtr);
        break;
    case NEW_ITEM:
        ErasePicO();
        strncpy(file.filename, "\pUntitled", 9);
        RenewWind();
        break;
    case TITLE_ITEM:
        EnableMItem(SAVE_ITEM);
        SelectWindow(winOPtr);
        ShowWindow(winOPtr);
        break;
}
    HiliteMenu(false,*(&data + 1)); /* data + 1 is address of menu id */
}

Sketch() /* sketch into current port, and into offscreen port */
{
    Point mouseLoc;
    GrafPortPtr thePortPtr = (GrafPortPtr)myEvent.wmTaskData;
    Rect theRect;
mouseLoc = myEvent.wmWhere;

StartDrawing(thePortPtr); /* set up correct drawing coordinate system */
GetPortRect(&theRect); /* copy current port rect */
GlobalToLocal(&mouseLoc); /* get cursor pos in local coordinates */

MoveTo(mouseLoc); /* set pen position to mouse loc */
SetPort(&picOPort); /* switch to offscreen port */
ClipRect(&theRect); /* clip offscreen drawing to window's port rect */
MoveTo(mouseLoc); /* set offscreen pen to same location */
SetPort(thePortPtr); /* switch back to window's port */

while (StillDown(O)) {
    GetMouse(&mouseLoc); /* get new mouse coordinates */
    LineTo(mouseLoc); /* draw line in both ports */
    SetPort(&picOPort);
    LineTo(mouseLoc);
    SetPort(thePortPtr);
}
SetOrigin(0,0); /* restore normal coordinates */

One of the most remarkable features of the IIgs is its ability to synthesize music and sounds. Some reviewers have declared that the IIgs offers the finest sound-synthesizing capabilities of any computer in its class. So it's no wonder that the s in IIgs stands for sound.

You don't have to be a musician or an audio engineer to understand how the synthesizer built into the IIgs works. To write sound and music programs for the Apple IIgs, however, it doesn't hurt to know a little bit about how a music synthesizer produces sound. So, in the first part of this chapter, you take a brief look at some important facts about the science of sound and how the IIgs produces sound and music. Then you type, assemble, and run a program that turns your IIgs keyboard into a music synthesizer capable of producing an almost limitless variety of sounds.

The Characteristics of Sound

When you hear a sound from a musical instrument, four characteristics are combined to create the sound you perceive. These four characteristics are

- Volume, or loudness
- Frequency, or pitch
- Timbre, or sound quality
Dynamic range, or the difference in level between the loudest sound that can be heard and the softest sound that can be heard during a given period of time. This time period can range between the time it takes to play a single note and the length of a much longer listening experience, such as a musical performance or a complete musical recording.

Sound Hardware in the IIgs

To produce sounds that have these four characteristics—volume, frequency, timbre, and dynamic range—the IIgs is equipped with a pair of special-purpose sound chips. One is the digital oscillator chip, or DOC, and the other is the general logic unit, or GLU. Let’s take a closer look at these two processors.

The Digital Oscillator Chip

The digital oscillator chip, or DOC, is a sound-generating microprocessor designed by the Ensoniq sound synthesizer company. DOCs are used in Ensoniq synthsizers as well as in the IIgs. The basic sound-generating unit used by the DOC is a component called an oscillator. To produce a sound, an oscillator must step through a table of sound samples stored as digital numbers. This table must be supplied by the application program using the oscillator. It can be created while a program is running, or it can be stored on a disk and loaded into memory in advance.

The DOC contains thirty-two oscillators, but two are unavailable for use in application programs. One is always used as a clock, and another is reserved for future use. That leaves thirty oscillators, each of which can function independently. In practice, however, the DOC’s oscillators are used in pairs because it takes at least two oscillators to produce a continuous instrumental voice.

When two oscillators are used together to produce a sound, they form a functional unit called a generator. So, in normal use, the DOC has fifteen generators and thus is a 15-voice chip.

The DOC also has a component called an analog-to-digital converter, or ADC. The ADC makes it possible for the DOC to record a digital sample of an actual sound, so that the sound can be played back later from its digital sample. More information about this capability is in the *Apple IIgs Hardware Reference*.

The General Logic Unit

The general logic unit, or GLU, is a chip that interfaces the DOC processor and the IIgs system. It also enables the IIgs to produce sound in the same way as older Apple IIs: by toggling a single-bit switch that can make a speaker vibrate at various rates of speed. But thanks to the GLU, this method of producing sound is improved; its volume can now be software controlled.

In addition to its DOC and GLU chips, the IIgs has 64K of dedicated RAM used only for storing sound samples. Because this area of memory is used only by the DOC, it is sometimes referred to as DOC RAM.
Sound Tools in the Toolbox

The IIgs Toolbox contains three tool kits that make it possible to write sound and music programs without accessing the sound registers used by the DOC and the GLU directly. These three tool sets are the

- Sound Tool Set, which starts and stops sounds, sets sound volumes, performs read and write operations to and from DOC registers, and reads and writes data to and from DOC RAM.
- Note Synthesizer, a higher-level tool set that produces and controls musical notes. The Note Synthesizer can emulate the sound of virtually any musical instrument and can produce unique musical sounds with almost any characteristics desired.
- Note Sequencer, a still higher-level tool set that makes it easier to combine various notes, chords, note patterns, and rhythms into musical performances and compositions.

The sample program in this chapter, MUSIC.S1, uses the Sound Tool Set and the Note Synthesizer. It does not use the Note Sequencer because it is an interactive program. The MUSIC.S1 program appears at the end of this chapter.

More About the Science of Sound

Now that you know something about how the IIgs produces music and sound, you’re ready to take a closer look at the four primary characteristics of every sound: volume, frequency, timbre, and dynamic range.

**Volume**

If you’ve ever turned a volume knob on a radio, you know just about all you’ll need to know about volume to write sound and music programs for the IIgs.

In programs written using the Sound Tool Set, the volume of a sound is controlled using the Sound Tool call `SetSoundVolume`. In programs that use the Note Synthesizer, volume is expressed as a value ranging from 0 to 127 and is controlled by passing a parameter to the Note Synthesizer call `NoteOn`.

As you shall see later, the `NoteOn` call must be made every time a note is produced by the Note Synthesizer. In the MUSIC.S1 program, volume is controlled using the `NoteOn` call. You’ll see how this is done later in this chapter.

**Frequency**

The pitch of a musical note is determined by its frequency. In programs written using the IIgs Note Synthesizer, frequency is measured in semitones, or halftones. A semitone value ranges from 0 to 127, with 60 representing middle C.

The frequency of a note, like the note’s volume, can be established by passing a parameter to the Note Synthesizer call `NoteOn`. An example is provided later in this chapter.
Timbre

Timbre, or note quality, is sometimes illustrated with the help of a waveform. There are four basic varieties of waves: sine wave, square wave (or pulse wave), triangle wave, and sawtooth wave. But these four types of waves can be combined with each other, and with irregular wave patterns, in endless varieties.

To understand how waveforms work, you need to know a little about musical harmonics. So here is a crash course in music theory.

With the help of an electronic instrument, you can generate a tone that has just one pure frequency. But when a note is played on a musical instrument, more than one frequency is usually produced. In addition to a primary frequency, or a fundamental, there is usually a set of secondary frequencies called harmonics. It is this total harmonic structure that determines the timbre of a sound.

When a tone containing only a fundamental frequency is viewed on an oscilloscope, the pattern produced on the screen is a pure sine wave. When a flute is played, the waveform produced is very close to that of a pure sine wave. The waveform of a sine wave is shown in figure 13–1.

When harmonics are added to a tone, the result is a richer sound that produces what is sometimes called a triangle wave. Triangle waveforms, or waves that are close to triangle waveforms, are produced by instruments such as xylophones, organs, and accordions. Figure 13–2 is a triangle wave.

When still more harmonics are added to a note, other kinds of waves are formed. Harpsichords and trumpets, for example, produce a type of wave sometimes called a sawtooth wave. A piano generates a squarish kind of wave called a square wave or a pulse wave. A sawtooth wave is illustrated in figure 13–3, and a pulse wave is shown in figure 13–4.

Another kind of waveform that the DOC can produce is a noise waveform. A noise waveform creates a random sound output that varies with a frequency proportionate to that of an oscillator built into Voice 1. Noise waveforms are often used to imitate the sound of explosions, drums, and other nonmusical noises.
In programs written for the IIGs, waveforms can be created when needed—as they are in the MUSIC.S1 program—or they can be created and loaded into memory in advance. No matter how a waveform is created, though, it must be moved into DOC RAM before it can be used to produce a sound.

**Dynamic Range**

The dynamic range of a note—the difference in volume between its loudest sound level and its softest sound level—can be illustrated in many ways. To illustrate and control the dynamic ranges of notes, audio engineers sometimes use a device called an *ADSR envelope*, or attack-decay-sustain-release envelope. An ADSR envelope illustrates four distinct stages in the life of a note: four phases every note undergoes between the time it starts and the time it fades away. These four phases—attack, decay, sustain, and release—are shown in the ADSR envelope illustrated in figure 13–5.

**A Close Look at an ADSR Envelope**

As figure 13–5 shows, every note starts with an attack. The attack phase of a note is the length of time it takes for the volume of the note to rise from a level of zero to the note’s peak volume.

As soon as a note reaches its peak volume, it begins to decay. The decay phase of a note is the length of time it takes for the note to decay from its peak volume to a predefined sustain volume.

When the decay phase of a note ends, the note is usually sustained for a certain period of time at a certain volume. Then a release phase begins. During this final phase, the volume of the note drops from its sustain level back down to zero.

When the IIGS Note Synthesizer is used in a program, the ADSR envelope of each sound in the program can be set up by creating a data structure called an instrument record. Then, when a note is played, the address of this record can be passed as a parameter to the Note Synthesizer call NoteOn.
Initializing the Sound Tool Set and the Note Synthesizer

The Sound Tool Set and the Note Synthesizer, like most tools in the IIGs Toolbox, must be loaded and started before they can be used in a program. In programs that use both tool kits, the Sound Tool Set must be started first because the Note Synthesizer uses part of the Sound Tool Set's direct page.

In the MUSIC.S1 program, the Sound Tool Set is initialized in a program segment labeled SoundStartUp, and the Note Synthesizer is started in a segment labeled NoteStartUp.

SoundStartUp, the call that initializes the Sound Tool Set, is quite straightforward. It takes one parameter—a pointer to a direct page work-space—and returns with the carry clear if there is no error.

NoteStartUp, the call that initializes the Note Synthesizer, takes two parameters. The first parameter is a 2-byte update rate, which determines the rate at which sound envelopes are generated. Update rates are expressed in units of .4 cycles per second, or hertz. In the MUSIC.S1 program, the update rate passed to the NoteStartUp call is the decimal number 70, so the sound envelope used in the program is updated at a rate of 60 times a second, or 60 hertz.

The second parameter passed to the NoteStartUp call is a pointer to an interrupt-driven routine that can be used for note sequencing. No interrupts are used in the MUSIC.S1 program, so the value for this parameter is zero.

How the Note Synthesizer Works

When the Note Synthesizer is used in an application program, a sound generator must be allocated for each voice used in the program. The call to allocate a generator is AllocGen.

The AllocGen call takes two parameters: a 2-byte space to return a
result on the stack and a 1-word value to establish the priority of the generator being allocated.

This is how generator priorities work. Generator priorities can range from 0 to 128. When a generator has a priority of 0, it is free and thus can be allocated. If there are no free generators when a generator is to be allocated, the Note Synthesizer looks for the lowest-priority generator and "steals" it—if it has a priority of less than 128. If a generator has a priority of 128, it cannot be stolen.

When the AllocGen call returns, a generator number ranging from 0 to 13 is pushed onto the stack. Then, when a note is to be played by one of the DOC's fifteen generators, the generator can be referred to by its assigned number.

**NoteOn Call**

When all the generators needed by a program are allocated, the NoteOn call can be made each time a note is to begin, and the NoteOff call can be made each time a note is to end.

The NoteOn call takes four parameters:

- A 1-word generator number (the identification number assigned by the AllocGen call)
- A 1-word semitone number (a number ranging from 0 to 127, with the value 60 representing middle C)
- A 1-word volume parameter (a number ranging from 0 to 127)
- A 2-word pointer to an instrument record

The structure of an instrument record is described in the next section. The NoteOn call does not return any parameters.

**The Structure of an Instrument Record**

When the NoteOn call is used in a program, one of the parameters passed to it is an instrument record. The instrument record used in the MUSIC.S1 program is shown in table 13–1. The routine that plays notes using the instrument record is in the PlayNote segment of the program. The following paragraphs describe each of the fields shown in table 13–1.

The Envelope field of an instrument record is composed of up to eight linear segments. Each of these segments has a breakpoint value and an increment value, or slope. During each segment, the volume of the note being played ramps (increases or decreases) from its current value to its breakpoint value. The time that this process takes is determined by the increment value of the note's envelope.

The value of a breakpoint can range from 0 to 127. This range of values represents the level of a sound on a logarithmic scale, with each 16 steps changing the note's amplitude by 6 decibels (dB). The last breakpoint used in an envelope should have a value of 0.

Each increment value in the envelope field can range from 0 through 127. An increment is a value that is added to or subtracted from a note's current level at the update rate passed to the NoteOn call, thus changing its
frequency at a rate determined by its update rate. The sustain level of an envelope is created by setting an increment value to 0.

An increment is a 2-byte, fixed-point number, that is, a number that represents a fraction. Specifically, the fraction represented by an increment value is the value over 256. Thus, if an increment value is 1, it represents the fraction 1/256 and has to be added to a note’s current volume 256 times—over a total elapsed time of 2.56 seconds—to cause the volume of the note to go up by 1.

The ReleaseSegment field of an instrument record is a number ranging from 0 to 7. This number determines how many segments it takes for the release of a note to go down to 0. When the release phase diminishes to 0, the note ends.

The PriorityIncrement field of an envelope is a number subtracted from the envelope’s generator priority when the envelope reaches its sustain phase. Then, when the note reaches its release phase, its priority is cut in half. The priority of each allocated generator is also decremented by 1 each time a new generator is allocated. The purpose of this process is to ensure that the “oldest” active generators are “stolen” first when a new generator needs to be allocated.

The PitchBlendRange of an envelope is the number of semitones that a pitch is raised when its pitchwheel—a constantly incrementing value—reaches 127. The PitchBlendRange field controls a sound’s vibrato effect. There are only three valid values for this field: 1, 2, and 4.

The VibratoDepth field defines the initial depth of a note’s vibrato. Vibrato depth can range from 0 to 127, with a value of 0 meaning no vibrato will be used. The VibratoSpeed field, a value ranging from 0 to 255, controls the rate of vibrato oscillation. The next field, field 7, is reserved for future expansion.

Each of the digital oscillator chip’s generators is made up of a pair of oscillators. Each oscillator in a pair can be used to synthesize as many different kinds of sound waves as desired. In an instrument record, field 8, AWaveCount, tells how many kinds of waves are defined for the first oscillator.
in a pair. Field 9, BWaveCount, tells how many kinds of waves are defined for the second oscillator.

In an instrument record, a WaveList is a variable length array. Each element in a WaveList array has 6 bytes, divided into four fields. Fields 8 and 9 of an instrument record—the AWaveCount and BWaveCount fields—determine how many WaveList arrays the record contains.

The five fields in a WaveList array are:

- **TopKey** (1 byte). The highest semitone (ranging from 0 to 127) that a waveform will play. When a note is played by an instrument, the Note Synthesizer examines the TopKey field in each of the instrument's waveforms until it finds one that will play the requested note. Therefore, the waveforms listed in each wavelist should be arranged in an order of increasing TopKey values, and the last TopKey value in a wavelist should be 127.

- **WaveAddress** (1 byte). This field contains the high byte of the address of a waveform. This value is placed directly into a DOC register that holds a pointer to a waveform address. The waveform stored at the indicated address must be supplied by the program being executed.

- **WaveSize** (1 byte). This 1-byte field is placed directly in a DOC register that defines the size of the wave being accessed.

- **DOCMode** (1 byte). This field determines what mode the DOC uses to play the waveform listed. The most commonly used DOC mode is swap mode, in which two oscillators are used together to form a generator. DOC mode 0 is swap mode. More information on DOC modes are in the *Apple IIgs Hardware Reference*.

- **RelPitch** (2 bytes). This field is a 2-byte word that tunes the waveform in which it appears. The high byte of the word (the second byte of the field) is expressed in semitones, but can be a signed number. The low byte (the first byte of the field) is a value expressed in increments representing 1/256 of a semitone.

### The MUSIC Program

Listing 13–1 is a complete listing of the MUSIC.S1 program. Listing 13–2, MUSIC.C, is a C language version of the program. INITQUIT.C, listing 13–3, is an include file that handles disk input and output for MUSIC.C. All three listings appear at the end of this chapter.

Type, assemble, and run the MUSIC program, and it will turn your IIgs keyboard into the keyboard of a real sound synthesizer. The keys on the Tab row are the synthesizer’s white keys, and the keys on the numbers row are the black keys. The keyboard layout of the MUSIC synthesizer is illustrated in figure 13–6.

After you know how the IIgs produces sound, it isn’t difficult to figure out how the MUSIC.S1 program works. It loads and starts up the Sound Tool
Set and the Note Synthesizer, and then enters a loop that reads characters typed on the IIGs keyboard. In a segment labeled GetKey, the program constantly checks to see if the user has pressed a key on either of the top two rows of the keyboard. If such a key is pressed, the ASCII code of the typed character is converted into a musical semitone, and the program segment labeled PlayNote produces the appropriate musical sound. MUSIC.C is a fairly straightforward translation of the program into C.

Not the End

This brings us to the end of this book, but we have barely begun to explore the amazing capabilities of the Apple IIGs. If you have typed, assembled, and executed the Name Game program, and the programs designed to demonstrate the capabilities of the IIGs graphics and sound tools, you have all the supplies to hack your way into the IIGs jungle and see what lies beyond that first row of trees. So happy hunting!

MUSIC.S1, MUSIC.C, and INITQUIT.C Listings

Listing 13–1
MUSIC.S1 program

* 
* MUSIC.S1: Creating a Mini-Synthesizer
* 

    keep music
    65816 on
    absaddr on
    mcopy music.macros
    longi on
    longa on
The Sound of Music

13—The Sound of Music

Music START

phk
plb

jsr SoundStartup

jsr LoadSound

jsr NoteStartup

cli ; this seems to be necessary

PrintLn ' Your computer is now a mini-synthesizer.'
PrintLn ' The white keys are on the TAB row.'
PrintLn ' The black keys are on the number row.'
PrintLn ' Keep shift lock down; press space bar to quit.'

loop PushWord #0
PushWord #0 ; no echo
_ReadChar
isa $7F ; read key the user typed
pl a
and #$7F ; clear high bit
cmp #$20 ; space bar?
beq exit

jsr GetKey ; convert ASCII to a note
bcs loop ; if carry set, no action

jsr PlayNote ; call Note Synthesizer
bra loop

exit jsr Shutdown

QUIT QuitParams

QuitParams anop

dc i4'0'
dc i2'0'

END
***

GetKey START

short m,i
ldx #23 ; 24 keys, starting from zero
loop cmp Key,x ; look for key in table
beq foundit
dex
bpl loop
jmp nonote ; search over--no note found

foundit anop
txa
adc #$2A ; convert X reg content to a note
clc ; found note--clear carry
jmp fini

nonote sec ; no note found--set carry
fini long m,i
rts

Key
dc h'09 31 32 35 33 45 52 35 54'; ascii codes
dc h'36 59 55 38 49 39 4f 30 50 5b'
dc h'3d 5d 7f 3d'

END

*  
* Start up the tools we'll need  
*

SoundStartup START

_TLStartup
PushWord #0
_MMStartup
ErrorCheck 'Could not call Memory Manager'

pla
sta MyID
_MTStartup
ErrorCheck 'Could not call Misc Tools'

PushLong #ToolTable
_LoadTools
ErrorCheck 'Could not load sound tools'

360
*** GET SOME DIRECT PAGE SPACE AND START UP SOUND TOOLS ***

PushLong #0 ; room for handle
PushLong #$100 ; one page
PushWord MyID
PushWord #$C001 ; type: locked, fixed
PushLong #0
_NewHandle
ErrorCheck 'Not enough memory!'
pla
sta 0 ; using addresses $0000
pla
sta 2 ; and $0002
lda [O] ; on direct page
pha
_SoundStartup
ErrorCheck 'Could not start up sound tool'
rts

MyID ds 2
ToolTable dc i'1,25,0' ; one tool: #25, version 0
X
end

*  
* Load Sound  
*

LoadSound START

*  
* This routine creates a square wave, which approximates the  
* waveform created by a piano.  
*

ldx #0
lda #$40

SetMode8 ; use 8-bit accumulator
topedge sta WaveForm,x ; draw top edge of wave
inx
cpx #128
bne topedge
The IIGS Toolbox

lowedge anop ; draw low edge of wave
  lda #$C0
  sta WaveForm,x
  inx
  cpx #256
  bne lowedge

  SetMode16 ; restore 16-bit accumulator

  Now we'll move the wave over to the DOC, using the sound tools.

  PushLong #WaveForm ; arg1: src ptr
  PushWord #0 ; doc start address
  PushWord #$100 ; byte count
  _WriteRamBlock
  ErrorCheck 'writing wave'
  rts

WaveForm ds 256
END

  NoteStartup START
  PushWord #70 ; 60 Hz updates
  PushLong #0 ; no IRQ routine for me
  _NSStartup
  ErrorCheck 'Could not start up note synthesizer'
  rts
END

  Now we play the note

  PlayNote START
  using NoteData
  sta SemiTone

  PushWord #0 ; space for result
  PushWord #64 ; medium priority
  _AllocGen
ErrorCheck 'Could not allocate generator' pla sta GenNum

PushWord GenNum
PushWord SemiTone
PushWord #112 ; medium volume
PushLong #Piano ; ptr to piano definition
_NoteOn
ErrorCheck 'Problem with NoteOn call'

* Normally, we would wait a while before issuing a note off. But
* because a piano has a fast attack and a long release, that
* isn't necessary in this case.

PushWord GenNum
PushWord SemiTone
_NoteOff
ErrorCheck 'Problem with NoteOff calloscillators'

rts

SemiTone ds 2
GenNum ds 2

END

***

NoteData DATA

Piano  dc i1'127,0,127' ; env: sharp attack
dc i1'112,20,1'
dc i1'0,48,0'
dc i1'0,20,5'
dc i1'0,0,0'
dc i1'0,0,0'
dc i1'0,0,0'
dc i1'0,0,0'
; fill out 8 stages with 0's
dc i1'3'
; release segment
dc i1'32'
; priority inc
dc i1'2,0,0,0,1,1' ; pbrange,vibdep,vibf,spare3
The Ilgs Toolbox

* Multi-sampled piano waveforms.
* First oscillator does the attack; second does loop.
*
AWaveList dc i1'127,0,0,0,12' ; topkey,addr,size,ctrl,pitch

BWaveList dc i1'127,0,0,0,12'

END

* Routine that shuts down tools.
*
Shutdown START

NSURLShutdown
ErrorCheck 'Problem with Note Synthesizer shutdown'
NSURLShutdown
rts

END

Listing 13-2
MUSIC.C program

#include "initquit.c"

#define space 

EventRecord myEvent;
Word waveform[257];
Instrument piano = {127,0x7F00, /* envelope */
               112,0x0114,
               0,0x0030,
               0,0x0514,
               0,0x0000,
               0,0x0000,
               0,0x0000,
               0,0x0000,
               0,0x0000, /* end envelope */
               3,32,
               2,0,0,0,1,1,
               127,0,0,0,0x0C00, /* aWaveForm */
               127,0,0,0,0x0C00 /* bWaveForm */
};

/* Keys contain the letters in "piano keyboard" order. The backslashes */
/* are followed by the octal ASCII values of Tab, Delete, and Return. */

364
char keys[] = "\0111Q2W3ER5T6YU8I90DE\n\177\015";

main()
{
    StartTools();
    Prompt();
    LoadSound();
    asm {
        /* it is necessary to clear interrupts */
        cli;
    }
    NSStartUp(70,nil);
    err("\pUnable to start up Note Synthesizer.\r\r";

    EventLoop();
    NSShutDown();
    Shutdown();
}

LoadSound() /* it is more efficient to store words instead of bytes */
{
    int i;

    for (i=0;i<64;i++)
        waveForm[i] = Ox4040;
    for (i=64;i<128;i++)
        waveForm[i] = OxC0C0;

    WriteRamBlock (waveForm,0,Ox100);
    err("Error in WriteRamBlock");
}

Prompt()
{
    GrafOff();
    printf("Your computer is now a mini-synthesizer\n\n");
    printf("The white keys are on the tab row.\n\n");
    printf("The black keys are on the number row.\n\n");
    printf("Keep shift lock down: Press space bar to quit.\n\n";
}

#define KEYMASK keyDownMask+autoKeyMask

EventLoop()
{
    Boolean done = false;
    Word i;
    char theKey;
while (!done)
    if (GetNextEvent(KEYMASK,&myEvent)) {
        theKey = (char)(myEvent.message);
        if (theKey == space)
            done = true;
        else
            if ((i = findChar(keys, theKey)) < 24)
                PlayNote(i + 0x2A);
    }

int findChar(str, c) /* position of c in str, strlen if not present */
char *str;
char c;
{
    int i = 0;
    while(*str != c) {
        if(* (str++))
            i++;
        else
            break;
    }
    return i;
}

PlayNote(semiTone)
Word semiTone;
{
    Word genNum;
    NoteOn((genNum = AllocGen(0, 64)), semiTone, 112, &piano);
    NoteOff(genNum, semiTone);
}

Listing 13–3
INITQUIT.C program

#include <TYPES.H>
#include <PRODOS.H>
#include <LOCATOR.H>
#include <MEMORY.H>
#include <MISCTOOL.H>
#include <QUICKDRAW.H>
#include <EVENT.H>
#include <SOUND.H>
#include <NOTESYN.H>
#define MODE mode320 /* 640 graphics mode def. from quickdraw.h */
#define MaxX 320       /* max X for cursor (for Event Mgr) */
#define dpAttr attrLocked+attrFixed+attrBank /* for allocating direct page space */
#define err(str) if(_toolErr) SysFailMgr(_toolErr,str)

int  myID;        /* for Memory Manager. */
Handle zp;        /* handle for page 0 space for tools */
QuitRec qParms = {NULL,0};

int toolTable[] = {4,
  4, 0x0100, /* QD */
  6, 0x0100, /* Event */
  8, 0x0100, /* Sound */
  25, 0x0000 /* NoteSyn */
};

StartTools()       /* start up these tools: */
{
  TLStartUp();     /* Tool Locator */
  LoadEmUp();      /* load tools from disk */
  myID = MMStartUp(); /* Mem Manager */
  err("\pUnable to start up Memory Mgr.\r\r");
  MTStartUp();     /* Misc Tools */
  err("\pUnable to start up Misc. Tools\r\r");
  ToolInit();      /* start up the rest */
}

LoadEmUp()         /* load tools, prompt for boot disk if not present */
{
  Word response;
  Pointer volName;

  GET_BOOT_VOL(&volName);
  LoadTools(toolTable);
  while(_toolErr == volumeNotFound) {
    response = TLMountVolume(0,195,30,"\pPlease insert the disk",volName,"\pOK","\pCancel");
    if(response == 1)
      LoadTools(toolTable);
    else {
      TLShutDown();
      QUIT(&qParms);       /* try to exit gracefully */
    }
  }
}
err("Unable to load tools\r\n");
}

ToolInit() /* init the rest of needed tools */
{
    zp = NewHandle(0x500L, myID, dpAttr, OL); /* reserve 6 pages */
    err("Unable to allocate DP space\r\n");

    QDStartUp(int) *zp, MODE, 160, myID); /* uses 3 pages */
    err("Unable to start up QuickDraw.\r\n");
    EMStartUp(int) (*zp + 0x300), 20, 0, MaxX, 0, 200, myID);
    err("Unable to start up Event Mgr.\r\n");
    SoundStartUp(int) (*zp + 0x400));
    err("Unable to start up Sound Mgr.\r\n");
}

ShutDown() /* shut down all of the tools we started */
{
    GrafOff();
    SoundShutDown();
    EMSHutDown();
    QDShutDown();
    MTShutDown();
    DisposeHandle(zp); /* release our page 0 space */
    MMShutDown(myID);
    TLShutDown();
}
PART 3

Appendix
APPENDIX A

The 65C816 Instruction Set

This section is a complete listing of the 65C816 instruction set. It does not include pseudo-operations (also known as pseudo-ops, or directives), which vary from assembler to assembler. Tables A-1, A-2, and A-3 list the abbreviations used in this appendix.

Table A-1
Processor Status (P) Register Flags

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Flag</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>Negative (sign)</td>
</tr>
<tr>
<td>v</td>
<td>Overflow</td>
</tr>
<tr>
<td>b</td>
<td>Break</td>
</tr>
<tr>
<td>d</td>
<td>Decimal</td>
</tr>
<tr>
<td>i</td>
<td>Interrupt</td>
</tr>
<tr>
<td>z</td>
<td>Zero</td>
</tr>
<tr>
<td>c</td>
<td>Carry</td>
</tr>
<tr>
<td>m</td>
<td>Memory/accumulator select</td>
</tr>
<tr>
<td>e</td>
<td>Emulation</td>
</tr>
</tbody>
</table>

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### Table A-2
#### 65C816 Registers

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Register</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Accumulator or 8-bit accumulator</td>
</tr>
<tr>
<td>B</td>
<td>B register (high-order byte of 16-bit accumulator)</td>
</tr>
<tr>
<td>C</td>
<td>16-bit accumulator</td>
</tr>
<tr>
<td>X</td>
<td>X register</td>
</tr>
<tr>
<td>Y</td>
<td>Y register</td>
</tr>
<tr>
<td>P</td>
<td>Program counter</td>
</tr>
<tr>
<td>S</td>
<td>Stack pointer</td>
</tr>
<tr>
<td>M</td>
<td>Memory register</td>
</tr>
<tr>
<td>D</td>
<td>Direct page register</td>
</tr>
<tr>
<td>DBR (or B)</td>
<td>Data bank register</td>
</tr>
<tr>
<td>PBR (or K)</td>
<td>Program bank register</td>
</tr>
</tbody>
</table>

### Table A-3
#### Addressing Modes

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>#</td>
<td>Immediate</td>
</tr>
<tr>
<td>(a)</td>
<td>Absolute indirect</td>
</tr>
<tr>
<td>(a,x)</td>
<td>Absolute indexed indirect</td>
</tr>
<tr>
<td>(d)</td>
<td>Direct indirect</td>
</tr>
<tr>
<td>(d),y</td>
<td>Direct indirect indexed</td>
</tr>
<tr>
<td>(d,x)</td>
<td>Direct indexed indirect</td>
</tr>
<tr>
<td>(r,s),y</td>
<td>Stack relative indirect indexed</td>
</tr>
<tr>
<td>a</td>
<td>Absolute</td>
</tr>
<tr>
<td>a,x</td>
<td>Absolute indexed with X</td>
</tr>
<tr>
<td>a,y</td>
<td>Absolute indexed with Y</td>
</tr>
<tr>
<td>Ace</td>
<td>Accumulator</td>
</tr>
<tr>
<td>al</td>
<td>Absolute long</td>
</tr>
<tr>
<td>al,x</td>
<td>Absolute indexed long</td>
</tr>
<tr>
<td>d</td>
<td>Direct</td>
</tr>
<tr>
<td>d,x</td>
<td>Direct indexed with X</td>
</tr>
<tr>
<td>d,y</td>
<td>Direct indexed with Y</td>
</tr>
<tr>
<td>i</td>
<td>Implied</td>
</tr>
<tr>
<td>r</td>
<td>Program counter relative</td>
</tr>
<tr>
<td>r,s</td>
<td>Stack relative</td>
</tr>
<tr>
<td>rl</td>
<td>Program counter relative long</td>
</tr>
<tr>
<td>s</td>
<td>Stack</td>
</tr>
<tr>
<td>xya</td>
<td>Block move</td>
</tr>
<tr>
<td>[d]</td>
<td>Direct indirect</td>
</tr>
<tr>
<td>[d],y</td>
<td>Direct indirect indexed</td>
</tr>
</tbody>
</table>
The 65C816 Instruction Set

adc  

add with carry  

6502, 65C02, 65C816

Adds the contents of the accumulator to the contents of the effective address specified by the operand. If the P register's carry flag is set, a carry is also added to the result. The sum is stored in the accumulator.

If the accumulator is in 8-bit mode when the adc instruction is issued, two 8-bit numbers will be added, and the result of the operation is also 8 bits long. If the operation results in a carry, the carry flag is set.

If the accumulator is in 16-bit mode when the instruction is issued, two 16-bit numbers are added, and the result of the operation is also 16 bits long. If this operation results in a carry, the P register’s carry flag is set.

The 65C816 has no instruction for adding without a carry. The adc instruction is the only addition instruction available. The carry flag can be cleared, however, with a clc instruction prior to an addition operation, and then no carry is added to the result.

It is considered good programming practice to issue a clc instruction before beginning any addition sequence. Then a carry bit will not be added to the result by mistake. If the first operation in an addition sequence results in a carry, the carry is added to the next higher-order operation, and each intermediate result correctly reflects the carry from the previous operation.

If the decimal flag is set when an adc instruction is issued, the addition operation is carried out in binary coded decimal (BCD) format. If the decimal flag is clear, binary addition is performed.

In emulation mode, adc is an 8-bit operation. In native mode, it is a 16-bit operation, with the high-order byte situated in the effective address plus 1.

Flags affected: n, v, z, c
Registers affected: A, P

<table>
<thead>
<tr>
<th>Addressing Mode</th>
<th>Bytes</th>
<th>Opcode (hex)</th>
</tr>
</thead>
<tbody>
<tr>
<td>adc (d)</td>
<td>2</td>
<td>72</td>
</tr>
<tr>
<td>adc (d),y</td>
<td>2</td>
<td>71</td>
</tr>
<tr>
<td>adc (d,x)</td>
<td>2</td>
<td>61</td>
</tr>
<tr>
<td>adc (r,s),y</td>
<td>2</td>
<td>73</td>
</tr>
<tr>
<td>adc d</td>
<td>2</td>
<td>65</td>
</tr>
<tr>
<td>adc d,x</td>
<td>2</td>
<td>75</td>
</tr>
<tr>
<td>adc r,s</td>
<td>2</td>
<td>63</td>
</tr>
<tr>
<td>adc [d]</td>
<td>2</td>
<td>67</td>
</tr>
<tr>
<td>adc [d],y</td>
<td>2</td>
<td>77</td>
</tr>
<tr>
<td>adc #</td>
<td>2 (3)</td>
<td>69</td>
</tr>
<tr>
<td>adc a</td>
<td>3</td>
<td>6D</td>
</tr>
<tr>
<td>adc a,x</td>
<td>3</td>
<td>7D</td>
</tr>
</tbody>
</table>
and

**logical AND**

6502, 65C02, 65C816

Performs a binary logical AND operation on the contents of the accumulator and the contents of the effective address specified by the operand. See figure A-1. Each bit in the accumulator is ANDed with the corresponding bit in the operand. The result of the operation is stored in the accumulator.

<table>
<thead>
<tr>
<th>AND</th>
<th>0</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

Figure A-1

Truth table for AND

The **and** instruction is often used as a mask, to clear specified bits in a memory location. When used as a mask, the instruction compares each bit in a memory location with the corresponding bit in the accumulator. Each bit cleared in the memory location clears the corresponding bit in the accumulator. Bits set in the memory location have no effect on their corresponding bits in the accumulator. For example, the sequence

```
lda #$00FF
and MEMLOC
sta MEMLOC
```

clears the high-order byte in MEMLOC, while leaving the low-order byte unchanged.

The **and** instruction conditions the P register’s n and z flags. The n flag is set if the most significant bit of the result of the AND operation is set; otherwise, it is cleared. The z flag is set if the result is 0; otherwise, it is cleared.

In emulation mode, **and** is an 8-bit operation. In native mode, it is a 16-bit operation, with the high-order byte situated in the effective address plus 1.

Flags affected: n, z

Registers affected: A, P

<table>
<thead>
<tr>
<th>Addressing Mode</th>
<th>Bytes</th>
<th>Opcode (hex)</th>
</tr>
</thead>
<tbody>
<tr>
<td>and (d)</td>
<td>2</td>
<td>32</td>
</tr>
<tr>
<td>and (d),y</td>
<td>2</td>
<td>31</td>
</tr>
<tr>
<td>and (d),x</td>
<td>2</td>
<td>21</td>
</tr>
<tr>
<td>and (r,s),y</td>
<td>2</td>
<td>33</td>
</tr>
<tr>
<td>and d</td>
<td>2</td>
<td>25</td>
</tr>
<tr>
<td>and d,x</td>
<td>2</td>
<td>35</td>
</tr>
</tbody>
</table>
asl  

**arithmetic shift left 6502, 65C02, 65C816**

Shifts each bit in the accumulator or the effective address specified by the operand one position to the left. See figure A-2. A 0 is deposited into the bit 0 position, and the leftmost bit of the operand is forced into the carry bit of the P register. The result of the operation is left in the accumulator or the affected memory register. The `asl` instruction is often used in assembly language programs as an easy method for dividing by 2.

In emulation mode, `asl` is an 8-bit operation. In native mode, it is a 16-bit operation, with the high-order byte situated in the effective address plus 1.

Flags affected: n, z, c

Registers affected: A, P, M

![Figure A-2](image)

**Addressing Mode**  **Bytes**  **Opcode (hex)**

| asl Acc | 1 | 0A |
| asl d   | 2 | 06 |
| asl d,x | 2 | 16 |
| asl a   | 3 | 0E |
| asl a,x | 3 | 1E |

bcc  

**branch if carry clear 6502, 65C02, 65C816**

(Alias: `bct`.) Tests the P register’s carry flag. Executes a branch if the carry flag is clear. Results in no operation if the carry flag is set.

The destination of the branch must be within a range of \(-128\) to \(+127\) memory addresses from the instruction immediately following the `bcc` instruction.
The \texttt{bcc} instruction is used for three main purposes:

- To test the carry flag after an arithmetic operation
- To test a bit that has been moved into the carry flag using a rotate, shift, or transfer operation
- To make a programming decision based on a comparison of two values

When \texttt{bcc} tests the result of a comparison operation, it comes after a comparison instruction (\texttt{cmp}, \texttt{cpx}, or \texttt{cpy}). When two values are compared with a comparison instruction, data in memory is subtracted from data in the accumulator. This does not affect the value of the accumulator, but it conditions the carry flag as a result of the comparison. The carry flag can then be tested using \texttt{bcc}. If the value in the accumulator is less than the value of the operand, the carry is clear and a branch is taken.

If \texttt{bcc} results in a branch, a 1-byte signed displacement, fetched from the second byte of the instruction, is sign-extended to 16 bits and added to the program counter. When the address of the branch is calculated, the result is loaded into the program counter, transferring control to that location.

Because the meaning of \texttt{bcc} is not intuitively clear when the instruction is used as the result of a branch-after-compare operation, the APW assembler also accepts an alias: \texttt{blt}, which stands for \textit{branch on less than} and assembles into the same machine language opcode as \texttt{bcc}.

Flags affected: None
Registers affected: None

<table>
<thead>
<tr>
<th>Addressing Mode</th>
<th>Bytes</th>
<th>Opcode (hex)</th>
</tr>
</thead>
<tbody>
<tr>
<td>\texttt{r}</td>
<td>2</td>
<td>90</td>
</tr>
</tbody>
</table>

\textbf{bcs} \hspace{1cm} \textbf{branch if carry set} \hspace{1cm} 6502, 65C02, 65C816

(Alias: \texttt{bge}.) Tests the P register's carry flag. Executes a branch if the carry flag is set. Results in no operation if the carry flag is clear.

The destination of the branch must be within a range of \(-128\) to \(+127\) memory addresses from the address immediately following the \texttt{bcs} instruction.

The \texttt{bcs} instruction is used for three main purposes:

- To test the carry flag after an arithmetic operation
- To test a bit that has been moved into the carry flag using a rotate, shift, or transfer operation
- To make a programming decision based on a comparison of two values

When \texttt{bcs} tests the result of a comparison operation, it comes after a comparison instruction (\texttt{cmp}, \texttt{cpx}, or \texttt{cpy}). When two values are compared using a comparison instruction, data in memory is subtracted from data in
the accumulator. This does not affect the value of the accumulator, but it conditions the carry flag as a result of the comparison. The carry flag can then be tested using bcs. If the value in the accumulator is greater than or equal to the value of the operand, the carry is set and a branch is taken.

If bcs results in a branch, a 1-byte signed displacement, fetched from the second byte of the instruction, is sign-extended to 16 bits and added to the program counter. When the address of the branch is calculated, the result is loaded into the program counter, transferring control to that location.

Because the meaning of bcs is not intuitively apparent when the instruction is used as the result of a branch-after-compare operation, the APW assembler also accepts an alias: bge, which stands for branch on greater than or equal to and assembles into the same machine language opcode as bcs.

Flags affected: None
Registers affected: None

<table>
<thead>
<tr>
<th>Addressing Mode</th>
<th>Bytes</th>
<th>Opcode (hex)</th>
</tr>
</thead>
<tbody>
<tr>
<td>r</td>
<td>2</td>
<td>80</td>
</tr>
</tbody>
</table>

**beq**  
branch if equal  

Tests the P register's zero flag. Executes a branch if the zero flag is set—that is, if the result of the last operation which affected the zero flag was 0. Results in no operation if the zero flag is clear.

The destination of the branch must be within a range of \(-128\) to \(+127\) memory addresses from the address immediately following the beq instruction.

The beq instruction is used for several purposes:

- To test whether a value that has been pulled, shifted, incremented, or decremented is equal to 0
- To test the value of an index register to determine whether a loop has been completed
- To make a programming decision based on a comparison of two values

When beq tests the result of a comparison operation, it comes after a comparison instruction (cmp, cpX, or cpy). When two values are compared using a comparison instruction, data in memory is subtracted from data in the accumulator. This does not affect the value of the accumulator, but it conditions the carry flag as a result of the comparison. The zero flag can then be tested using beq. If the value in the accumulator is equal to the value of the operand, the zero flag is set and a branch is made.

If beq results in a branch, a 1-byte signed displacement, fetched from the second byte of the instruction, is sign-extended to 16 bits and added to the program counter. When the address of the branch is calculated, the result is loaded into the program counter, transferring control to that location.
Appendix A

Flags affected: None
Registers affected: None

<table>
<thead>
<tr>
<th>Addressing Mode</th>
<th>Bytes</th>
<th>Opcode (hex)</th>
</tr>
</thead>
<tbody>
<tr>
<td>r</td>
<td>2</td>
<td>F0</td>
</tr>
</tbody>
</table>

**bge**

*branch if carry set*

*bge* is not a 65C816 instruction, but an alias recognized by the APW assembler. When assembled, it generates the same machine language opcode as the assembly language instruction *bcs*. For further details, see *bcs*.

**bit**

*test memory bits against accumulator*

6502, 65C02, 65C816

Performs a binary logical AND operation on the contents of the accumulator and the contents of a specified memory location. The contents of the accumulator are not affected, but three flags in the P register are affected.

If any bits in the accumulator and the value being tested match, the z flag is cleared. If no match is found, the z flag is set. Thus, a *bit* instruction followed by a *bne* instruction can determine if there is a bit match between the accumulator and the value of the operand. Similarly, a *bit* instruction followed by a *beq* instruction detects a no-match condition.

Another result of the *bit* instruction, in all of its addressing modes except immediate, is that bits 6 and 7 of the value in memory being tested are transferred directly into the v and n flags of the P register. This feature of the *bit* instruction is often used in signed binary arithmetic. If a *bit* operation results in the setting of the n flag, the value tested is negative. If the operation results in the setting of the v flag, that indicates an overflow condition when signed numbers are used.

In the immediate addressing mode, the only P register flag affected by the *bit* instruction is the z flag.

Flags affected in all modes except immediate addressing mode: n, v, z
Flags affected in immediate addressing mode: z
Registers affected: P

<table>
<thead>
<tr>
<th>Addressing Mode</th>
<th>Bytes</th>
<th>Opcode (hex)</th>
</tr>
</thead>
<tbody>
<tr>
<td>bit d</td>
<td>2</td>
<td>24</td>
</tr>
<tr>
<td>bit d, x</td>
<td>2</td>
<td>34</td>
</tr>
</tbody>
</table>
blt  branch if less than

`blt` is not a 65C816 instruction, but an alias recognized by the APW assembler. When assembled, it generates the same opcode as the assembly language instruction `bce`. For further details, see `bce`.

bmi  branch on minus 6502, 65C02, 65C816

Tests the P register’s `n` flag. Executes a branch if the `n` flag is set. Results in no operation if the `n` flag is clear.

The destination of the branch must be within a range of $-128$ to $+127$ memory addresses from the address immediately following the `bmi` instruction.

In operations involving two’s complement arithmetic, `bmi` is often used to determine whether a value is negative. In logical operations, it is used to determine if the high bit of a value is set. It is sometimes used to detect whether short loops have counted down past 0.

If `bmi` results in a branch, a 1-byte signed displacement, fetched from the second byte of the instruction, is sign-extended to 16 bits and added to the program counter. When the address of the branch is calculated, the result is loaded into the program counter, transferring control to that location.

Flags affected: None
Registers affected: None

<table>
<thead>
<tr>
<th>Addressing Mode</th>
<th>Bytes</th>
<th>Opcode (hex)</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>r</code></td>
<td>2</td>
<td>30</td>
</tr>
</tbody>
</table>

bne  branch if not equal 6502, 65C02, 65C816

Tests the P register’s zero flag. Executes a branch if the zero flag is clear (if the result of the last operation which affected the zero flag was not zero). Results in no operation if the zero flag is set.

The destination of the branch must be within a range of $-128$ to $+127$ memory addresses from the address immediately following the `bne` instruction.

The `bne` instruction is used for several purposes:

- To test whether a value that has been pulled, shifted, incremented, or decremented is equal to zero
• To test the value of an index register to determine whether a loop has been completed
• To make a programming decision based on a comparison of two values

When `bne` tests the result of a comparison operation, it is used after a comparison instruction (`cmp`, `cpx`, or `cpy`). When two values are compared using a comparison instructions, data in memory is subtracted from data in the accumulator. This does not affect the value of the accumulator, but it conditions the carry flag as a result of the comparison. The zero flag can then be tested using `bne`. If the value in the accumulator is not equal to the value of the operand, the zero flag is set and a branch is made.

If `bne` results in a branch, a 1-byte signed displacement, fetched from the second byte of the instruction, is sign-extended to 16 bits and added to the program counter. When the address of the branch is calculated, the result is loaded into the program counter, transferring control to that location.

Flags affected: None
Registers affected: None

<table>
<thead>
<tr>
<th>Addressing Mode</th>
<th>Bytes</th>
<th>Opcode (hex)</th>
</tr>
</thead>
<tbody>
<tr>
<td>r</td>
<td>2</td>
<td>D0</td>
</tr>
</tbody>
</table>

**bpl**  

**branch on plus**  

6502, 65C02, 65C816

Tests the P register’s n flag. Executes a branch if the n flag is clear. Results in no operation if the n flag is set.

The destination of the branch must be within a range of −128 to +127 memory addresses from the address immediately following the `bpl` instruction.

In operations involving two’s complement arithmetic, `bpl` is often used to determine whether a value is negative. In logical operations, it is used to determine if the high bit of a value is clear.

If `bpl` results in a branch, a 1-byte signed displacement, fetched from the second byte of the instruction, is sign-extended to 16 bits and added to the program counter. When the address of the branch is calculated, the result is loaded into the program counter, transferring control to that location.

Flags affected: None
Registers affected: None

<table>
<thead>
<tr>
<th>Addressing Mode</th>
<th>Bytes</th>
<th>Opcode (hex)</th>
</tr>
</thead>
<tbody>
<tr>
<td>r</td>
<td>2</td>
<td>10</td>
</tr>
</tbody>
</table>

**bra**  

**branch always**  

65C02, 65C816

The `bra` instruction always results in a branch; no testing is done. There are three major differences between `bra` and the unconditional jump instruction `jmp`. 
Because signed displacements are used, a statement that uses the \texttt{bra} instruction is only 2 bytes long, compared with the 3-byte length of a statement containing a \texttt{jmp} instruction. Second, the \texttt{bra} instruction uses displacements from the program counter and is thus relocatable. Last, the destination of the branch must be within a range of $-128$ to $+127$ memory addresses from the address immediately following the \texttt{bra} instruction.

When the branch instruction is used, a 1-byte signed displacement, fetched from the second byte of the instruction, is sign-extended to 16 bits and added to the program counter. After the branch address is calculated, the result is loaded into the program counter, transferring control to that location.

Flags affected: None
Registers affected: None

<table>
<thead>
<tr>
<th>Addressing Mode</th>
<th>Bytes</th>
<th>Opcode (hex)</th>
</tr>
</thead>
<tbody>
<tr>
<td>\texttt{r}</td>
<td>2</td>
<td>80</td>
</tr>
</tbody>
</table>

\textbf{brk} \hspace{1em} \textit{break, or software interrupt}

Forces a software interrupt, usually passing control of the Apple IIgs to the monitor. In programs written for the 65C816, a \texttt{brk} instruction can be handled in two ways, depending on whether the processor is in native mode or emulation mode.

If the 65C816 is in native mode, the program bank register is pushed onto the stack. Next, the program counter is incremented by 2 and pushed onto the stack. This incrementation takes place so that a break instruction can be followed by a signature byte identifying which break in a program caused the program to halt.

After the program counter is incremented by 2 and placed on the stack, the program bank register is cleared to 0, and the program counter is loaded from a special \texttt{brk} vector situated at $00FFFE6$ and $00FFFE7$. (This vector exists only in native mode, not in emulation mode, and that is why there is no need for the P register to have a break flag when the 65C816 is configured for emulation mode. In emulation mode, a \texttt{brk} instruction sends a program to vector $00FE6$-$00FE7$ instead of setting a special flag.) After the break is executed, the P register's decimal flag is cleared to 0.

If the 65C816 is in emulation mode when a \texttt{brk} instruction is given, the program bank register is cleared to 0 and the program counter is loaded from a special \texttt{brk} vector situated at $00FFFE6$ and $00FFFE7$. The interrupt disable flag is then set, and the program counter is loaded from an interrupt vector at $FFFF$ and $FFFF$.

This is a different interrupt vector from the one the \texttt{brk} instruction uses when the 65C816 is in native mode. In native mode, the \texttt{brk} instruction does not have its own interrupt vector, as it does in emulation mode, but shares
one with hardware interrupts (IRQs). This shared vector is at memory addresses $FFFFE$ and $FFFFF$. So, after an interrupt occurs, the interrupt handling routine at $FFFFE-$FFFFF must pull the processor status register off the stack and check the b flag to determine whether program processing was halted by a software interrupt (brk) instruction or a hardware interrupt.

If the break was caused by a software interrupt, the flag is set. But hardware IRQs push the P register onto the stack with the b flag clear. So, if the b flag is not set, the program was halted by a hardware IRQ.

When the 65C816 is in native mode, the P register’s decimal flag is not modified by the brk instruction.

Flags affected in native mode: b and i

Flags affected in emulation mode: b, d, and i

Registers affected: None

<table>
<thead>
<tr>
<th>Addressing Mode</th>
<th>Bytes</th>
<th>Opcode (hex)</th>
</tr>
</thead>
<tbody>
<tr>
<td>i</td>
<td>2†</td>
<td>00</td>
</tr>
</tbody>
</table>

†brk is a 1-byte instruction, but increments the program counter by 2 before pushing it onto the stack.

**brl**

**branch always long**

65C816

The brl instruction, like the bra instruction, always causes a branch. But brl is a 3-byte instruction. The 2 bytes immediately following the opcode form a 16-bit signed displacement from the program counter. Thus, the destination of a brl instruction can be anywhere within the current 64K program bank.

After the destination address of the branch is calculated, the result is loaded into the program counter, transferring control to that address.

There are two major differences between the brl instruction and the jump instruction jmp. The brl instruction (like any other branch instruction) is relocatable, but the jmp instruction is not. Also, jmp executes one cycle faster than brl.

Flags affected: None

Registers affected: None

<table>
<thead>
<tr>
<th>Addressing Mode</th>
<th>Bytes</th>
<th>Opcode (hex)</th>
</tr>
</thead>
<tbody>
<tr>
<td>r</td>
<td>3</td>
<td>82</td>
</tr>
</tbody>
</table>

**bvc**

**branch if overflow clear**

6502, 65C02, 65C816

Tests the overflow (v) flag in the 65C816 P register. Executes a branch if the overflow flag is clear. Results in no operation if the overflow flag is set. This instruction is used primarily in operations involving signed numbers.
The destination of the branch must be within a range of $-128$ to $+127$ memory addresses from the address immediately following the \texttt{bvc} instruction.

The most common use for \texttt{bvc} is to detect whether there is an overflow from bit 6 to bit 7 in a calculation involving signed numbers. The instruction can also test bit 6 in a value that has been moved into the v flag by the \texttt{bit} instruction.

The v flag can be altered by the instructions \texttt{adc}, \texttt{sbc}, \texttt{clv}, \texttt{bit} (in all but immediate mode), \texttt{sep}, and \texttt{rep}. It is also one of the flags restored from the stack by the \texttt{plp} and \texttt{rti} instructions.

Flags affected: None
Registers affected: None

<table>
<thead>
<tr>
<th>bvs</th>
<th>\texttt{branch if overflow set}</th>
<th>6502, 65C02, 65C816</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tests the overflow (v) flag in the 65C816 P register. Executes a branch if the overflow flag is set. Results in no operation if the overflow flag is clear. This instruction is used primarily in operations involving signed numbers.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The destination of the branch must be within a range of $-128$ to $+127$ memory addresses from the address immediately following the \texttt{bvs} instruction.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The most common use for \texttt{bvs} is to detect if there is an overflow from bit 6 to bit 7 in a calculation involving signed numbers. The instruction can also test bit 6 in a value that is moved into the v flag by the \texttt{bit} instruction.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The v flag can be altered by the instructions \texttt{adc}, \texttt{sbc}, \texttt{clv}, \texttt{bit} (in all but immediate mode), \texttt{sep}, and \texttt{rep}. It is also one of the flags restored from the stack by the \texttt{plp} and \texttt{rti} instructions.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flags affected: None</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Registers affected: None</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>clc</th>
<th>\texttt{clear carry}</th>
<th>6502, 65C02, 65C816</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clears the carry bit of the processor status register. The \texttt{clc} instruction should be used prior to addition (\texttt{adc}) operations to make sure that the carry flag is clear before addition begins. It should also be used prior to the \texttt{xce} (exchange carry flag with emulation bit) instruction when the intent of the instruction is to put the 65C816 into native mode.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flags affected: c</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Registers affected: P</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Appendix A

<table>
<thead>
<tr>
<th>Addressing Mode</th>
<th>Bytes</th>
<th>Opcode (hex)</th>
</tr>
</thead>
<tbody>
<tr>
<td>i</td>
<td>1</td>
<td>18</td>
</tr>
</tbody>
</table>

**cld**

clear decimal mode

Puts the computer into binary mode (its default mode) so that binary operations (the kind most often used) can be carried out properly. When the decimal flag is set, adc and sbc calculations are carried out in binary coded decimal (BCD) mode.

It is a good practice to clear the decimal flag before beginning arithmetic operations that should be carried out in binary mode, in case the flag has been left in decimal mode following some previous decimal mode operation.

Flags affected: d

Registers affected: P

<table>
<thead>
<tr>
<th>Addressing Mode</th>
<th>Bytes</th>
<th>Opcode (hex)</th>
</tr>
</thead>
<tbody>
<tr>
<td>i</td>
<td>1</td>
<td>D8</td>
</tr>
</tbody>
</table>

**cli**

clear interrupt disable flag

6502, 65C02, 65C816

Enables hardware interrupts (IRQs) by clearing the P register’s interrupt disable (i) flag. (If the i flag is set, hardware interrupts are ignored.) When the 65C816 starts servicing an interrupt, it finishes the instruction currently executing and then pushes the program counter and the P register on the stack. It then sets the i flag and jumps to one of ten interrupt vectors on page $FF$ of bank 0. The routine that it finds there must determine the nature of the interrupt and handle it accordingly.

When the interrupt service routine ends with rti, the rti instruction pulls the P register off the stack and returns to the instruction following the one that was executed just before the interrupt began. The restored P register contains a cleared i flag, so cli is ordinarily not necessary. However, if the interrupt service routine is designed to service interrupts that occur while a previous interrupt is still being handled, other interrupt handling routines must be reenabled with a cli instruction.

The cli instruction is also used to reenable interrupts if they have been disabled to allow the execution of time critical code or other code that cannot be interrupted.

Flags affected: i

Registers affected: P
Addressing Mode | Bytes | Opcode (hex)
---|---|---
clv | i | 58

clear overflow flag 6502, 65C02, 65C816

Clears the P register’s overflow (v) flag by setting it to 0. Because the v flag is cleared by a nonoverflow result of an adc instruction, it is not usually necessary to clear it before an addition operation. So, until the advent of the bra (branch always) and brl (branch always—long) instructions, the most common use of the clv instruction was to force an unconditional branch with a sequence of code such as

```
clv
bvc SOMEPLACE
```

Now, the bra and brl instructions have made such sequences as this one unnecessary. It is up to you to find some useful function for the clv instruction.

Incidentally, there is no specific instruction for setting the v flag. It can, however, be set with the 65C02/65C816 instruction rep or by using a bit instruction with a mask that has bit 6 set.

Flags affected: v

Registers affected: P

Addressing Mode | Bytes | Opcode (hex)
---|---|---
cmp | i | B8

cmp 6502, 65C02, 65C816

Compares a specified literal number or the contents of a specified memory location with the contents of the accumulator. The n, z, and c flags of the status register are affected by this operation, and a branch instruction usually follows. The result of the operation thus depends on what branch instruction is used and whether the value in the accumulator is less than, equal to, or more than the value tested.

When a cmp instruction is issued, the contents of the specified memory location are subtracted from the accumulator. The result is not stored in the accumulator, but the n, z, and c flags are conditioned as follows.

The z flag is set if the result of the comparison is 0 and cleared otherwise. The n flag is set or cleared by the condition of the sign bit (bit 7) of the result. The c flag is set if the value in the accumulator is greater than or equal to the value in memory. A bcc instruction can then be used to detect if the
value in the accumulator is greater than the value in memory. The beq instruction can detect if the two values are equal. The bcs instruction can detect if the value in the accumulator is greater than or equal to the value in memory. A beq followed by bcs can detect if the value in the accumulator is greater than the value in memory.

Flags affected: n, z, c
Registers affected: P

<table>
<thead>
<tr>
<th>Addressing Mode</th>
<th>Bytes</th>
<th>Opcode (hex)</th>
</tr>
</thead>
<tbody>
<tr>
<td>cmp (d)</td>
<td>2</td>
<td>D2</td>
</tr>
<tr>
<td>cmp (d),y</td>
<td>2</td>
<td>D1</td>
</tr>
<tr>
<td>cmp (d,x)</td>
<td>2</td>
<td>C1</td>
</tr>
<tr>
<td>cmp (r,s),y</td>
<td>2</td>
<td>D3</td>
</tr>
<tr>
<td>cmp d</td>
<td>2</td>
<td>C5</td>
</tr>
<tr>
<td>cmp d,x</td>
<td>2</td>
<td>D5</td>
</tr>
<tr>
<td>cmp r,s</td>
<td>2</td>
<td>C3</td>
</tr>
<tr>
<td>cmp [d]</td>
<td>2</td>
<td>C7</td>
</tr>
<tr>
<td>cmp [d],y</td>
<td>2</td>
<td>D7</td>
</tr>
<tr>
<td>cmp #</td>
<td>2 (3)</td>
<td>C9</td>
</tr>
<tr>
<td>cmp a</td>
<td>3</td>
<td>CD</td>
</tr>
<tr>
<td>cmp a,x</td>
<td>3</td>
<td>DD</td>
</tr>
<tr>
<td>cmp a,y</td>
<td>3</td>
<td>D9</td>
</tr>
<tr>
<td>cmp al</td>
<td>4</td>
<td>CF</td>
</tr>
<tr>
<td>cmp al,x</td>
<td>4</td>
<td>DF</td>
</tr>
<tr>
<td>cmp i</td>
<td>2</td>
<td>02</td>
</tr>
</tbody>
</table>

**cop**

**coprocessor enable**

65C816

The cop instruction allows the 65C816 to turn control over to another processor, such as a math, graphics, or music chip. When the coprocessor completes its assignment, it can return control to the 65C816.

The cop instruction, much like a brk instruction, causes a software interrupt, but through a different vector: $00FFF4 and $00FFF5.

When a cop instruction is issued, the program counter is incremented by 2 and pushed onto the stack. This operation allows the programmer to follow cop with a signature byte that specifies which coprocessor handling routine to execute. Unlike the brk instruction, which makes a signature byte optional, the cop instruction requires a signature byte. Signature bytes from $80 through $FF are reserved by the Western Design Center, which designed the 65C816. Signature bytes in the range $00 through $7F are available for use in application programs.

There are some differences between the way cop works in emulation mode and native mode. When a cop instruction is used in emulation mode, the program counter is incremented by 2 and pushed onto the stack, the status register is pushed onto the stack, the interrupt disable flag is set, and the
The program counter is loaded from the emulation mode coprocessor vector at $FFF4-FFF5. Then, after the command is executed, the P register's d (decimal) flag is cleared.

When a cop instruction is issued in native mode, the program counter bank register is pushed onto the stack, the program counter is incremented by 2 and pushed onto the stack, the status register is pushed onto the stack, the interrupt disable flag is set, the program bank register is cleared to 0, and the program counter is loaded from the native mode coprocessor vector at $00FFE4–00FFE5. Then, after the instruction is issued, the d (decimal) flag is cleared.

Flags affected: d, i
Registers affected: P

<table>
<thead>
<tr>
<th>Addressing Mode</th>
<th>Bytes</th>
<th>Opcode (hex)</th>
</tr>
</thead>
<tbody>
<tr>
<td>i</td>
<td>2†</td>
<td>02</td>
</tr>
</tbody>
</table>

†cop is a 1-byte instruction, but the program counter is incremented by 2 before it is pushed onto the stack, allowing (in fact requiring) a signature byte to be used following the instruction.

cpa

cpa is not a 65C816 instruction, but an alias that the APW assembler recognizes as an alternate for the assembly language statement cmp a. For further details, see cmp.

cpx

compare with X register 6502, 65C02, 65C816

Compares a specified literal number or the contents of a specified memory location with the contents of the X register. The n, z, and c flags of the status register are affected by this operation, and a branch instruction usually follows. The result of the operation thus depends upon what branch instruction is used and whether the value in the X register is less than, equal to, or more than the value tested.

When a cpx instruction is issued, the contents of the specified memory location are subtracted from the value of the X register. The result is not stored in the X register, but the n, z, and c flags are conditioned as follows.

The z flag is set if the result of the comparison is 0 and cleared otherwise. The n flag is set or cleared by the condition of the sign bit (bit 7) of the result. The c flag is set if the value in the X register is greater than or equal to the value in memory. A bcc instruction can then be used to detect if the value in the X register is greater than the value in memory. A beq instruction can detect if the two values are equal. A bcs instruction can detect if the value in the X register is greater than or equal to the value in memory.
Appendix A

instruction followed by bcs can detect if the value in the X register is greater than the value in memory.
Flags affected: n, z, c
Registers affected: P

<table>
<thead>
<tr>
<th>Addressing Mode</th>
<th>Bytes</th>
<th>Opcode (hex)</th>
</tr>
</thead>
<tbody>
<tr>
<td>cpx d</td>
<td>2</td>
<td>E4</td>
</tr>
<tr>
<td>cpx #</td>
<td>2 (3)</td>
<td>E0</td>
</tr>
<tr>
<td>cpx a</td>
<td>3</td>
<td>EC</td>
</tr>
</tbody>
</table>

cpy

compare with Y register 6502, 65C02, 65C816

Compares a specified literal number or the contents of a specified memory location with the contents of the Y register. The n, z, and c flags of the status register are affected by this operation, and a branch instruction usually follows. The result of the operation thus depends upon what branch instruction is used and whether the value in the Y register is less than, equal to, or more than the value tested.

When a cpy instruction is issued, the contents of the specified memory location are subtracted from the value of the Y register. The result is not stored in the Y register, but the n, z, and c flags are conditioned as follows.

The z flag is set if the result of the comparison is 0 and cleared otherwise. The n flag is set or cleared by the condition of the sign bit (bit 7) of the result. The c flag is set if the value in the Y register is greater than or equal to the value in memory. A beq instruction can then be used to detect if the value in the Y register is greater than the value in memory. A bcc instruction can detect if the two values are equal. A bcs instruction can detect if the value in the Y register is greater than or equal to the value in memory. A beq instruction followed by bcs can detect if the value in the Y register is greater than the value in memory.

Flags affected: n, z, c
Registers affected: P

<table>
<thead>
<tr>
<th>Addressing Mode</th>
<th>Bytes</th>
<th>Opcode (hex)</th>
</tr>
</thead>
<tbody>
<tr>
<td>cpy d</td>
<td>2</td>
<td>C4</td>
</tr>
<tr>
<td>cpy #</td>
<td>2 (3)</td>
<td>C0</td>
</tr>
<tr>
<td>cpy a</td>
<td>3</td>
<td>CC</td>
</tr>
</tbody>
</table>

dea

dea is not a 65C816 instruction, but an alias that the APW assembler recognizes as an alternate for the assembly language statement dec a. For further details, see dec.
**dec**  
**decrement a memory location 6502, 65C02, 65C816**

Decrement the contents of a specified memory location by 1. It is important to note that `dec` does not affect the carry flag. Thus, if the value to be decremented is $00$, the result of the `dec` operation is $\text{FF}$.

Because `dec` does not change the carry flag, the carry flag cannot be used to test the outcome of a `dec` operation. A `dec` instruction does condition the n and z flags, however, so they can be used to test a value decremented by `dec`.

- Flags affected: n, z
- Registers affected: P

<table>
<thead>
<tr>
<th>Addressing Mode</th>
<th>Bytes</th>
<th>Opcode (hex)</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>dec Acc</code></td>
<td>1</td>
<td>3A</td>
</tr>
<tr>
<td><code>dec d</code></td>
<td>2</td>
<td>C6</td>
</tr>
<tr>
<td><code>dec d,x</code></td>
<td>2</td>
<td>D6</td>
</tr>
<tr>
<td><code>dec a</code></td>
<td>3</td>
<td>CE</td>
</tr>
<tr>
<td><code>dec a,x</code></td>
<td>3</td>
<td>DE</td>
</tr>
</tbody>
</table>

**dex**  
**decrement the X register 6502, 65C02, 65C816**

Decrement the contents of the X register by 1. It is important to note that `dex` does not affect the carry flag. Thus, if the value to be decremented is $00$, the result of `dex` is $\text{FF}$.

Because `dex` does not change the carry flag, the carry flag cannot be used to test the outcome of a `dex` operation. The `dex` instruction does condition the n and z flags, however, so they can be used to test a value decremented by `dex`.

- Flags affected: n, z
- Registers affected: P, M

<table>
<thead>
<tr>
<th>Addressing Mode</th>
<th>Bytes</th>
<th>Opcode (hex)</th>
</tr>
</thead>
<tbody>
<tr>
<td>i</td>
<td>1</td>
<td>CA</td>
</tr>
</tbody>
</table>

**dey**  
**decrement the Y register 6502, 65C02, 65C816**

Decrement the contents of the Y register by 1. It is important to note that `dey` does not affect the carry flag. Thus, if the value to be decremented is $00$, the result of `dey` is $\text{FF}$.

Because `dey` does not change the carry flag, the carry flag cannot be used to test the outcome of a `dey` operation. The `dey` instruction does condition the n and z flags, however, so they can be used to test a value decremented by `dey`. 
Flags affected: n, z
Registers affected: P, M

<table>
<thead>
<tr>
<th>Addressing Mode</th>
<th>Bytes</th>
<th>Opcode (hex)</th>
</tr>
</thead>
<tbody>
<tr>
<td>i</td>
<td>1</td>
<td>88</td>
</tr>
</tbody>
</table>

**eor** exclusive-OR with accumulator

Performs an exclusive-OR operation on the contents of the accumulator and a specified literal value or memory location. Each bit in the accumulator is EORed with the corresponding bit in the operand, and the result of the operation is stored in the accumulator. See figure A-3.

The eor instruction is often used as a mask, to set specified bits in a memory location. When used as a mask, the instruction compares each bit in a memory location with the corresponding bit in the accumulator. If one and only one of the two bits being compared is set, the corresponding bit in the accumulator is set. Otherwise, the corresponding bit in the accumulator is cleared.

When eor is used with a mask consisting of all ones—that is, a mask of $FFFF$ in native mode or a mask of $FF$ in emulation mode—each bit in the operand is reversed; that is, each set bit is cleared, and each cleared bit is set. So eor is used quite often to reverse the settings of the bits in a word or a byte.

Here is another useful characteristic of eor. When it is used on a value twice in succession and with the same operand, the value is changed to another value the first time the instruction is used, and it is converted back into its original value the second time the instruction is used. Because of this characteristic, the eor instruction is often used to encode values and then to restore them to their original states. To encode a value using eor, just perform an EOR operation on it using an arbitrary 1-byte key. Later, the value can be restored to its original state by performing another EOR operation using the same key.

The eor instruction conditions the P register’s n and z flags. The n flag is set if the most significant bit of the result of the EOR operation is set; otherwise, it is cleared. The z flag is set if the result is 0; otherwise, it is cleared.

In emulation mode, eor is an 8-bit operation. In native mode, it is a 16-bit operation, with the high-order byte situated in the effective address plus 1.

```
<table>
<thead>
<tr>
<th>EOR 0</th>
<th>EOR 1</th>
<th>EOR 0</th>
<th>EOR 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>
```

Figure A-3
Truth table for EOR
The 65C816 Instruction Set

Flags affected: n, z
Registers affected: A, P

<table>
<thead>
<tr>
<th>Addressing Mode</th>
<th>Bytes</th>
<th>Opcode (hex)</th>
</tr>
</thead>
<tbody>
<tr>
<td>eor (d)</td>
<td>2</td>
<td>52</td>
</tr>
<tr>
<td>eor (d),y</td>
<td>2</td>
<td>51</td>
</tr>
<tr>
<td>eor (d,x)</td>
<td>2</td>
<td>41</td>
</tr>
<tr>
<td>eor (r,s),y</td>
<td>2</td>
<td>53</td>
</tr>
<tr>
<td>eor d</td>
<td>2</td>
<td>45</td>
</tr>
<tr>
<td>eor d,x</td>
<td>2</td>
<td>55</td>
</tr>
<tr>
<td>eor r,s</td>
<td>2</td>
<td>43</td>
</tr>
<tr>
<td>eor [d]</td>
<td>2</td>
<td>47</td>
</tr>
<tr>
<td>eor [d],y</td>
<td>2</td>
<td>57</td>
</tr>
<tr>
<td>eor #</td>
<td>2 (3)</td>
<td>49</td>
</tr>
<tr>
<td>eor a</td>
<td>3</td>
<td>4D</td>
</tr>
<tr>
<td>eor a,x</td>
<td>3</td>
<td>5D</td>
</tr>
<tr>
<td>eor a,y</td>
<td>3</td>
<td>59</td>
</tr>
<tr>
<td>eor al</td>
<td>4</td>
<td>4F</td>
</tr>
<tr>
<td>eor al,x</td>
<td>4</td>
<td>5F</td>
</tr>
</tbody>
</table>

ina

ina is not a 65C816 instruction, but an alias that the APW assembler recognizes as an alternate for the assembly language statement inc a. For further details, see inc.

inc

increment memory 6502, 65C02, 65C816

Increments the contents of a specified memory location by 1. The inc instruction neither affects nor is affected by the carry flag. So, if a value being incremented is $FF, the result of the inc operation is $00. Because inc does not affect the carry flag, the result of an inc operation cannot be tested by checking the carry flag. It does condition the n and z flags, however, so they can be used to test the result of an inc operation.

Flags affected: n, z
Registers affected: M, P

<table>
<thead>
<tr>
<th>Addressing Mode</th>
<th>Bytes</th>
<th>Opcode (hex)</th>
</tr>
</thead>
<tbody>
<tr>
<td>inc Acc</td>
<td>1</td>
<td>1A</td>
</tr>
<tr>
<td>inc d</td>
<td>2</td>
<td>E6</td>
</tr>
</tbody>
</table>
Appendix A

\[
\begin{array}{|c|c|c|}
\hline
\text{Instruction} & \text{Addressing Mode} & \text{Address Size} \\
\hline
\text{inc d},x & i & 16 \text{ bits} \\
\text{inc a} & i & 16 \text{ bits} \\
\text{inc a},x & i & 24 \text{ bits} \\
\hline
\end{array}
\]

**incx**

**increment X register**

6502, 65C02, 65C816

Increments the contents of the X register by 1. The \text{incx} instruction neither affects nor is affected by the carry flag. So, if a value being incremented is $\text{FF}$, the result of the \text{incx} operation is $\text{00}$. Because \text{incx} does not affect the carry flag, the result of an \text{incx} operation cannot be tested by checking the carry flag. It does condition the \text{n} and \text{z} flags, however, so they can be used to test the result of an \text{incx} operation.

Flags affected: \text{n}, \text{z}

Registers affected: X, P

**iny**

**increment Y register**

6502, 65C02, 65C816

Increments the contents of the Y register by 1. The \text{iny} instruction neither affects nor is affected by the carry flag. So, if a value being incremented is $\text{FF}$, the result of the \text{iny} operation is $\text{00}$. Because \text{iny} does not affect the carry flag, the result of an \text{iny} operation cannot be tested by checking the carry flag. It does condition the \text{n} and \text{z} flags, however, so they can be used to test the result of an \text{iny} operation.

Flags affected: \text{n}, \text{z}

Registers affected: X, P

**jmp**

**jump to address**

6502, 65C02, 65C816

Causes program execution to jump to the address specified. When a \text{jmp} instruction is issued, the program counter is loaded with the target address, causing control of the program in progress to be shifted to that address. When \text{jmp} is used in the absolute addressing mode, its operand can be either 16 bits or 24 bits. If a 16-bit address is used, the destination of the jump can be anywhere within the current program bank. If a 24-bit address is used, the jump is referred to as a long jump, and its destination address can be anywhere within the address space of the IIIGs. When \text{jmp} carries out a long jump, it has the same result as the \text{jml} instruction.
Flags affected: None
Registers affected: None

<table>
<thead>
<tr>
<th>Addressing Mode</th>
<th>Bytes</th>
<th>Opcode (hex)</th>
</tr>
</thead>
<tbody>
<tr>
<td>jmp (a)</td>
<td>3</td>
<td>6C</td>
</tr>
<tr>
<td>jmp (a,x)</td>
<td>3</td>
<td>7C</td>
</tr>
<tr>
<td>jmp a</td>
<td>3</td>
<td>4C</td>
</tr>
<tr>
<td>jmp al</td>
<td>4</td>
<td>5C</td>
</tr>
</tbody>
</table>

jsl

**Jump to subroutine—long**

Jumps to a subroutine using long (24-bit) addressing. The jsl instruction takes a 24-bit operand. It pushes a 24-bit (long) return address onto the stack, then transfers control to the subroutine at the 24-bit address that is the operand. This return address is the address of the last instruction byte (the fourth instruction byte, or the third operand byte), not the address of the next instruction. It is the return address minus 1.

When you issue a jsl instruction, the current program counter bank is pushed onto the stack first. Then the high-order byte and the low-order byte of the address are pushed onto the stack in standard 6502/65C816 order, low byte first. The program bank register and the program counter are then loaded with the effective address specified by the operand, and control is transferred to the specified address.

Flags affected: None
Registers affected: None

<table>
<thead>
<tr>
<th>Addressing Mode</th>
<th>Bytes</th>
<th>Opcode (hex)</th>
</tr>
</thead>
<tbody>
<tr>
<td>al</td>
<td>4</td>
<td>22</td>
</tr>
</tbody>
</table>

jsr

**Jump to subroutine**

Causes program execution to jump to the address that follows the instruction. That address should be the starting address of a subroutine that ends with the rts instruction. When the program reaches the rts instruction, execution of the program returns to the next instruction after the jsr instruction that caused the jump to the subroutine.

When a jsr instruction is issued, the high-order byte and the low-order byte of the address are pushed onto the stack in standard 6502/65C816 order,
low byte first. The program counter is then loaded with the effective address specified by the operand, and control is transferred to the specified address.

Flags affected: None
 Registers affected: None

<table>
<thead>
<tr>
<th>Addressing Mode</th>
<th>Bytes</th>
<th>Opcode (hex)</th>
</tr>
</thead>
<tbody>
<tr>
<td>jsr (a,x)</td>
<td>3</td>
<td>FC</td>
</tr>
<tr>
<td>jsr a</td>
<td>3</td>
<td>20</td>
</tr>
</tbody>
</table>

**Ida**

*load the accumulator  6502, 65C02, 65C816*

Loads the accumulator with the contents of the effective address of the operand. The n flag is set if a value with the high bit set is loaded into the accumulator. The z flag is set if the value loaded into the accumulator is 0.

In emulation mode, Lda is an 8-bit operation. In native mode, it is a 16-bit operation, with the high-order byte situated in the effective address plus 1.

Flags affected: n, z
 Registers affected: A, P

<table>
<thead>
<tr>
<th>Addressing Mode</th>
<th>Bytes</th>
<th>Opcode (hex)</th>
</tr>
</thead>
<tbody>
<tr>
<td>lda (d)</td>
<td>2</td>
<td>B2</td>
</tr>
<tr>
<td>lda (d),y</td>
<td>2</td>
<td>B1</td>
</tr>
<tr>
<td>lda (d,x)</td>
<td>2</td>
<td>A1</td>
</tr>
<tr>
<td>lda (r,s),y</td>
<td>2</td>
<td>B3</td>
</tr>
<tr>
<td>lda d</td>
<td>2</td>
<td>A5</td>
</tr>
<tr>
<td>lda d,x</td>
<td>2</td>
<td>B5</td>
</tr>
<tr>
<td>lda r,s</td>
<td>2</td>
<td>A3</td>
</tr>
<tr>
<td>lda [d]</td>
<td>2</td>
<td>A7</td>
</tr>
<tr>
<td>lda [d],y</td>
<td>2</td>
<td>B7</td>
</tr>
<tr>
<td>lda #</td>
<td>2 (3)</td>
<td>A9</td>
</tr>
<tr>
<td>lda a</td>
<td>3</td>
<td>AD</td>
</tr>
<tr>
<td>lda a,x</td>
<td>3</td>
<td>BD</td>
</tr>
<tr>
<td>lda a,y</td>
<td>3</td>
<td>B9</td>
</tr>
<tr>
<td>lda al</td>
<td>4</td>
<td>AF</td>
</tr>
<tr>
<td>lda aL,x</td>
<td>4</td>
<td>BF</td>
</tr>
</tbody>
</table>

**I dx**

*load the X register  6502, 65C02, 65C816*

 Loads the X register with the contents of the effective address of the operand. The n flag is set if a value with the high bit set is loaded into the X register. The z flag is set if the value loaded into the X register is 0.

In emulation mode, Ldx is an 8-bit operation. In native mode, it is a
16-bit operation, with the high-order byte situated in the effective address plus 1.

Flags affected: n, z
Registers affected: X, P

<table>
<thead>
<tr>
<th>Addressing Mode</th>
<th>Bytes</th>
<th>Opcode (hex)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ldx d</td>
<td>2</td>
<td>A6</td>
</tr>
<tr>
<td>ldx d,y</td>
<td>2</td>
<td>B6</td>
</tr>
<tr>
<td>ldx #</td>
<td>2 (3)</td>
<td>A2</td>
</tr>
<tr>
<td>ldx a</td>
<td>3</td>
<td>AE</td>
</tr>
<tr>
<td>ldx a,y</td>
<td>3</td>
<td>BE</td>
</tr>
</tbody>
</table>

ldy

load the Y register

6502, 65C02, 65C816

 Loads the Y register with the contents of the effective address of the operand. The n flag is set if a value with the high bit set is loaded into the Y register. The z flag is set if the value loaded into the Y register is 0.

In emulation mode, ldy is an 8-bit operation. In native mode, it is a 16-bit operation, with the high-order byte situated in the effective address plus 1.

Flags affected: n, z
Registers affected: Y, P

<table>
<thead>
<tr>
<th>Addressing Mode</th>
<th>Bytes</th>
<th>Opcode (hex)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ldy d</td>
<td>2</td>
<td>A4</td>
</tr>
<tr>
<td>ldy d,x</td>
<td>2</td>
<td>B4</td>
</tr>
<tr>
<td>ldy #</td>
<td>2 (3)</td>
<td>A0</td>
</tr>
<tr>
<td>ldy a</td>
<td>3</td>
<td>AC</td>
</tr>
<tr>
<td>ldy a,x</td>
<td>3</td>
<td>BC</td>
</tr>
</tbody>
</table>

lsr

logical shift right

6502, 65C02, 65C816

Moves each bit in the accumulator one position to the right. See figure A-4. A 0 is deposited into the leftmost position (bit 15 in native mode and bit 7 in emulation mode), and bit 0 is deposited into the carry. The result is left in the accumulator or in the affected memory register.

In emulation mode, lsr is an 8-bit operation. In native mode, it is a 16-bit operation, with the high-order byte situated in the effective address plus 1.

![Figure A-4](LSR operation)
Flags affected: n, z, c
Registers affected: A, P, M

<table>
<thead>
<tr>
<th>Addressing Mode</th>
<th>Bytes</th>
<th>Opcode (hex)</th>
</tr>
</thead>
<tbody>
<tr>
<td>lsr Acc</td>
<td>1</td>
<td>4A</td>
</tr>
<tr>
<td>lsr d</td>
<td>2</td>
<td>46</td>
</tr>
<tr>
<td>lsr d,x</td>
<td>2</td>
<td>56</td>
</tr>
<tr>
<td>lsr a</td>
<td>3</td>
<td>4E</td>
</tr>
<tr>
<td>lsr a,x</td>
<td>3</td>
<td>5E</td>
</tr>
</tbody>
</table>

**mvn**

**move block next, or move block negative**

Copies a block of memory from one RAM address to another. Both mvn and the 65C816's other block move instruction, mvp (move block previous, or move block positive), can copy blocks from one bank to another and can copy memory blocks that overlap. When overlapping blocks are moved, however, mvn should be used only if the starting address of the block to be moved is higher than the starting address of the destination. If the blocks overlap and the starting address of the destination is higher than the starting address of the source, use the mvp instruction. Otherwise, part of the block being copied may be overwritten.

The mvn instruction takes two operands, each consisting of 1 byte. In programs written using the APW assembler-editor, the operands are separated by a comma. The first operand specifies the bank containing the block to be moved, and the second specifies the bank to which the block will be moved.

The source address, destination address, and length of the move are passed to the mvn instruction in the X, Y, and C (double accumulator) registers. The X register holds the source address, the Y register holds the destination address, and the C register holds the length of the block being moved, minus 1. For example, if the C register holds the value $00FF, 256 bytes (or $FF bytes in hexadecimal notation) are moved. The complete C register is always used, regardless of the setting of the m flag.

When you issue an mvn instruction, the first byte to be moved is copied from the source address stored in the X register to the destination address stored in the Y register. Then the X and Y registers are incremented. Next, the C register is decremented, and the next byte is moved. This sequence of operations continues until the number of bytes originally stored in the C register, plus 1, are moved (until the value in C is $FFFF).

When the execution of an mvn operation is complete, the X and Y registers point to addresses that lie 1 byte beyond the ends of the blocks to which they originally pointed. The data bank register holds the value of the destination bank value (the value of the first byte of the operand).

If the source and destination blocks do not overlap, the source block remains intact after it is copied to the destination.

The operand field of the mvn instruction must be coded as two addresses:
first the source, then the destination. When the instruction is assembled into machine code, however, this order is reversed.

If the 65C816 receives an interrupt while an mvn move is in progress, the copying of the byte being moved is completed and then the interrupt is serviced. If the interrupt handling routine restores all registers or leaves them intact and ends with an rti instruction, the block move is resumed automatically when the interrupt ends.

The mvn instruction is useful when blocks of code are moved from one bank to another. For moves that take place within one bank, however, operations that use other algorithms may be faster and more efficient.

If the 65C816 is in emulation mode or the A, X, and Y registers are in 8-bit mode when the mvn instruction is issued, both addresses specified in the operand must be on page 0 because the high bytes of the index registers contain zeros.

Flags affected: None
Registers affected: None

<table>
<thead>
<tr>
<th>Addressing Mode</th>
<th>Bytes</th>
<th>Opcode (hex)</th>
</tr>
</thead>
<tbody>
<tr>
<td>xya</td>
<td>3</td>
<td>54</td>
</tr>
</tbody>
</table>

**mvp**

**move block previous, or move block positive**

Copies a block of memory from one RAM address to another. Both.mvp and the 65C816's other block move instruction, mvn (move block next, or move block negative), can copy blocks from one bank to another and can copy memory blocks that overlap. When overlapping blocks are moved, however, mvp should be used only if the starting address of the block to be moved is lower than the starting address of the destination. If the blocks overlap and the starting address of the destination is higher than the starting address of the source, use the mvn instruction. Otherwise, part of the block being copied may be overwritten.

The mvp instruction takes two operands, each consisting of 1 byte. In programs written using the APW assembler-editor, the operands are separated by a comma. The first operand specifies the bank containing the block to be moved, and the second specifies the bank to which the block will be moved.

The source address, destination address, and length of the move are passed to the mvp instruction in the X, Y, and C (double accumulator) registers. The X register holds the address of the last byte of the block to be moved, the Y register holds the last byte of the destination block, and the C register holds the length of the block being moved, minus 1. For example, if the C register holds the value $00FF, 256 bytes (or $FF bytes in hexadecimal notation) are moved. The complete C register is always used, regardless of the setting of the m flag.

When you issue an mvp instruction, the first byte to be moved is copied from the source address stored in the X register to the destination address
stored in the Y register. Then the X and Y registers are decremented. Next, the C register is decremented, and the next byte is moved. This sequence of operations continues until the number of bytes originally stored in the C register, plus 1, are moved (until the value in C is $FFFF$).

When the execution of an mvp operation is complete, the X and Y registers point to addresses that lie 1 byte past the starting addresses of the blocks to which they originally pointed. The data bank register holds the value of the destination bank value (the value of the first byte of the operand).

If the source and destination blocks do not overlap, the source block remains intact after it is copied to the destination.

The operand field of the mvp instruction must be coded as two addresses: first the address of the last byte of the source block, then the address of the last byte of the destination block. When the instruction is assembled into machine code, however, this order is reversed.

If the 65C816 receives an interrupt while an mvp move is in progress, the copying of the byte being moved is completed and then the interrupt is serviced. If the interrupt handling routine restores all registers or leaves them intact and ends with an rti instruction, the block move is resumed automatically when the interrupt ends.

The mvp instruction is useful when blocks of code are moved from one bank to another. For moves that take place within one bank, however, operations that use other algorithms may be faster and more efficient.

If the 65C816 is in emulation mode or the A, X, and Y registers are in 8-bit mode when the mvp instruction is issued, both addresses specified in the operand must be on page 0 because the high bytes of the index registers contain zeros.

Flags affected: None
Registers affected: None

<table>
<thead>
<tr>
<th>Addressing Mode</th>
<th>Bytes</th>
<th>Opcode (hex)</th>
</tr>
</thead>
<tbody>
<tr>
<td>xya</td>
<td>3</td>
<td>44</td>
</tr>
</tbody>
</table>

**nop**

no operation 6502, 65C02, 65C816

Causes the 65C816 to wait, and do nothing, for one or more cycles. The nop instruction does not affect any registers except the program counter, which is incremented once to point to the next instruction.

The nop instruction is often used to indicate spots in a program where more code may be inserted. For example, in a sequence such as

LAB1    nop
       lda #$FF

you could insert more lines of source code between the nop and lda instructions, without retyping the line containing the label LAB1.
The `nop` instruction can also be used to take up time. Every `nop` in a program takes two cycles, so `nop` instructions are often used in delay loops and to adjust the speeds of loops in which timing is important.

Flags affected: None
 Registers affected: None

<table>
<thead>
<tr>
<th>Addressing Mode</th>
<th>Bytes</th>
<th>Opcode (hex)</th>
</tr>
</thead>
<tbody>
<tr>
<td>i</td>
<td>1</td>
<td>EA</td>
</tr>
</tbody>
</table>

**ora**

**OR accumulator with memory**

6502, 65C02, 65C816

Performs a binary inclusive-OR operation on the value in the accumulator and a literal value or the contents of a specified memory location or immediate value. See figure A-5. Each bit in the accumulator is ORed with the corresponding bit in the operand, and the result of the operation is stored in the accumulator.

The `ora` instruction is often used as a mask, to set specified bits in a memory location. When used as a mask, the instruction compares each bit in a memory location with the corresponding bit in the accumulator. Each bit set in the memory location sets the corresponding bit in the accumulator. Bits cleared in the accumulator have no effect on their corresponding bits in the memory location. For example, the sequence

```
l da #00FF
ora MEMLOC
sta MEMLOC
```

sets all bits in the the low-order byte of `MEMLOC`, while leaving the high-order byte of `MEMLOC` unchanged.

The `ora` instruction conditions the P register's n and z flags. The n flag is set if the most significant bit of the result of the ORA operation is set; otherwise, it is cleared. The z flag is set if the result is 0; otherwise it is cleared.

In emulation mode, `ora` is an 8-bit operation. In native mode, it is a 16-bit operation, with the high-order byte situated in the effective address plus 1.

Flags affected: n, z
 Registers affected: A, P

<table>
<thead>
<tr>
<th>C</th>
<th>0</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>ORA</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>C</th>
<th>0</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>ORA</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>C</th>
<th>0</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>ORA</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

Figure A-5
Truth table for `ORA`
### Addressing Mode

<table>
<thead>
<tr>
<th>Addressing Mode</th>
<th>Bytes</th>
<th>Opcode (hex)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ora (d)</td>
<td>2</td>
<td>12</td>
</tr>
<tr>
<td>ora (d),y</td>
<td>2</td>
<td>11</td>
</tr>
<tr>
<td>ora (d,x)</td>
<td>2</td>
<td>01</td>
</tr>
<tr>
<td>ora (r,s),y</td>
<td>2</td>
<td>13</td>
</tr>
<tr>
<td>ora d</td>
<td>2</td>
<td>05</td>
</tr>
<tr>
<td>ora d,x</td>
<td>2</td>
<td>15</td>
</tr>
<tr>
<td>ora r,s</td>
<td>2</td>
<td>03</td>
</tr>
<tr>
<td>ora [d]</td>
<td>2</td>
<td>07</td>
</tr>
<tr>
<td>ora [d],y</td>
<td>2</td>
<td>17</td>
</tr>
<tr>
<td>ora #</td>
<td>2 (3)</td>
<td>09</td>
</tr>
<tr>
<td>ora a</td>
<td>3</td>
<td>0D</td>
</tr>
<tr>
<td>ora a,x</td>
<td>3</td>
<td>1D</td>
</tr>
<tr>
<td>ora a,y</td>
<td>3</td>
<td>19</td>
</tr>
<tr>
<td>ora al</td>
<td>4</td>
<td>0F</td>
</tr>
<tr>
<td>ora al,x</td>
<td>4</td>
<td>1F</td>
</tr>
</tbody>
</table>

### pea

**push effective address**

65C816

Pushes a 16-bit operand, always expressed in absolute addressing mode, onto the stack. This operation always pushes 16 bits of data, regardless of the settings of the m and x mode select flags, and the stack pointer is decremented twice.

Although the mnemonic `pea` would seem to suggest that the value pushed onto the stack must be an address, the instruction can actually be used to place any 16-bit value on the stack. For instance, the instruction

#### pea 0

pushes a 0 on the stack. Notice, however, that when `pea` places a literal value on the stack, the context is unusual. The operand of the instruction is interpreted by the assembler as a literal value. Thus, it does not require the prefix `#` to designate it as a literal value. So, in this example, a literal 0, not the value of memory address $0000$, is pushed onto the stack.

Flags affected: None

Registers affected: S

<table>
<thead>
<tr>
<th>Addressing Mode</th>
<th>Bytes</th>
<th>Opcode (hex)</th>
</tr>
</thead>
<tbody>
<tr>
<td>s</td>
<td>3</td>
<td>F4</td>
</tr>
</tbody>
</table>

### pei

**push effective indirect address**

65C816

Pushes the 16-bit value located at the address formed by adding the direct page offset specified by the operand to the direct page register. Although the
mnemonic **pei** may seem to suggest that the instruction’s operand must be an address, it actually can be any kind of 16-bit data. The instruction always pushes 16 bits of data, regardless of the settings of the m and x mode select flags.

The first byte pushed is the byte at the direct page offset plus 1 (the high byte of the double byte stored at the direct page offset). The byte of the direct page offset itself (the low byte) is pushed next. The stack pointer then points to the next available stack location, directly below the last byte pushed.

The syntax of the **pei** instruction is that of direct page indirect. Unlike other instructions that use this syntax, however, the effective indirect address, rather than the data stored at that address, is pushed onto the stack.

Flags affected: None

Registers affected: S

<table>
<thead>
<tr>
<th>Addressing Mode</th>
<th>Bytes</th>
<th>Opcode (hex)</th>
</tr>
</thead>
<tbody>
<tr>
<td>s</td>
<td>2</td>
<td>D4</td>
</tr>
</tbody>
</table>

**per**

**push effective PC**

**relative indirect address**

Adds the current value of the program counter to the value of a 2-byte operand and pushes the result on the stack. When the program counter is added to the operand, it contains the address of the next instruction (the instruction following the **per** instruction).

After the program counter and the operand are added, the high byte of their sum is pushed onto the stack first, followed by the low byte. After the instruction is completed, the stack pointer points to the next available stack location, immediately below the last byte pushed. The **per** instruction always pushes 16 bits of data, regardless of the settings of the m and x mode select flags.

The syntax used with the **per** instruction is similar to that used with branch instructions; that is, the data to be referenced is used as an operand. The address referred to must be in the current program bank because **per**’s displacement is relative to the program counter.

The **per** instruction is useful when you write self-relocatable code in which a given address (typically the address of a data area) must be accessed. In this kind of application, the address pushed onto the stack is the run time address of the data area, regardless of where the program was loaded in memory. It could be pulled into a register, stored in an indirect pointer, or used on the stack with the stack relative indirect indexed addressing mode to access the data at that location.

The **per** instruction can also be used to push return addresses on the stack, either as part of a simulated branch-to-subroutine or to place the return address beneath the stacked parameters to a subroutine call. When **per** is
used in this way, it should be noted that a pushed return address should be the desired return address minus 1.

Flags affected: None
Registers affected: S

<table>
<thead>
<tr>
<th>Addressing Mode</th>
<th>Bytes</th>
<th>Opcode (hex)</th>
</tr>
</thead>
<tbody>
<tr>
<td>s</td>
<td>3</td>
<td>62</td>
</tr>
</tbody>
</table>

**pha**  
**push accumulator**

Flushes the contents of the accumulator on the stack. The accumulator and the P register are not affected.

In emulation mode, **pha** is an 8-bit operation. The contents of an 8-bit accumulator are pushed on the stack, and the stack pointer is decremented by 1.

In native mode, **pha** is a 16-bit operation. The high byte in the accumulator is pushed first, then the low byte. The stack pointer then points to the next available stack location, directly below the last byte pushed.

Flags affected: None
Registers affected: None

<table>
<thead>
<tr>
<th>Addressing Mode</th>
<th>Bytes</th>
<th>Opcode (hex)</th>
</tr>
</thead>
<tbody>
<tr>
<td>s</td>
<td>1</td>
<td>48</td>
</tr>
</tbody>
</table>

**phb**  
**push data bank register**

Flushes the value of the data bank register (DBR) onto the stack. The stack pointer then points to the next available stack location, directly below the byte pushed. The data bank register itself is left unchanged.

The 65C816 data bank register is an 8-bit register, so only 1 byte is pushed onto the stack, regardless of the settings of the m and x (mode select) flags.

The **phb** instruction allows the programmer to save the current value of the data bank register before changing the data bank’s value. It is therefore useful when a program in one bank must access data in another. After the data in the other bank is accessed, the original value of the data bank register can be restored.

Flags affected: None
Register affected: S
Addressing Mode  Bytes  Opcode (hex)

```
<table>
<thead>
<tr>
<th>Addressing Mode</th>
<th>Bytes</th>
<th>Opcode (hex)</th>
</tr>
</thead>
<tbody>
<tr>
<td>s</td>
<td>1</td>
<td>8B</td>
</tr>
</tbody>
</table>
```

**phd**

**push direct page register**  
65C816

Pushes the contents of the direct page register (D) onto the stack. The most important use of the phd instruction is to save the value of the D register temporarily, prior to starting an operation that may change its value. After the contents of the D register are saved, a subroutine may specify its own direct page. Then, after the subroutine ends, the original value of the D register can be restored.

Because the direct page register is always a 16-bit register, phd is always a 16-bit operation, regardless of the settings of the m and x (mode select) flags. When you use this instruction, the high byte of the direct page register is pushed first, then the low byte. The direct page register itself is unchanged. The stack pointer then points to the next available stack location, directly below the last byte pushed.

Flags affected: None
Register affected: S

```
<table>
<thead>
<tr>
<th>Addressing Mode</th>
<th>Bytes</th>
<th>Opcode (hex)</th>
</tr>
</thead>
<tbody>
<tr>
<td>s</td>
<td>1</td>
<td>0B</td>
</tr>
</tbody>
</table>
```

**phk**

**push program bank register**  
65C816

Pushes the current value of the program bank register onto the stack. The phk instruction is often used to set the data bank register and the program bank register so that they contain the same values. A program can then access data in its own bank.

To make the program bank register and the data bank register the same, the following sequence is often used:

```
phk ; push contents of PBR on stack
plb ; pull PBR value into data bank register
```

When the phk instruction is used, the program bank register itself is unchanged. The stack pointer then points to the next available stack location, directly below the byte pushed. Because the program bank register is an 8-bit register, only 1 byte is pushed onto the stack, regardless of the settings of the m and x (mode select) flags.

Flags affected: None
Register affected: S
### Appendix A

<table>
<thead>
<tr>
<th>Addressing Mode</th>
<th>Bytes</th>
<th>Opcode (hex)</th>
</tr>
</thead>
<tbody>
<tr>
<td>s</td>
<td>1</td>
<td>48</td>
</tr>
</tbody>
</table>

**php**

**push processor status** 6502, 65C02, 65C816

Pushes the contents of the P register on the stack. The P register itself is left unchanged, and no other registers are affected.

Because the program bank register is an 8-bit register, only 1 byte is pushed onto the stack, regardless of the settings of the m and x (mode select) flags.

Note that the P register’s e flag, a “hanging flag,” is not pushed onto the stack by the php instruction. The only way to access the e flag is with the xce instruction.

- Flags affected: None
- Registers affected: None

<table>
<thead>
<tr>
<th>Addressing Mode</th>
<th>Bytes</th>
<th>Opcode (hex)</th>
</tr>
</thead>
<tbody>
<tr>
<td>s</td>
<td>1</td>
<td>08</td>
</tr>
</tbody>
</table>

**phx**

**push X register** 65C02, 65C816

Pushes the contents of the X index register onto the stack. The X register itself is unchanged.

When the 65C816 is in emulation mode or when the X and Y registers are set to 8-bit lengths, the 8-bit contents of the X register are pushed onto the stack. The stack pointer then points to the next available stack location, directly below the byte pushed.

When the 65C816 is in native mode and the X and Y registers are set to 16-bit lengths, the 16-bit contents of the X register are pushed onto the stack. The high byte is pushed first, then the low byte. The stack pointer then points to the next available stack location, directly below the last byte pushed.

- Flags affected: None
- Registers affected: S

<table>
<thead>
<tr>
<th>Addressing Mode</th>
<th>Bytes</th>
<th>Opcode (hex)</th>
</tr>
</thead>
<tbody>
<tr>
<td>s</td>
<td>1</td>
<td>DA</td>
</tr>
</tbody>
</table>

**phy**

**push Y register** 65C02, 65C816

Pushes the contents of the Y index register onto the stack. The Y register itself is unchanged.

When the 65C816 is in emulation mode or when the X and Y registers are set to 8-bit lengths, the 8-bit contents of the Y register are pushed onto
the stack. The stack pointer then points to the next available stack location, directly below the byte pushed.

When the 65C816 is in native mode and the X and Y registers are set to 16-bit lengths, the 16-bit contents of the X register are pushed onto the stack. The high byte is pushed first, then the low byte. The stack pointer then points to the next available stack location, directly below the last byte pushed.

Flags affected: None
Registers affected: S

<table>
<thead>
<tr>
<th>Addressing Mode</th>
<th>Bytes</th>
<th>Opcode (hex)</th>
</tr>
</thead>
<tbody>
<tr>
<td>s</td>
<td>1</td>
<td>5A</td>
</tr>
</tbody>
</table>

**Pla** pull accumulator 6502, 65C02, 65C816

Removes 1 byte from the stack and deposits it in the accumulator. The n and z flags are conditioned, just as if an Lda operation had been carried out.

When the 6C816 is in emulation mode or when the accumulator is set to an 8-bit length, the stack pointer is first incremented. Then the byte pointed to by the stack pointer is loaded into the accumulator.

When the 65C816 is in native mode and the accumulator is set to a 16-bit length, the low-order byte of the accumulator is pulled first, followed by the high-order byte.

Flags affected: n, z
Registers affected: A, S, P

<table>
<thead>
<tr>
<th>Addressing Mode</th>
<th>Bytes</th>
<th>Opcode (hex)</th>
</tr>
</thead>
<tbody>
<tr>
<td>s</td>
<td>1</td>
<td>68</td>
</tr>
</tbody>
</table>

**Plb** pull data bank register 6502, 65C02, 65C816

Pulls the 8-bit value on top of the stack into the data bank register (B) and changes the value of the data bank to that value. All instructions referencing data that specifies only 16-bit addresses will then get their bank address from the value pulled into the data bank register. This is the only instruction that can modify the data bank register.

The plb instruction is often used with phk (push program bank register) to set the data bank register and the program bank register so that they contain the same values. A program can then access data that is in its own bank. To make the program bank register and the data bank register the same, the following sequence is often used:

```
phk ; push contents of PBR on stack
plb ; pull PBR value into data bank register
```
When \( \text{plb} \) is used in a program, the stack pointer is incremented, then the byte pointed to by the stack pointer is loaded into the register. Because the bank register is an 8-bit register, \( \text{plb} \) pulls only 1 byte from the stack, regardless of the settings of the \( m \) and \( x \) (mode select) flags.

Flags affected: \( n, z \)
Registers affected: \( B, S, P \)

### Addressing Mode | Bytes | Opcode (hex)
---|---|---
\( s \) | 1 | AB

**pld**

**pull direct page register**

Pulls the 16-bit value on top of the stack into the direct page register (D), giving the D register a new value.

The most common use of \( \text{pld} \) is to restore the direct page register to a previous value. When a program calls a subroutine that has its own direct page, the program can save its direct page by using the instruction \( \text{phd} \) (push direct page) before the subroutine is called. When the subroutine ends and control returns to the program that called it, the original state of the D register can be restored with a \( \text{pld} \) instruction.

The direct page register is a 16-bit register, so 2 bytes are pulled from the stack, regardless of the settings of the \( m \) and \( x \) (mode select) flags. The low byte of the direct page register is pulled first, then the high byte. The stack pointer then points to where the high byte just pulled was stored, and that is the next available stack location.

Flags affected: \( n, z \)
Register affected: \( D, S, P \)

### Addressing Mode | Bytes | Opcode (hex)
---|---|---
\( s \) | 1 | 2B

**plp**

**pull processor status register**

Pulls the 8-bit value on top of the stack into the processor status register (P), changing the value of the P register. \( \text{plp} \) is often used to restore flag settings previously saved on the stack with a \( \text{php} \) (push processor status register) instruction.

It should be noted, however, that the P register’s e flag (the emulation mode flag) cannot be retrieved from the stack with a \( \text{plp} \) instruction. That is because it is a “hanging flag” that is not pushed on the stack by the \( \text{php} \) instruction. The only way to set the e flag is with the xc e instruction.

The status register is an 8-bit register, so only 1 byte is pulled from the stack by the \( \text{plp} \) instruction, regardless of the settings of the \( m \) and \( x \) (mode select) flags. When the instruction is used in a program, the stack pointer is
first incremented. Then the byte pointed to by the stack pointer is loaded into the status register.

Flags affected: All except e
Registers affected: S, P

<table>
<thead>
<tr>
<th>Addressing Mode</th>
<th>Bytes</th>
<th>Opcode (hex)</th>
</tr>
</thead>
<tbody>
<tr>
<td>s</td>
<td>1</td>
<td>28</td>
</tr>
</tbody>
</table>

plx

**pull X register from stack** 65C02, 65C816

Pulls the value on top of the stack into the X index register, destroying the register’s previous contents. This operation conditions the n and z flags.

When the 65C816 is in emulation mode or when the X register is set to an 8-bit length, the stack pointer is first incremented. Then the byte pointed to by the stack pointer is loaded into the X register.

When the 65C816 is in native mode and the X register is set to a 16-bit length, the low-order byte of the X register is pulled first, followed by the high-order byte.

Flags affected: n, z
Registers affected: X, S, P

<table>
<thead>
<tr>
<th>Addressing Mode</th>
<th>Bytes</th>
<th>Opcode (hex)</th>
</tr>
</thead>
<tbody>
<tr>
<td>s</td>
<td>1</td>
<td>FA</td>
</tr>
</tbody>
</table>

ply

**pull Y register from stack** 65C02, 65C816

Pulls the value on top of the stack into the Y index register, destroying the register’s previous contents. This operation conditions the n and z flags.

When the 65C816 is in emulation mode or the Y register is set to an 8-bit length, the stack pointer is first incremented. Then the byte pointed to by the stack pointer is loaded into the Y register.

When the 65C816 is in native mode and the Y register is set to a 16-bit length, the low-order byte of the Y register is pulled first, followed by the high-order byte.

Flags affected: n, z
Registers affected: S, Y, P

<table>
<thead>
<tr>
<th>Addressing Mode</th>
<th>Bytes</th>
<th>Opcode (hex)</th>
</tr>
</thead>
<tbody>
<tr>
<td>s</td>
<td>1</td>
<td>7A</td>
</tr>
</tbody>
</table>

rep

**reset status bits** 65C816

Clears flags in the status register according to the contents of an 8-bit operand. For each bit set to 1 in the operand, rep resets, or clears, the corresponding
bit in the status register to 0. For example, if bit 5 in the operand byte is set, bit 5 in the P register is cleared to 0. Zeros in the operand byte have no effect on their corresponding status register bits.

The rep instruction allows the programmer to reset any flag or combination of flags in the status register with a single 2-byte instruction. It is the only direct means of clearing the m flag and the x flag (although instructions that pull the P register affect the m and x flags).

When the 65C816 is in emulation mode, rep does not affect the break flag or bit 5, the 6502's undefined flag bit. In native mode, however, all flags except the e flag (the "hanging" flag) can be cleared with the rep instruction. The only way to access the e flag is with the xce instruction.

- Flags affected in native mode: All flags except e
- Flags affected in emulation mode: All flags except b
- Registers affected: P

### Addressing Mode | Bytes | Opcode (hex)
--- | --- | ---
# | 2 | C2

**rol**

**rotate left**

6502, 65C02, 65C816

Moves each bit in the accumulator or a specified memory location one position to the left. See figure A-6.

![Figure A-6: ROL operation](image)

The carry bit is deposited into the bit 0 location and is replaced by the leftmost bit (bit 15 in native mode and bit 7 in emulation mode) of the accumulator or the affected memory register. The n, z, and c flags are conditioned according to the result of the rotation operation.

- Flags affected: n, z, c
- Registers affected: A, P, M

### Addressing Mode | Bytes | Opcode (hex)
--- | --- | ---
rol Acc | 1 | 2A
rol d | 2 | 26
rol d,x | 2 | 36
rol a | 3 | 2E
rol a,x | 3 | 3E
**ror** \(\text{rotate right}\) \(\text{6502, 65C02, 65C816}\)

Moves each bit in the accumulator or a specified memory location one position to the right. See figure A-7.

The carry bit is deposited into the leftmost location (bit 15 in native mode and bit 7 in emulation mode) and is replaced by bit 0 of the accumulator or the affected memory register. The n, c, and z flags are conditioned according to the result of the rotation operation.

Flags affected: n, z, c
Registers affected: A, P, M

<table>
<thead>
<tr>
<th>Addressing Mode</th>
<th>Bytes</th>
<th>Opcode (hex)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ror Acc</td>
<td>1</td>
<td>6A</td>
</tr>
<tr>
<td>ror d</td>
<td>2</td>
<td>66</td>
</tr>
<tr>
<td>ror d, x</td>
<td>2</td>
<td>76</td>
</tr>
<tr>
<td>ror a</td>
<td>3</td>
<td>6E</td>
</tr>
<tr>
<td>ror a, x</td>
<td>3</td>
<td>7E</td>
</tr>
</tbody>
</table>

**rti** \(\text{return from interrupt}\) \(\text{6502, 65C02, 65C816}\)

The status of both the program counter and the P register are pulled from the stack and restored to their original values in preparation for resuming the routine in progress when an interrupt occurred. If the 65C816 is in native mode, the program bank register is also pulled from the stack. The rti instruction is used to end interrupt handling routines and return control to the program in progress when the interrupt occurred.

The rti instruction pulls values off the stack in the reverse order from the way they were pushed onto the stack by a hardware interrupt (IRQ) or a software interrupt (brk or cop). It is up to the interrupt handling routine to ensure that the values pulled off the stack by rti are valid.

When the 65C02 is in native mode, 4 bytes are pulled from the stack: the 8-bit status register, the 16-bit program counter, and the 8-bit program bank register.

In emulation mode, 3 bytes are pulled from the stack: the status register and the program counter.
Flags affected: n, v, b, d, i, z, c
Registers affected: S, P

<table>
<thead>
<tr>
<th>Addressing Mode</th>
<th>Bytes</th>
<th>Opcode (hex)</th>
</tr>
</thead>
<tbody>
<tr>
<td>s</td>
<td>1</td>
<td>40</td>
</tr>
</tbody>
</table>

**rtl**

**Returns from subroutine long**

65C816

Returns to the program in progress from a subroutine that was called using the instruction jsr (jump to subroutine—long).

When you call a subroutine using jsr, the 8-bit value of the program bank register is pushed onto the stack, followed by the 16-bit value of the program counter.

When you use an rtl instruction to end a subroutine, the instruction pulls the value of the program counter from the stack, increments it by 1, and loads the incremented value into the program counter. Then it pulls the program bank register off the stack and loads that into the program bank register.

Flags affected: all except e
Register affected: S, P

<table>
<thead>
<tr>
<th>Addressing Mode</th>
<th>Bytes</th>
<th>Opcode (hex)</th>
</tr>
</thead>
<tbody>
<tr>
<td>s</td>
<td>1</td>
<td>6B</td>
</tr>
</tbody>
</table>

**rts**

**Returns from subroutine**

6502, 65C02, 65C816

At the end of a subroutine, rts returns execution of a program to the next address after the jsr (jump to subroutine) instruction that caused the program to jump to the subroutine. At the end of an assembly language program, the rts instruction returns control of the IIGS to the utility that was in control before the program began.

When a subroutine is called in a 65C816 program with a jsr instruction, the contents of the program counter (a 16-bit value) are pushed onto the stack. When the subroutine ends with an rts instruction, the rts instruction pulls the return address from the stack, increments it, and places it in the program counter, transferring control back to the instruction immediately following the jsr instruction.

The instructions jsr and rts do not push or pull the contents of the program bank register. Therefore, they cannot be used to jump across bank boundaries. When a program must cross a bank boundary to jump to a subroutine, it must use the instructions jsr (jump to subroutine—long) and rtl (return from subroutine—long).

Flags affected: None
Registers affected: S
subtracts the content of the effective address of the operand from the contents of the accumulator. The opposite of the carry flag is also subtracted; because subtraction is really reverse addition, the carry flag in a subtraction operation is treated as a borrow.

Because of the way the carry flag is used in subtraction operations, you should set it before a subtraction takes place. Then, if there is a borrow by a lower-order word (or byte in emulation mode) from a higher-order word (or byte in emulation mode), the carry flag is cleared. That causes a borrow, and the result of the subtraction will be accurate.

In emulation mode, *sbc* is an 8-bit operation. In native mode, it is a 16-bit operation, with the high-order byte situated in the effective address plus 1.

The *n*, *v*, *z*, and *c* flags are all conditioned by the *sbc* instruction, and its result is deposited in the accumulator.

Flags affected: *n*, *v*, *z*, *c*
Registers affected: A, P

---

ses set carry 6502, 65C02, 65C816

Sets the carry flag. The *ses* instruction is often used before the *sbc* instruction so that there is not an extra borrow in the subtraction operation. *ses* is also used prior to an *xce* (exchange carry flag with emulation bit) instruction if the intent of the instruction is to put the 65C816 into 8-bit emulation mode.

Flags affected: c
Registers affected: P
Appendix A

<table>
<thead>
<tr>
<th>Addressing Mode</th>
<th>Bytes</th>
<th>Opcode (hex)</th>
</tr>
</thead>
<tbody>
<tr>
<td>i</td>
<td>1</td>
<td>38</td>
</tr>
</tbody>
</table>

**sed**

### set decimal mode

Sets the P register’s d flag, taking the 65C816 out of normal binary mode and preparing it for operations using BCD (binary coded decimal) numbers. BCD arithmetic is more accurate than binary arithmetic—the usual type of 6510 arithmetic—but it is slower and more difficult to use and consumes more memory. BCD arithmetic is most often used in accounting programs, bookkeeping programs, and floating-point arithmetic.

The decimal flag can be cleared, returning the 65C816 to its default binary mode, with a **cld** (clear decimal flag) instruction.

Flags affected: d

Registers affected: P

<table>
<thead>
<tr>
<th>Addressing Mode</th>
<th>Bytes</th>
<th>Opcode (hex)</th>
</tr>
</thead>
<tbody>
<tr>
<td>i</td>
<td>1</td>
<td>F8</td>
</tr>
</tbody>
</table>

**sei**

### set interrupt disable

Sets the P register’s i (interrupt disable) flag, disabling the processing of hardware interrupts (IRQs). When the i bit is set, maskable hardware interrupts are ignored.

When the 65C816 begins servicing an interrupt, it sets the i flag, so interrupt handling routines that are themselves intended to be interruptable must reenable interrupts with a **cli** (clear interrupt) instruction. If other interrupts are to remain disabled during the interrupt being serviced, a **cli** instruction is not necessary, because the **rti** (return from interrupt) instruction automatically restores the status register with the i flag clear, reenabling interrupts.

Flags affected: i

Registers affected: P

<table>
<thead>
<tr>
<th>Addressing Mode</th>
<th>Bytes</th>
<th>Opcode (hex)</th>
</tr>
</thead>
<tbody>
<tr>
<td>i</td>
<td>1</td>
<td>78</td>
</tr>
</tbody>
</table>

**sep**

### set status bits

Sets bits in the processor status register according to the value of an 8-bit operand. For each bit set in the operand, **sep** sets the corresponding bit in the status register to 1. For example, if bit 5 is set in the operand byte, bit 5 in the status register is set to 1. Zeros in the operand byte have no effect on their corresponding bits in the P register.
The sep instruction enables the programmer to set any flag or combination of flags in the status register with a single 2-byte instruction. Also, it is the only direct means of setting the m and x (mode select) flags, although instructions that pull the P status register indirectly affect the m and x mode select flags.

When the 65C816 is in emulation mode, sep does not affect the break flag or bit 5, the 6502's non-flag bit.

Flags affected in native mode: n, v, m, x, i, z, c
Flags affected in emulation mode: n, v, d, i, z, c
Registers affected: P

<table>
<thead>
<tr>
<th>Addressing Mode</th>
<th>Bytes</th>
<th>Opcode (hex)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>sep #</strong></td>
<td>2</td>
<td>E2</td>
</tr>
</tbody>
</table>

**store accumulator 6502, 65C02, 65C816**

Stores the contents of the accumulator in a specified memory location. The contents of the accumulator are not affected.

In emulation mode, sta is an 8-bit operation. In native mode, it is a 16-bit operation, with the high-order byte situated in the effective address plus 1.

Flags affected: None
Registers affected: M

<table>
<thead>
<tr>
<th>Addressing Mode</th>
<th>Bytes</th>
<th>Opcode (hex)</th>
</tr>
</thead>
<tbody>
<tr>
<td>sta (d)</td>
<td>2</td>
<td>92</td>
</tr>
<tr>
<td>sta (d),y</td>
<td>2</td>
<td>91</td>
</tr>
<tr>
<td>sta (d,x)</td>
<td>2</td>
<td>81</td>
</tr>
<tr>
<td>sta (r,s),y</td>
<td>2</td>
<td>93</td>
</tr>
<tr>
<td>sta dta</td>
<td>2</td>
<td>85</td>
</tr>
<tr>
<td>sta d,x</td>
<td>2</td>
<td>95</td>
</tr>
<tr>
<td>sta r,s</td>
<td>2</td>
<td>83</td>
</tr>
<tr>
<td>sta [d]</td>
<td>2</td>
<td>87</td>
</tr>
<tr>
<td>sta [d],y</td>
<td>2</td>
<td>97</td>
</tr>
<tr>
<td>sta a</td>
<td>3</td>
<td>8D</td>
</tr>
<tr>
<td>sta a,x</td>
<td>3</td>
<td>9D</td>
</tr>
<tr>
<td>sta a,y</td>
<td>3</td>
<td>99</td>
</tr>
<tr>
<td>sta al</td>
<td>4</td>
<td>8F</td>
</tr>
<tr>
<td>sta aL,x</td>
<td>4</td>
<td>9F</td>
</tr>
</tbody>
</table>

**stop the processor 6502, 65C02, 65C816**

Puts the 65C816 into a dormant state until a hardware reset occurs, that is, until the processor's RES pin is pulled low.

The stp instruction is designed for use in battery-powered computers and other systems engineered to support a low-power mode. It can reduce
power consumption to almost 0 by putting the 65C816 out of action while it is not actively in use.

Flags affected: None
Registers affected: None

<table>
<thead>
<tr>
<th>Addressing Mode</th>
<th>Bytes</th>
<th>Opcode (hex)</th>
</tr>
</thead>
<tbody>
<tr>
<td>i</td>
<td>1</td>
<td>DB</td>
</tr>
</tbody>
</table>

**stx**

**store X register**

6502, 65C02, 65C816

Stores the contents of the X register in a specified memory location. The contents of the X register are not affected.

In emulation mode, **stx** is an 8-bit operation. In native mode, it is a 16-bit operation, with the high-order byte situated in the effective address plus 1.

Flags affected: None
Registers affected: M

<table>
<thead>
<tr>
<th>Addressing Mode</th>
<th>Bytes</th>
<th>Opcode (hex)</th>
</tr>
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<tbody>
<tr>
<td>stx d</td>
<td>2</td>
<td>86</td>
</tr>
<tr>
<td>stx d,y</td>
<td>2</td>
<td>96</td>
</tr>
<tr>
<td>stx a</td>
<td>3</td>
<td>8E</td>
</tr>
</tbody>
</table>

**sty**

**store Y register**

6502, 65C02, 65C816

Stores the contents of the Y register in a specified memory location. The contents of the Y register are not affected.

In emulation mode, **sty** is an 8-bit operation. In native mode, it is a 16-bit operation, with the high-order byte situated in the effective address plus 1.

Flags affected: None
Registers affected: M

<table>
<thead>
<tr>
<th>Addressing Mode</th>
<th>Bytes</th>
<th>Opcode (hex)</th>
</tr>
</thead>
<tbody>
<tr>
<td>sty d</td>
<td>2</td>
<td>84</td>
</tr>
<tr>
<td>sty d,x</td>
<td>2</td>
<td>94</td>
</tr>
<tr>
<td>sty a</td>
<td>3</td>
<td>8C</td>
</tr>
</tbody>
</table>

**stz**

**store zero to memory**

65C02, 65C816

Stores a 0 in the effective address specified by the operand. The **stz** instruction does not affect any of the flags in the P register.

In emulation mode, **stz** is an 8-bit operation. In native mode, it is a
16-bit operation, with the high-order byte situated in the effective address plus 1.

Flags affected: None
Registers affected: M

<table>
<thead>
<tr>
<th>Addressing Mode</th>
<th>Bytes</th>
<th>Opcode (hex)</th>
</tr>
</thead>
<tbody>
<tr>
<td>stz d</td>
<td>2</td>
<td>64</td>
</tr>
<tr>
<td>stz d,x</td>
<td>2</td>
<td>74</td>
</tr>
<tr>
<td>stz a</td>
<td>3</td>
<td>9C</td>
</tr>
<tr>
<td>stz a,x</td>
<td>3</td>
<td>9E</td>
</tr>
</tbody>
</table>

**tax:**

**transfer accumulator to X register**

6502, 65C02, 65C816

Deposits the value in the accumulator into the X register. The n and z flags are conditioned according to the result of this operation. The contents of the accumulator are not changed.

In emulation mode, tax is an 8-bit operation. In native mode, it is a 16-bit operation, with the high-order byte situated in the effective address plus 1.

Flags affected: n, z
Registers affected: X, P

<table>
<thead>
<tr>
<th>Addressing Mode</th>
<th>Bytes</th>
<th>Opcode (hex)</th>
</tr>
</thead>
<tbody>
<tr>
<td>i</td>
<td>1</td>
<td>AA</td>
</tr>
</tbody>
</table>

**tay**

**transfer accumulator to Y register**

6502, 65C02, 65C816

Deposits the value in the accumulator into the Y register. The n and z flags are conditioned according to the result of this operation. The contents of the accumulator are not changed.

In emulation mode, tay is an 8-bit operation. In native mode, it is a 16-bit operation, with the high-order byte situated in the effective address plus 1.

Flags affected: n, z
Registers affected: Y, P
## Appendix A

<table>
<thead>
<tr>
<th>Addressing Mode</th>
<th>Bytes</th>
<th>Opcode (hex)</th>
</tr>
</thead>
<tbody>
<tr>
<td>i</td>
<td>1</td>
<td>A8</td>
</tr>
</tbody>
</table>

### tcd

**transfer 16-bit accumulator to direct page register**

Transfers the value in the 16-bit accumulator (C) to the direct page register (D). The value of C is not changed.

When the tcd instruction is issued, both bytes in the 16-bit accumulator are copied into the direct page register, regardless of the setting of the m flag. If the accumulator is in 8-bit mode, the low-order byte of the 16-bit accumulator (A) is transferred to the low byte of the direct page register, and the value in the accumulator’s ‘‘hidden’’ high-order byte (B) is transferred to the high byte of the direct page register.

Flags affected: n, z

Registers affected: D, P

<table>
<thead>
<tr>
<th>Addressing Mode</th>
<th>Bytes</th>
<th>Opcode (hex)</th>
</tr>
</thead>
<tbody>
<tr>
<td>i</td>
<td>1</td>
<td>5B</td>
</tr>
</tbody>
</table>

### tcs

**transfer accumulator to stack pointer**

Transfers the value in the accumulator to the stack pointer. The accumulator’s value is unchanged.

If the 65C816 is in native mode, tcs transfers both bytes in the 16-bit accumulator (C) to the stack pointer, regardless of the setting of the m flag. The accumulator’s low-order byte (A) is transferred to the low byte of the stack pointer, and the value in the accumulator’s ‘‘hidden’’ high-order byte (B) is transferred to the high byte of the stack pointer. If the 65C816 is in emulation mode, only the 8-bit accumulator (A) is transferred.

The tcs and txs (transfer the X register to the stack pointer) instructions are the only instructions for changing the value in the stack pointer. They are also the only two transfer instructions that do not alter the n and z flags.

Flags affected: None

Registers affected: S
**Addressing Mode** | **Bytes** | **Opcode (hex)**
---|---|---
*i* | 1 | **1B**

**tdc:** transfer direct page register to 16-bit accumulator

Transfers the value of the direct page register (D) to the 16-bit accumulator (C). The value of the D register is not changed.

The `tdc` instruction transfers 16 bytes, regardless of the setting of the m (accumulator/memory mode) flag. If the accumulator is in 8-bit mode, the accumulator’s low-order byte (A) takes the value of the low byte of the direct page register, and the accumulator’s “hidden” B register takes the value of the high byte of the direct page register.

Flags affected: n, z
Registers affected: A, B, C, P

**Addressing Mode** | **Bytes** | **Opcode (hex)**
---|---|---
*i* | 1 | **7B**

**trb:** test and reset memory bits against accumulator

Logically ANDs the value in the accumulator with the complement of the value in a memory location. This operation clears each memory bit that corresponds to a set bit in the accumulator, while leaving unchanged each memory bit that corresponds to a cleared bit in the accumulator. The result of the operation is stored in the memory location.

In addition, the P register’s z flag is conditioned by the result of the AND operation. It sets the z flag if the result of the operation is zero and clears it if the result is not zero. This is the same way that the `bit` instruction conditions the zero flag. But `trb`, unlike `bit`, is a read-modify-write instruction. It not only calculates a result and modifies a flag, but also stores the result in memory.

In emulation mode, `trb` is an 8-bit operation. In native mode, it is a 16-bit operation, with the high-order byte situated in the effective address plus 1.

Flags affected: z
Registers affected: M, P

**Addressing Mode** | **Bytes** | **Opcode (hex)**
---|---|---
`trb d` | 2 | **14**
`trb a` | 3 | **1C**
**tsb**

**test and set memory bits**

against **accumulator**

65C02, 65C816

Logically ORs the value in the accumulator with the value stored in a memory location. This operation sets each memory bit that corresponds to a set bit in the accumulator, while leaving unchanged each memory bit that corresponds to a cleared bit in the accumulator. The result of the operation is stored in the memory location.

In addition, the **P** register's **z** flag is conditioned by the result of the **OR** operation. It sets the **z** flag if the result of the operation is zero and clears it if the result is not zero. This is the same way that the **bit** instruction conditions the **zero** flag. But **tsb**, unlike **bit**, is a read-modify-write instruction. It not only calculates a result and modifies a flag, but also stores the result in memory.

In emulation mode, **tsb** is an 8-bit operation. In native mode, it is a 16-bit operation, with the high-order byte situated in the effective address plus 1.

Flags affected: **z**

Registers affected: M, P

<table>
<thead>
<tr>
<th>Addressing Mode</th>
<th>Bytes</th>
<th>Opcode (hex)</th>
</tr>
</thead>
<tbody>
<tr>
<td>tsb d</td>
<td>2</td>
<td>04</td>
</tr>
<tr>
<td>tsb a</td>
<td>3</td>
<td>0C</td>
</tr>
</tbody>
</table>

**tsc**

**transfer stack pointer**

to **16-bit accumulator**

65C816

Transfers the value in the stack pointer (S) to the accumulator. The stack pointer's value is unchanged.

If the 65C816 is in native mode, **tsc** transfers both bytes in the stack pointer to the 16-bit accumulator (C), regardless of the setting of the m flag. The accumulator's low-order byte (A) takes the value of the low byte of the stack pointer, and the value in the accumulator's "hidden" high-order byte (B) takes the value of the high byte of the stack pointer. If the 65C816 is in emulation mode, B always takes a value of 1 because the stack is always page 1 in 8-bit emulation mode.

Flags affected: None

Registers affected: A, B, C
Deposits the value in the stack pointer into the X register. The n and c flags are conditioned according to the result of this operation. The value of the stack pointer is not changed.

When the 65C816 is in emulation mode, tsx is an 8-bit operation. If the 65C816 is in native mode and the X register is in 16-bit mode, tsx is a 16-bit operation. If the 65C816 is in native mode and the X register is in 8-bit mode, only the low-order byte of the stack pointer is transferred to the X register.

Flags affected: n, c
Registers affected: X, P

Deposits the value in the X register into the accumulator. The n and z flags are conditioned according to the result of this operation. The value of the X register is not changed.

If the 65C816 is in native mode and the A and X registers are both in 16-bit mode, both bytes of the X register are transferred to the accumulator.

If the 65C816 is in emulation mode and the A and X registers are both in 8-bit mode, the 8-bit X register is transferred to the 8-bit accumulator.

If the 65C816 is in native mode and the accumulator is in 8-bit mode and the X register is in 16-bit mode, the low byte of the X register is moved into the accumulator’s low byte (A) and the accumulator’s high byte (the “hidden” register B) is not affected by the transfer.

If the 65C816 is in native mode and the accumulator is in 16-bit mode and the X register is in 8-bit mode, the X register is moved into the accumulator’s low byte (A) and the accumulator’s high byte (B) takes a value of 0.

Flags affected: n, z
Registers affected: A, P
### Appendix A

<table>
<thead>
<tr>
<th>Addressing Mode</th>
<th>Bytes</th>
<th>Opcode (hex)</th>
</tr>
</thead>
<tbody>
<tr>
<td>i</td>
<td>i</td>
<td>8A</td>
</tr>
</tbody>
</table>

**txs**

**transfer stack to X register**

Deposits the value in the X register into the stack pointer. No flags are conditioned by this operation. The value of the X register is not changed.

When the 65C816 is in emulation mode, **txs** is an 8-bit operation. If the 65C816 is in native mode and the X register is in 16-bit mode, **txs** is a 16-bit operation. If the 65C816 is in native mode and the X register is in 8-bit mode, the X register is transferred to the low byte of the stack pointer and the high byte of the stack pointer is zeroed.

Flags affected: None

Registers affected: S

<table>
<thead>
<tr>
<th>Addressing Mode</th>
<th>Bytes</th>
<th>Opcode (hex)</th>
</tr>
</thead>
<tbody>
<tr>
<td>i</td>
<td>i</td>
<td>9A</td>
</tr>
</tbody>
</table>

**txy**

**transfer X register to Y register**

Transfers the value of the X register to the Y register. The value of the X register is not changed.

When the 65C816 is in emulation mode, **txy** is an 8-bit operation. When the 65C816 is in native mode and the X and Y registers are in native mode, **txy** is a 8-bit operation. When the 65C816 is in native mode and the X and Y registers are in 16-bit mode, **txy** is a 16-bit operation.

Flags affected: n, z

Registers affected: Y, P

<table>
<thead>
<tr>
<th>Addressing Mode</th>
<th>Bytes</th>
<th>Opcode (hex)</th>
</tr>
</thead>
<tbody>
<tr>
<td>i</td>
<td>i</td>
<td>9B</td>
</tr>
</tbody>
</table>

**tya**

**transfer Y register to accumulator**

Deposits the value in the Y register into the accumulator. The n and z flags are conditioned according to the result of this operation. The value of the Y register is not changed.

If the 65C816 is in native mode and the A and Y registers are both in 16-bit mode, both bytes of the Y register are transferred to the accumulator.
If the 65C816 is in emulation mode and the A and X registers are both in 8-bit mode, the 8-bit Y register is transferred to the 8-bit accumulator.

If the 65C816 is in native mode and the accumulator is in 8-bit mode and the Y register is in 16-bit mode, the low byte of the Y register is moved into the accumulator’s low byte (A) and the accumulator’s high byte (the ‘‘hidden’’ register B) is not affected by the transfer.

If the 65C816 is in native mode and the accumulator is in 16-bit mode and the Y register is in 8-bit mode, the Y register is moved into the accumulator’s low byte (A) and the accumulator’s high byte (B) takes a value of 0.

Flags affected: n, z
Registers affected: A, P

<table>
<thead>
<tr>
<th>Addressing Mode</th>
<th>Bytes</th>
<th>Opcode (hex)</th>
</tr>
</thead>
<tbody>
<tr>
<td>i</td>
<td>1</td>
<td>98</td>
</tr>
</tbody>
</table>

**tyx**  
**transfer Y register to X register**

Transfers the value of the Y register to the X register. The value of the Y register is not changed.

When the 65C816 is in emulation mode, **tyx** is an 8-bit operation. When the 65C816 is in native mode and the X and Y registers are in native mode, **tyx** is an 8-bit operation. When the 65C816 is in native mode and the X and Y registers are in 16-bit mode, **tyx** is an 16-bit operation.

Flags affected: n, z
Registers affected: Y, P

<table>
<thead>
<tr>
<th>Addressing Mode</th>
<th>Bytes</th>
<th>Opcode (hex)</th>
</tr>
</thead>
<tbody>
<tr>
<td>i</td>
<td>1</td>
<td>BB</td>
</tr>
</tbody>
</table>

**wa**  
**wait for interrupt**

The **wa** instruction puts the 65C816 in a dormant condition during an external event to reduce its power consumption or to provide an immediate response to interrupts so that the processor can be synchronized with the external event.

After an interrupt is received, control is generally vectored through one of the hardware interrupt vectors, and an **rti** instruction in an interrupt handling routine returns control to the instruction following the **wa** instruction. But if interrupts are disabled by setting the P register’s i flag and a hardware interrupt takes place, the 65C816’s wait condition is terminated and control resumes with the next instruction, rather than through the interrupt.
Appendix A

Vectors. This system provides a very fast response to an interrupt, allowing synchronization with external events.

Flags affected: None
Registers affected: None

<table>
<thead>
<tr>
<th>Addressing Mode</th>
<th>Bytes</th>
<th>Opcode (hex)</th>
</tr>
</thead>
<tbody>
<tr>
<td>i</td>
<td>1</td>
<td>CB</td>
</tr>
</tbody>
</table>

wdm reserved for future expansion 65C816

The letters wdm are the initials of William D. Mensch, Jr., the designer of the 65C02 and the 65C816. The wdm instruction uses opcode $42, the only one of the 65C816’s 256 possible machine language opcodes that is not used. It is left unused so that it can be a gateway to any new assembly language instructions that may be added to the 65C816’s instruction set. If new instructions are added, they have to take 2-byte opcodes, and the wdm instruction will signify that the next byte is an opcode in the processor’s expanded instruction set.

If the wdm instruction is used in a IIGS program, it has no effect except to consume time. It behaves like a 2-byte nop instruction. But you should not use wdm in a program because it would make the program incompatible with any future 65C02 family chips.

Flags affected: None
Registers affected: None

<table>
<thead>
<tr>
<th>Addressing Mode</th>
<th>Bytes</th>
<th>Opcode (hex)</th>
</tr>
</thead>
<tbody>
<tr>
<td>i</td>
<td>2†</td>
<td>42</td>
</tr>
</tbody>
</table>

†Subject to change in future processors.

xba swap the B and A accumulators

Swaps the contents of the 8-bit A register (the low-order byte of the 16-bit accumulator C) with the contents of the 8-bit B register (the high-order byte of the 16-bit accumulator C). When the 65C816 is in emulation mode, this is the only way to access the accumulator’s “hidden” B register. The transfer conditions the P register’s n and z flags.

The xba instruction can be used to invert the low-order, high-order arrangement of a 16-bit value or to store an 8-bit value in the B register. Because it is an exchange, the previous contents of both accumulators are changed, replaced by the previous contents of the other.

Neither the m (mode select) flag nor the e (emulation mode) flag affects this operation.

Flags affected: n, z
Registers affected: A, B, C, P
Swaps the P register’s carry flag with the e (emulation mode) flag. The xce instruction is the only method for toggling the 65C816 between 16-bit native mode and 8-bit emulation mode.

If the processor is in emulation mode, it can be switched to native mode by clearing the carry bit and then executing the xce instruction. If the processor is in native mode, it can be switched to emulation mode by setting the carry bit and then executing the xce instruction.

Flags affected: c, e
Registers affected: P
his appendix contains most of the calls in the Apple IIgs Toolbox. The calls are listed alphabetically.

### Tool Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADB</td>
<td>Apple Desktop Bus</td>
</tr>
<tr>
<td>CM</td>
<td>Control Manager</td>
</tr>
<tr>
<td>DM</td>
<td>Desk Manager</td>
</tr>
<tr>
<td>DLM</td>
<td>Dialog Manager</td>
</tr>
<tr>
<td>EM</td>
<td>Event Manager</td>
</tr>
<tr>
<td>FM</td>
<td>Font Manager</td>
</tr>
<tr>
<td>IM</td>
<td>Integer Math Tool Set</td>
</tr>
<tr>
<td>LE</td>
<td>LineEdit Tool Set</td>
</tr>
<tr>
<td>LM</td>
<td>List Manager</td>
</tr>
<tr>
<td>MM</td>
<td>Memory Manager</td>
</tr>
<tr>
<td>MUM</td>
<td>Menu Manager</td>
</tr>
<tr>
<td>MTS</td>
<td>Miscellaneous Tool Set</td>
</tr>
<tr>
<td>PM</td>
<td>Print Manager</td>
</tr>
</tbody>
</table>
## Tool Abbreviations (cont.)

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>QD</td>
<td>QuickDraw II</td>
</tr>
<tr>
<td>SAN</td>
<td>SANE Tool Set</td>
</tr>
<tr>
<td>SK</td>
<td>Scheduler</td>
</tr>
<tr>
<td>ST</td>
<td>Sound Tool Set</td>
</tr>
<tr>
<td>SF</td>
<td>Standard File Operations Tool Set</td>
</tr>
<tr>
<td>TT</td>
<td>Text Tool Set</td>
</tr>
<tr>
<td>WM</td>
<td>Window Manager</td>
</tr>
</tbody>
</table>

### Toolbox Calls

<table>
<thead>
<tr>
<th>Call</th>
<th>Tool</th>
<th>Call Number</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>AbsOff</td>
<td>ADB</td>
<td>$1009</td>
<td>Disables automatic polling of an absolute device.</td>
</tr>
<tr>
<td>AbsOn</td>
<td>ADB</td>
<td>$0F09</td>
<td>Enables automatic polling from an absolute device.</td>
</tr>
<tr>
<td>AddFamily</td>
<td>FM</td>
<td>$0D1B</td>
<td>Allows a family to be added to the Font Manager's list of font families.</td>
</tr>
<tr>
<td>AddFontVar</td>
<td>FM</td>
<td>$141B</td>
<td>Allows a pre-existing family to be added to the available font list.</td>
</tr>
<tr>
<td>AddPt</td>
<td>QD</td>
<td>$8004</td>
<td>Adds two points and leaves their sum in the destination point.</td>
</tr>
<tr>
<td>Alert</td>
<td>DLM</td>
<td>$1715</td>
<td>Invokes an alert defined by a specified alert template.</td>
</tr>
<tr>
<td>ASynchADBReceive</td>
<td>ADB</td>
<td>$0D09</td>
<td>Receives data from an ADB device.</td>
</tr>
<tr>
<td>AutoAbsPoll</td>
<td>ADB</td>
<td>$1109</td>
<td>Reads flags to determine if automatic polling is on or off.</td>
</tr>
<tr>
<td>BeginUpdate</td>
<td>WM</td>
<td>$1E0E</td>
<td>Starts the window drawing procedure when a window is updated.</td>
</tr>
<tr>
<td>BlockMove</td>
<td>MM</td>
<td>$2B02</td>
<td>Copies a specified number of bytes from a source to a destination.</td>
</tr>
<tr>
<td>BringToFront</td>
<td>WM</td>
<td>$240E</td>
<td>Brings a window to the front and redraws other windows as necessary.</td>
</tr>
<tr>
<td>Button</td>
<td>EM</td>
<td>$0D06</td>
<td>Returns the current state of the specified mouse button.</td>
</tr>
<tr>
<td>CalcMenuSize</td>
<td>MUM</td>
<td>$1C0F</td>
<td>Sets menu dimensions, either manually or automatically.</td>
</tr>
<tr>
<td>Call</td>
<td>Tool</td>
<td>Call Number</td>
<td>Function</td>
</tr>
<tr>
<td>---------------------</td>
<td>------</td>
<td>-------------</td>
<td>---------------------------------------------------------------------------</td>
</tr>
<tr>
<td>CautionAlert</td>
<td>DLM</td>
<td>$1A15</td>
<td>Performs functions similar to those of the Alert routine.</td>
</tr>
<tr>
<td>CharBounds</td>
<td>QD</td>
<td>$AC04</td>
<td>Sets a specified rectangle to be the bounds of a specified character.</td>
</tr>
<tr>
<td>CharWidth</td>
<td>QD</td>
<td>$A804</td>
<td>Returns the width in pixels of a specified character.</td>
</tr>
<tr>
<td>CheckHandle</td>
<td>MM</td>
<td>$1E02</td>
<td>Checks a handle to see if it's valid.</td>
</tr>
<tr>
<td>CheckMItem</td>
<td>MUM</td>
<td>$320F</td>
<td>Displays or removes a check mark to the left of a menu item.</td>
</tr>
<tr>
<td>CheckUpdate</td>
<td>WM</td>
<td>$0A0E</td>
<td>Checks to see if any windows need updating.</td>
</tr>
<tr>
<td>ChooseCDA</td>
<td>DM</td>
<td>$1105</td>
<td>Activates the Desk Manager and displays the CDA menu.</td>
</tr>
<tr>
<td>ChooserFont</td>
<td>FM</td>
<td>$161B</td>
<td>Displays a dialog for selection of a new font, size, and/or style.</td>
</tr>
<tr>
<td>CirHeartBeat</td>
<td>MTS</td>
<td>$1403</td>
<td>Removes all tasks from the heartbeat interrupt task queue.</td>
</tr>
<tr>
<td>ClampMouse</td>
<td>MTS</td>
<td>$1C03</td>
<td>Sets mouse clamp values and places the mouse at the minimum values.</td>
</tr>
<tr>
<td>ClearMouse</td>
<td>MTS</td>
<td>$1B03</td>
<td>Sets the mouse's X and Y axis positions to 0000 or clamp minimums.</td>
</tr>
<tr>
<td>ClearScreen</td>
<td>QD</td>
<td>$1504</td>
<td>Sets the words in screen memory to a specified value.</td>
</tr>
<tr>
<td>ClearSRQTable</td>
<td>ADB</td>
<td>$1609</td>
<td>Clears the SRQ list of all entries.</td>
</tr>
<tr>
<td>ClipRect</td>
<td>QD</td>
<td>$2604</td>
<td>Makes the current port's clip rectangle equal to a given rectangle.</td>
</tr>
<tr>
<td>CloseAIINDAs</td>
<td>DM</td>
<td>$1D05</td>
<td>Closes all open NDAs.</td>
</tr>
<tr>
<td>CloseDialog</td>
<td>DLM</td>
<td>$0C15</td>
<td>Removes a dialog from the screen and deletes it from the window list.</td>
</tr>
<tr>
<td>CloseNDA</td>
<td>DM</td>
<td>$1605</td>
<td>Closes a specified new desk accessory.</td>
</tr>
<tr>
<td>CloseNDAbyWinPtr</td>
<td>DM</td>
<td>$1C05</td>
<td>Closes the NDA whose window pointer is passed.</td>
</tr>
<tr>
<td>ClosePoly</td>
<td>QD</td>
<td>$C204</td>
<td>Completes the polygon creation started with OpenPoly.</td>
</tr>
<tr>
<td>ClosePort</td>
<td>QD</td>
<td>$1A04</td>
<td>Deallocates the regions in a port.</td>
</tr>
<tr>
<td>Call</td>
<td>Tool</td>
<td>Call Number</td>
<td>Function</td>
</tr>
<tr>
<td>--------------------</td>
<td>------</td>
<td>-------------</td>
<td>--------------------------------------------------------------------------</td>
</tr>
<tr>
<td>CloseRgn</td>
<td>QD</td>
<td>$6E04</td>
<td>Stops processing of a region and returns the created region.</td>
</tr>
<tr>
<td>CloseWindow</td>
<td>WM</td>
<td>$0V0E</td>
<td>Removes a window from the screen and deletes it from the window list.</td>
</tr>
<tr>
<td>CompactMem</td>
<td>MM</td>
<td>$1F02</td>
<td>Compacts memory.</td>
</tr>
<tr>
<td>CopyRgn</td>
<td>QD</td>
<td>$6904</td>
<td>Copies the contents of a region from one region to another.</td>
</tr>
<tr>
<td>CountFamilies</td>
<td>FM</td>
<td>$091B</td>
<td>Returns the number of font families available.</td>
</tr>
<tr>
<td>CountFonts</td>
<td>FM</td>
<td>$101B</td>
<td>Returns the number of fonts available that fit a certain description.</td>
</tr>
<tr>
<td>CountMItems</td>
<td>MUM</td>
<td>$140F</td>
<td>Returns the number of items in a specified menu.</td>
</tr>
<tr>
<td>CreateList</td>
<td>LM</td>
<td>$091C</td>
<td>Creates a list control and returns its handle.</td>
</tr>
<tr>
<td>CStringBounds</td>
<td>QD</td>
<td>4AE04</td>
<td>Sets a specified rectangle to be the bounds of a specified C string.</td>
</tr>
<tr>
<td>CStringWidth</td>
<td>QD</td>
<td>$AA04</td>
<td>Returns the width of a specified C string.</td>
</tr>
<tr>
<td>CtlBootInit</td>
<td>CM</td>
<td>$0110</td>
<td>Called only by the Tool Locator when the system is booted.</td>
</tr>
<tr>
<td>CtlNewRes</td>
<td>CM</td>
<td>$1210</td>
<td>Reinitializes resolution and mode.</td>
</tr>
<tr>
<td>CtlReset</td>
<td>CM</td>
<td>$0510</td>
<td>Called on system reset.</td>
</tr>
<tr>
<td>CtlShutDown</td>
<td>CM</td>
<td>$0310</td>
<td>Deactivates the Control Manager.</td>
</tr>
<tr>
<td>CtlStartUp</td>
<td>CM</td>
<td>$0210</td>
<td>Starts up the Control Manager for use by an application.</td>
</tr>
<tr>
<td>CtlStatus</td>
<td>CM</td>
<td>$0610</td>
<td>Checks the current status of the Control Manager.</td>
</tr>
<tr>
<td>CtlTextDev</td>
<td>TT</td>
<td>$160C</td>
<td>Passes a control code to a specified text device.</td>
</tr>
<tr>
<td>CtlVersion</td>
<td>CM</td>
<td>$0410</td>
<td>Returns the version number of the Control Manager.</td>
</tr>
<tr>
<td>Dec2Int</td>
<td>IM</td>
<td>$280B</td>
<td>Converts an ASCII string into a 16-bit signed or unsigned integer.</td>
</tr>
<tr>
<td>Dec2Long</td>
<td>IM</td>
<td>$290B</td>
<td>Converts an ASCII string into a 32-bit integer.</td>
</tr>
<tr>
<td>DefaultFilter</td>
<td>DLM</td>
<td>$3615</td>
<td>Calls a modal or an alert dialog's standard default filter.</td>
</tr>
<tr>
<td>Call</td>
<td>Tool</td>
<td>Call Number</td>
<td>Function</td>
</tr>
<tr>
<td>--------------</td>
<td>------</td>
<td>-------------</td>
<td>--------------------------------------------------------------------------</td>
</tr>
<tr>
<td>DeleteID</td>
<td>MTS</td>
<td>$2103</td>
<td>Deletes all references to a specified user ID.</td>
</tr>
<tr>
<td>DeleteMenu</td>
<td>MUM</td>
<td>$0E0F</td>
<td>Removes a specified menu from the menu list.</td>
</tr>
<tr>
<td>DeleteMItem</td>
<td>MUM</td>
<td>$100F</td>
<td>Removes a specified item from the current menu.</td>
</tr>
<tr>
<td>DelHeartBeat</td>
<td>MTS</td>
<td>$1303</td>
<td>Deletes a specified task from the heartbeat interrupt task queue.</td>
</tr>
<tr>
<td>DeskBootlnit</td>
<td>DM</td>
<td>$0105</td>
<td>Internal routine called at boot time to initialize the Desk Manager.</td>
</tr>
<tr>
<td>DeskReset</td>
<td>DM</td>
<td>$0505</td>
<td>Resets the Desk Manager.</td>
</tr>
<tr>
<td>DeskShutDown</td>
<td>DM</td>
<td>$0305</td>
<td>Shuts down the Desk Manager.</td>
</tr>
<tr>
<td>DeskStartUp</td>
<td>CM</td>
<td>$0205</td>
<td>Starts up the Desk Manager.</td>
</tr>
<tr>
<td>DeskStatus</td>
<td>DM</td>
<td>$0605</td>
<td>Tells if the Desk Manager is active.</td>
</tr>
<tr>
<td>Desktop</td>
<td>WM</td>
<td>$0C0E</td>
<td>Keeps track of regions on the desktop and controls desktop pattern.</td>
</tr>
<tr>
<td>DeskVersion</td>
<td>DM</td>
<td>$0405</td>
<td>Returns the version number of the Desk Manager.</td>
</tr>
<tr>
<td>DialogBootlnit</td>
<td>DLM</td>
<td>$0115</td>
<td>Called by the Tool Locator at initialization.</td>
</tr>
<tr>
<td>DialogReset</td>
<td>DLM</td>
<td>$0515</td>
<td>Resets the Dialog Manager.</td>
</tr>
<tr>
<td>DialogSelect</td>
<td>DLM</td>
<td>$1115</td>
<td>Handles modeless dialog events.</td>
</tr>
<tr>
<td>DialogShutDown</td>
<td>DLM</td>
<td>$0315</td>
<td>Shuts down the Dialog Manager.</td>
</tr>
<tr>
<td>DialogStartUp</td>
<td>DLM</td>
<td>$0215</td>
<td>Starts up the Dialog Manager.</td>
</tr>
<tr>
<td>DialogStatus</td>
<td>DLM</td>
<td>$0615</td>
<td>Indicates if the Dialog Manager is active.</td>
</tr>
<tr>
<td>DialogVersion</td>
<td>DLM</td>
<td>$0415</td>
<td>Returns the version number of the Dialog Manager.</td>
</tr>
<tr>
<td>DiffRgn</td>
<td>QD</td>
<td>47304</td>
<td>Returns a region that is the difference between two regions.</td>
</tr>
<tr>
<td>Disable Increment</td>
<td>ST</td>
<td></td>
<td>Enables auto-increment mode.</td>
</tr>
<tr>
<td>DisableDItem</td>
<td>DLM</td>
<td>$3915</td>
<td>Disables a specified item in a specified dialog.</td>
</tr>
<tr>
<td>DisableMItem</td>
<td>MUM</td>
<td>$310F</td>
<td>Displays an item in dimmed characters and makes it unselectable.</td>
</tr>
<tr>
<td>DisposeAll</td>
<td>MM</td>
<td>$1102</td>
<td>Discards all the handles belonging to a specified user ID.</td>
</tr>
</tbody>
</table>

**Toolbox Calls**
<table>
<thead>
<tr>
<th>Call</th>
<th>Tool</th>
<th>Call Number</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>DisposeControl</td>
<td>CM</td>
<td>$0A10</td>
<td>Deletes a specified control from its window's control list.</td>
</tr>
<tr>
<td>DisposeHandle</td>
<td>MM</td>
<td>$1002</td>
<td>Disposes of a specified block and deallocates its handle.</td>
</tr>
<tr>
<td>DisposeMenu</td>
<td>MUM</td>
<td>$2E0F</td>
<td>Frees the memory allocated by NewMenu.</td>
</tr>
<tr>
<td>DisposeRgn</td>
<td>QD</td>
<td>$6804</td>
<td>Deallocates space for a specified region.</td>
</tr>
<tr>
<td>DlgCopy</td>
<td>DLM</td>
<td>$1315</td>
<td>Applies the LineEdit procedure LECopy to an EditLine item.</td>
</tr>
<tr>
<td>DlgCut</td>
<td>DLM</td>
<td>$1215</td>
<td>Applies the LineEdit procedure LECut to an EditLine item.</td>
</tr>
<tr>
<td>DlgDelete</td>
<td>DLM</td>
<td>$1515</td>
<td>Applies the LineEdit procedure LEDelete to an EditLine item.</td>
</tr>
<tr>
<td>DlgPaste</td>
<td>DLM</td>
<td>$1415</td>
<td>Applies the LineEdit procedure LEPaste to an EditLine item.</td>
</tr>
<tr>
<td>DoWindows</td>
<td>EM</td>
<td>$0906</td>
<td>Returns the address of the Event Manager's direct page work area.</td>
</tr>
<tr>
<td>DragControl</td>
<td>CM</td>
<td>$1710</td>
<td>Pulls a dotted outline of a control around the screen.</td>
</tr>
<tr>
<td>DragRect</td>
<td>CM</td>
<td>$1D10</td>
<td>Pulls a dotted outline of a rectangle around the screen.</td>
</tr>
<tr>
<td>DragWindow</td>
<td>WM</td>
<td>$1A0E</td>
<td>Pulls around the outline of a window, following mouse movements.</td>
</tr>
<tr>
<td>DrawChar</td>
<td>QD</td>
<td>$A404</td>
<td>Draws a specified character at the current pen location.</td>
</tr>
<tr>
<td>DrawControls</td>
<td>CM</td>
<td>$1010</td>
<td>Draws all controls currently visible in a specified window.</td>
</tr>
<tr>
<td>DrawCString</td>
<td>QD</td>
<td>$A604</td>
<td>Draws a specified C string at the current pen location.</td>
</tr>
<tr>
<td>DrawDialog</td>
<td>DLM</td>
<td>$1615</td>
<td>Draws the contents of a specified dialog box.</td>
</tr>
<tr>
<td>DrawIcon</td>
<td>QD</td>
<td>$0B12</td>
<td>Draws an icon on the screen.</td>
</tr>
<tr>
<td>DrawMember</td>
<td>LM</td>
<td>$0C1C</td>
<td>Redraws a member of the list whose state may have changed.</td>
</tr>
<tr>
<td>DrawMenuBar</td>
<td>MUM</td>
<td>$2A0F</td>
<td>Draws the current menu bar, along with any menu titles on the bar.</td>
</tr>
<tr>
<td>DrawOneCtl</td>
<td>CM</td>
<td>$2510</td>
<td>Draws a specified control.</td>
</tr>
</tbody>
</table>
# Toolbox Calls

<table>
<thead>
<tr>
<th>Call</th>
<th>Tool</th>
<th>Call Number</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>DrawString</td>
<td>QD</td>
<td>$A504</td>
<td>Draws a specified string at the current pen location.</td>
</tr>
<tr>
<td>DrawText</td>
<td>QD</td>
<td>$A704</td>
<td>Draws specified text at the current pen location.</td>
</tr>
<tr>
<td>EMBootInit</td>
<td>EM</td>
<td>$0106</td>
<td>Called at boot time by the Tool Locator.</td>
</tr>
<tr>
<td>EmptyRect</td>
<td>QD</td>
<td>$5204</td>
<td>Returns whether or not a specified rectangle is empty.</td>
</tr>
<tr>
<td>EmptyRgn</td>
<td>QD</td>
<td>$7804</td>
<td>Checks to see if a specified region is empty.</td>
</tr>
<tr>
<td>EMReset</td>
<td>EM</td>
<td>$0506</td>
<td>Returns an error if the Event Manager is active.</td>
</tr>
<tr>
<td>EMShutDown</td>
<td>EM</td>
<td>$0306</td>
<td>Shuts down the Event Manager and releases any workspace allocated to it.</td>
</tr>
<tr>
<td>EMStartUp</td>
<td>EM</td>
<td>$0206</td>
<td>Initializes the Event Manager and sets the size of the event queue.</td>
</tr>
<tr>
<td>EMStatus</td>
<td>EM</td>
<td>$0606</td>
<td>Indicates a nonzero value if the Event Manager is active.</td>
</tr>
<tr>
<td>EMVersion</td>
<td>EM</td>
<td>$0406</td>
<td>Returns the version of the Event Manager.</td>
</tr>
<tr>
<td>EnableDtItem</td>
<td>DLM</td>
<td>$3A15</td>
<td>Enables a specified item in a specified dialog.</td>
</tr>
<tr>
<td>EnableMItem</td>
<td>MUM</td>
<td>$300F</td>
<td>Displays an item normally and allows it to be selected.</td>
</tr>
<tr>
<td>EndInfoDrawing</td>
<td>WM</td>
<td>$510E</td>
<td>Puts the Window Manager back into a global coordinate system.</td>
</tr>
<tr>
<td>EndUpdate</td>
<td>WM</td>
<td>$1F0E</td>
<td>Ends the window drawing procedure started by BeginUpdate.</td>
</tr>
<tr>
<td>EqualPt</td>
<td>QD</td>
<td>$8304</td>
<td>Indicates whether two points are equal.</td>
</tr>
<tr>
<td>EqualRect</td>
<td>QD</td>
<td>$5104</td>
<td>Compares two rectangles and indicates if they are equal.</td>
</tr>
<tr>
<td>EqualRgn</td>
<td>QD</td>
<td>$7704</td>
<td>Compares two regions and tells if they are equal.</td>
</tr>
<tr>
<td>EraseArc</td>
<td>QD</td>
<td>$6404</td>
<td>Erases an arc by filling it with the background pattern.</td>
</tr>
<tr>
<td>EraseControl</td>
<td>CM</td>
<td>$2410</td>
<td>Makes a specified control invisible.</td>
</tr>
<tr>
<td>EraseOval</td>
<td>QD</td>
<td>$5A04</td>
<td>Erases an oval by filling it with the background pattern.</td>
</tr>
<tr>
<td>ErasePoly</td>
<td>QD</td>
<td>SBE04</td>
<td>Erases a specified polygon.</td>
</tr>
<tr>
<td>Call</td>
<td>Tool</td>
<td>Call Number</td>
<td>Function</td>
</tr>
<tr>
<td>----------------------</td>
<td>------</td>
<td>-------------</td>
<td>--------------------------------------------------------------------------</td>
</tr>
<tr>
<td>EraseRect</td>
<td>QD</td>
<td>$5504</td>
<td>Erases a rectangle by filling it with the background pattern.</td>
</tr>
<tr>
<td>EraseRgn</td>
<td>QD</td>
<td>$7B04</td>
<td>Fills the interior of a specified region with the background pattern.</td>
</tr>
<tr>
<td>EraseRRect</td>
<td>QD</td>
<td>45F04</td>
<td>Erases the interior of a round rectangle.</td>
</tr>
<tr>
<td>ErrorSound</td>
<td>DLM</td>
<td>$0915</td>
<td>Sets the sound procedure for alerts to a specified procedure.</td>
</tr>
<tr>
<td>ErrWriteBlock</td>
<td>TT</td>
<td>$1F0C</td>
<td>Writes a block of text to the error output text device.</td>
</tr>
<tr>
<td>ErrWriteChar</td>
<td>TT</td>
<td>$190C</td>
<td>Writes a character to the error output text device.</td>
</tr>
<tr>
<td>ErrWriteCString</td>
<td>TT</td>
<td>$210C</td>
<td>Writes a C-style string to the error output text device.</td>
</tr>
<tr>
<td>ErrWriteLine</td>
<td>TT</td>
<td>$1B0C</td>
<td>Writes a string, plus a carriage return, to the error output text device.</td>
</tr>
<tr>
<td>ErrWriteString</td>
<td>TT</td>
<td>$1D0C</td>
<td>Writes a string to the error output text device.</td>
</tr>
<tr>
<td>EventAvail</td>
<td>EM</td>
<td>$0B06</td>
<td>Accesses the next available event but leaves it in the queue.</td>
</tr>
<tr>
<td>FakeMouse</td>
<td>EM</td>
<td>$1906</td>
<td>Allows an application to use an alternative pointing device.</td>
</tr>
<tr>
<td>FamNum2ItemID</td>
<td>FM</td>
<td>$171B</td>
<td>Translates a font family number into a menu item ID.</td>
</tr>
<tr>
<td>FamNum2ItemID</td>
<td>FM</td>
<td>$1B1B</td>
<td>Tells if a menu item is displayed in a specified font family.</td>
</tr>
<tr>
<td>FFGeneratorStatus</td>
<td>ST</td>
<td>$1108</td>
<td>Reads the first 2 bytes of a block corresponding to a generator.</td>
</tr>
<tr>
<td>FFSoundDoneStatus</td>
<td>ST</td>
<td>$1408</td>
<td>Returns the free-form synthesizer sound-playing status.</td>
</tr>
<tr>
<td>FFSoundStatus</td>
<td>ST</td>
<td>$1008</td>
<td>Returns the status of all fifteen generators.</td>
</tr>
<tr>
<td>FFStartSound</td>
<td>ST</td>
<td>$0E08</td>
<td>Enables the DOC to start generating sound on a particular generator.</td>
</tr>
<tr>
<td>FFStopSound</td>
<td>ST</td>
<td>$0F08</td>
<td>Stops sound generators that may be running.</td>
</tr>
<tr>
<td>FillArc</td>
<td>QD</td>
<td>$6604</td>
<td>Fills the interior of an arc.</td>
</tr>
<tr>
<td>FillOval</td>
<td>QD</td>
<td>$5C04</td>
<td>Fills an oval with a specified pattern.</td>
</tr>
<tr>
<td>Call</td>
<td>Tool</td>
<td>Call Number</td>
<td>Function</td>
</tr>
<tr>
<td>-----------------</td>
<td>------</td>
<td>-------------</td>
<td>--------------------------------------------------------------------------</td>
</tr>
<tr>
<td>FillPoly</td>
<td>QD</td>
<td>$C004</td>
<td>Fills a specified polygon with a specified pen pattern.</td>
</tr>
<tr>
<td>FillRect</td>
<td>QD</td>
<td>$5704</td>
<td>Fills the interior of a specified rectangle with a specified pattern.</td>
</tr>
<tr>
<td>FillRgn</td>
<td>QD</td>
<td>$7D04</td>
<td>Fills the interior of a specified region with a specified pattern.</td>
</tr>
<tr>
<td>FillRRect</td>
<td>QD</td>
<td>$6104</td>
<td>Fills a round rectangle with a specified pattern.</td>
</tr>
<tr>
<td>FindControl</td>
<td>CM</td>
<td>$1310</td>
<td>Tells in which control the mouse button was pressed.</td>
</tr>
<tr>
<td>FindDItem</td>
<td>DLM</td>
<td>$2415</td>
<td>Returns the ID of the item located at a specified point in a dialog.</td>
</tr>
<tr>
<td>FindFamily</td>
<td>FM</td>
<td>$0A1B</td>
<td>Returns the family number and name of a particular font family.</td>
</tr>
<tr>
<td>FindFontStats</td>
<td>FM</td>
<td>$111B</td>
<td>Places a FontID and a FontStatBits in a specified FontStat record.</td>
</tr>
<tr>
<td>FindHandle</td>
<td>MM</td>
<td>$1A02</td>
<td>Returns the handle of the block containing a specified address.</td>
</tr>
<tr>
<td>FindWindow</td>
<td>WM</td>
<td>$170E</td>
<td>Tells if the mouse was clicked inside a window, and where.</td>
</tr>
<tr>
<td>Fix2Frac</td>
<td>IM</td>
<td>$1C0B</td>
<td>Converts fixed to fraction.</td>
</tr>
<tr>
<td>Fix2Long</td>
<td>IM</td>
<td>$1B0B</td>
<td>Converts fixed to long integer.</td>
</tr>
<tr>
<td>Fix2X</td>
<td>IM</td>
<td>$1E0B</td>
<td>Converts fixed to extended.</td>
</tr>
<tr>
<td>FixAppleMenu</td>
<td>DM</td>
<td>$1E05</td>
<td>Adds the names of new desk accessories to the specified menu.</td>
</tr>
<tr>
<td>FixATan2</td>
<td>IM</td>
<td>$170B</td>
<td>Returns a fixed arc tangent of the coordinates of two like inputs.</td>
</tr>
<tr>
<td>FixDiv</td>
<td>IM</td>
<td>$110b</td>
<td>Divides two like inputs and returns a rounded fixed result.</td>
</tr>
<tr>
<td>FixFontMenu</td>
<td>FM</td>
<td>$151B</td>
<td>Appends the names of available font families onto a specified menu.</td>
</tr>
<tr>
<td>FixMenuBar</td>
<td>MUM</td>
<td>$130F</td>
<td>Computes standard sizes for the menu bar and menus.</td>
</tr>
<tr>
<td>FixMul</td>
<td>IM</td>
<td>$0F0B</td>
<td>Multiplies two 32-bit fixed inputs and returns a 32-bit fixed result.</td>
</tr>
<tr>
<td>FixRatio</td>
<td>IM</td>
<td>$0E0B</td>
<td>Returns a 32-bit fixed-number ratio of a numerator and a denominator.</td>
</tr>
<tr>
<td>Call</td>
<td>Tool</td>
<td>Call Number</td>
<td>Function</td>
</tr>
<tr>
<td>-----------------</td>
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<td>-------------</td>
<td>--------------------------------------------------------------------------</td>
</tr>
<tr>
<td>FixRound</td>
<td>IM</td>
<td>$130B</td>
<td>Takes a fixed input and returns a rounded integer result.</td>
</tr>
<tr>
<td>FlashMenuBar</td>
<td>MUM</td>
<td>$0C0F</td>
<td>Flashs the current menu bar using colors set by NewInvertColor.</td>
</tr>
<tr>
<td>FlushEvents</td>
<td>EM</td>
<td>$1506</td>
<td>Removes specified queue events until a stop mask is encountered.</td>
</tr>
<tr>
<td>FMBootInit</td>
<td>FM</td>
<td>$011B</td>
<td>Called at boot time by the Tool Locator.</td>
</tr>
<tr>
<td>FMGetCurFID</td>
<td>FM</td>
<td>$1A1B</td>
<td>Returns the FontID of the current font.</td>
</tr>
<tr>
<td>FMGetSysFID</td>
<td>FM</td>
<td>$191B</td>
<td>Returns the FontID of the system font.</td>
</tr>
<tr>
<td>FMReset</td>
<td>FM</td>
<td>$051B</td>
<td>Returns an error if the Font Manager is active.</td>
</tr>
<tr>
<td>FMSetSysFont</td>
<td>FM</td>
<td>$181B</td>
<td>Loads a specified font into memory, makes it unpurgeable.</td>
</tr>
<tr>
<td>FMShtDown</td>
<td>FM</td>
<td>$031B</td>
<td>Shuts down the Font Manager.</td>
</tr>
<tr>
<td>FMStartUp</td>
<td>FM</td>
<td>$021B</td>
<td>Initializes the Font Manager for use by an application.</td>
</tr>
<tr>
<td>FMStatus</td>
<td>FM</td>
<td>$061B</td>
<td>Returns a nonzero value if the Font Manager is active.</td>
</tr>
<tr>
<td>FMVersion</td>
<td>FM</td>
<td>$041B</td>
<td>Returns the version number of the Font Manager.</td>
</tr>
<tr>
<td>ForceBufDims</td>
<td>QD</td>
<td>SCC04</td>
<td>Works like SetBufDims, but does not pad MaxFBRExtent.</td>
</tr>
<tr>
<td>Frac2Fix</td>
<td>IM</td>
<td>$1D0B</td>
<td>Converts fraction to fixed.</td>
</tr>
<tr>
<td>Frac2X</td>
<td>IM</td>
<td>$1F0B</td>
<td>Converts fraction to extended.</td>
</tr>
<tr>
<td>FracCos</td>
<td>IM</td>
<td>$150B</td>
<td>Takes a fixed input and returns its fractional cosine.</td>
</tr>
<tr>
<td>FracDiv</td>
<td>IM</td>
<td>$120B</td>
<td>Divides two like inputs and returns a rounded fractional result.</td>
</tr>
<tr>
<td>FracMul</td>
<td>IM</td>
<td>$100B</td>
<td>Multiplies two fractional inputs and returns a rounded fractional result.</td>
</tr>
<tr>
<td>FracSart</td>
<td>IM</td>
<td>$140B</td>
<td>Takes a fractional input and returns a rounded fractional square root.</td>
</tr>
<tr>
<td>FracSin</td>
<td>IM</td>
<td>$160B</td>
<td>Takes a fixed input and returns its fractional sine.</td>
</tr>
<tr>
<td>Call</td>
<td>Tool</td>
<td>Call Number</td>
<td>Function</td>
</tr>
<tr>
<td>-----------------</td>
<td>------</td>
<td>-------------</td>
<td>--------------------------------------------------------------------------</td>
</tr>
<tr>
<td>FrameArc</td>
<td>QD</td>
<td>$6204</td>
<td>Draws the boundary of an arc using the current pen state and pattern.</td>
</tr>
<tr>
<td>FrameOval</td>
<td>QD</td>
<td>$5804</td>
<td>Frames an oval using the current pen state and pen pattern.</td>
</tr>
<tr>
<td>FramePoly</td>
<td>QD</td>
<td>$BC04</td>
<td>Frames a specified polygon.</td>
</tr>
<tr>
<td>FrameRect</td>
<td>QD</td>
<td>$5304</td>
<td>Frames a rectangle using the current pen state and pen pattern.</td>
</tr>
<tr>
<td>FrameRgn</td>
<td>QD</td>
<td>$7904</td>
<td>Frames a specified region using the current pen state and pattern.</td>
</tr>
<tr>
<td>FrameRRect</td>
<td>QD</td>
<td>$5D04</td>
<td>Frames a round rectangle using the current pen state and pen pattern.</td>
</tr>
<tr>
<td>FreeMem</td>
<td>MM</td>
<td>$1B02</td>
<td>Returns the total number of free bytes in memory.</td>
</tr>
<tr>
<td>FrontWindow</td>
<td>WM</td>
<td>$150E</td>
<td>Returns a pointer to the first visible window in the window list.</td>
</tr>
<tr>
<td>FWEntry</td>
<td>MTS</td>
<td>$2403</td>
<td>Allows some Apple II entry points to be supported from native mode.</td>
</tr>
<tr>
<td>GetAbsClamp</td>
<td>MTS</td>
<td>$2B03</td>
<td>Returns the current values for the absolute device clamps.</td>
</tr>
<tr>
<td>GetAbsScale</td>
<td>ADB</td>
<td>$1309</td>
<td>Reads absolute device scaling values.</td>
</tr>
<tr>
<td>GetAddr</td>
<td>MTS</td>
<td>$1603</td>
<td>Returns the address of a parameter referenced by the firmware.</td>
</tr>
<tr>
<td>GetAddress</td>
<td>QD</td>
<td>$0904</td>
<td>Returns a pointer to a specified table.</td>
</tr>
<tr>
<td>GetAlertStage</td>
<td>DLM</td>
<td>$3415</td>
<td>Returns the stage of the last occurrence of an alert.</td>
</tr>
<tr>
<td>GetBackColor</td>
<td>QD</td>
<td>$A304</td>
<td>Returns the value of the background color field from the GrafPort.</td>
</tr>
<tr>
<td>GetBackPat</td>
<td>QD</td>
<td>$3504</td>
<td>Returns the current background pattern.</td>
</tr>
<tr>
<td>GetBarColors</td>
<td>MUM</td>
<td>$180F</td>
<td>Returns the colors for the current menu bar.</td>
</tr>
<tr>
<td>GetCaretTime</td>
<td>EM</td>
<td>$1206</td>
<td>Returns the time between blinks of the caret.</td>
</tr>
<tr>
<td>GetCharExtra</td>
<td>QD</td>
<td>SD504</td>
<td>Returns the chExtra field from the GrafPort.</td>
</tr>
<tr>
<td>Call</td>
<td>Tool</td>
<td>Call Number</td>
<td>Function</td>
</tr>
<tr>
<td>----------------------</td>
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<td>-------------</td>
<td>---------------------------------------------------------------</td>
</tr>
<tr>
<td>GetClip</td>
<td>QD</td>
<td>$2504</td>
<td>Copies the ClipRgn to a specified region.</td>
</tr>
<tr>
<td>GetClipHandle</td>
<td>QD</td>
<td>$C704</td>
<td>Returns a copy of the handle to the ClipRgn.</td>
</tr>
<tr>
<td>GetColorEntry</td>
<td>QD</td>
<td>$1104</td>
<td>Returns the value of a color in a specified color table.</td>
</tr>
<tr>
<td>GetColorTable</td>
<td>QD</td>
<td>$0F04</td>
<td>Fills a color table with the contents of another color table.</td>
</tr>
<tr>
<td>GetContentDraw</td>
<td>WM</td>
<td>$480E</td>
<td>Returns a pointer to the routine that draws a window's contents.</td>
</tr>
<tr>
<td>GetContentOrigin</td>
<td>WM</td>
<td>$3E0E</td>
<td>Returns values used to set the origin of a window's port.</td>
</tr>
<tr>
<td>GetContentRgn</td>
<td>WM</td>
<td>$2F0E</td>
<td>Returns a handle to a specified window's content region.</td>
</tr>
<tr>
<td>GetControlDItem</td>
<td>DLM</td>
<td>$1E15</td>
<td>Returns a handle to the control for a specified item.</td>
</tr>
<tr>
<td>GetCtlAction</td>
<td>CM</td>
<td>$2110</td>
<td>Returns the current value of a specified control's CtlAction field.</td>
</tr>
<tr>
<td>GetCtlDpage</td>
<td>CM</td>
<td>$1F10</td>
<td>Returns the value of the Control Manager's direct page.</td>
</tr>
<tr>
<td>GetCtlParams</td>
<td>CM</td>
<td>$1C10</td>
<td>Returns a specified control's additional parameter settings.</td>
</tr>
<tr>
<td>GetCtlRefCon</td>
<td>CM</td>
<td>$2310</td>
<td>Returns the current value of a specified control's CtlRefCon field.</td>
</tr>
<tr>
<td>GetCtlTitle</td>
<td>CM</td>
<td>$0D10</td>
<td>Returns the value in a specified control's CtlData field.</td>
</tr>
<tr>
<td>GetCtlValue</td>
<td>CM</td>
<td>$1A10</td>
<td>Returns a specified control's current CtlValue field.</td>
</tr>
<tr>
<td>GetCursorAddr</td>
<td>QD</td>
<td>$8F04</td>
<td>Returns a pointer to the current cursor record.</td>
</tr>
<tr>
<td>GetDAStrPtr</td>
<td>DM</td>
<td>$1405</td>
<td>Returns the pointer to a table of desk accessory strings.</td>
</tr>
<tr>
<td>GetDataSize</td>
<td>WM</td>
<td>$400E</td>
<td>Returns the height and width of the data area of a specified window.</td>
</tr>
<tr>
<td>GetDbITime</td>
<td>EM</td>
<td>$1106</td>
<td>Sets the time required between mouse clicks for a double click.</td>
</tr>
<tr>
<td>GetDefButton</td>
<td>DLM</td>
<td>$3715</td>
<td>Returns the ID of the default button item in a specified dialog.</td>
</tr>
<tr>
<td>GetDefProc</td>
<td>WM</td>
<td>$310E</td>
<td>Returns the address of a routine that controls a window's behavior.</td>
</tr>
<tr>
<td>Call</td>
<td>Tool</td>
<td>Call Number</td>
<td>Function</td>
</tr>
<tr>
<td>----------------------</td>
<td>------</td>
<td>-------------</td>
<td>--------------------------------------------------------------------------</td>
</tr>
<tr>
<td>GetDItemBox</td>
<td>DLM</td>
<td>$2815</td>
<td>Returns the display rectangle of a specified item.</td>
</tr>
<tr>
<td>GetDItemType</td>
<td>DLM</td>
<td>$2615</td>
<td>Returns the type of a specified item.</td>
</tr>
<tr>
<td>GetDItemValue</td>
<td>DLM</td>
<td>$2E15</td>
<td>Returns the current value of a specified item.</td>
</tr>
<tr>
<td>GetErrGlobals</td>
<td>TT</td>
<td>$0E0C</td>
<td>Returns the current values for the error output device's global parameters.</td>
</tr>
<tr>
<td>GetErrorDevice</td>
<td>TT</td>
<td>$140C</td>
<td>Returns the type of driver installed as the error output device.</td>
</tr>
<tr>
<td>GetFamInfo</td>
<td>FM</td>
<td>$0B1B</td>
<td>Returns the name of a font family that has a specified family number.</td>
</tr>
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<tr>
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</tr>
<tr>
<td>InflateText-Buffer</td>
<td>QD</td>
<td>$D704</td>
<td>Inflates the text buffer to a specified size, if necessary.</td>
</tr>
<tr>
<td>InitColorTable</td>
<td>QD</td>
<td>$0D04</td>
<td>Returns a copy of the standard color table for the current mode.</td>
</tr>
<tr>
<td>InitCursor</td>
<td>QD</td>
<td>SCA04</td>
<td>Reinitializes the cursor.</td>
</tr>
<tr>
<td>InitMouse</td>
<td>MTS</td>
<td>$1803</td>
<td>Sets mouse clamp values to $000 minimum and $3FF maximum.</td>
</tr>
<tr>
<td>InitPalette</td>
<td>MUM</td>
<td>$2F0F</td>
<td>Reinitializes the palettes used to draw the apple on the menu bar.</td>
</tr>
<tr>
<td>InitPort</td>
<td>QD</td>
<td>$1904</td>
<td>Initializes specified memory locations as a standard port.</td>
</tr>
<tr>
<td>InitTextDev</td>
<td>TT</td>
<td>$150C</td>
<td>Initializes a specified text device.</td>
</tr>
<tr>
<td>Call</td>
<td>Tool</td>
<td>Call Number</td>
<td>Function</td>
</tr>
<tr>
<td>---------------</td>
<td>------</td>
<td>-------------</td>
<td>----------------------------------------------------</td>
</tr>
<tr>
<td>InsertMenu</td>
<td>MUM</td>
<td>$0D0F</td>
<td>Inserts a menu into the menu list.</td>
</tr>
<tr>
<td>InsertMItem</td>
<td>MUM</td>
<td>$0F0F</td>
<td>Inserts an item into a menu.</td>
</tr>
<tr>
<td>InsetRect</td>
<td>QD</td>
<td>$4C04</td>
<td>Inserts a specified rectangle by specified displacements.</td>
</tr>
<tr>
<td>InsetRgn</td>
<td>QD</td>
<td>$7004</td>
<td>Shrinks or expands a specified region.</td>
</tr>
<tr>
<td>InstallCDA</td>
<td>DM</td>
<td>$0F05</td>
<td>Installs a specified classic desk accessory in the system.</td>
</tr>
<tr>
<td>InstallFont</td>
<td>FM</td>
<td>$0E1B</td>
<td>Loads a given font into memory and makes it current and unpurgeable.</td>
</tr>
<tr>
<td>InstallNDA</td>
<td>DM</td>
<td>$0E05</td>
<td>Installs a specified new desk accessory in the system.</td>
</tr>
<tr>
<td>Int2Dec</td>
<td>IM</td>
<td>$260B</td>
<td>Returns a string representing a 16-bit signed or unsigned integer.</td>
</tr>
<tr>
<td>Int2Hex</td>
<td>IM</td>
<td>$220B</td>
<td>Converts a 16-bit unsigned integer into a hexadecimal string.</td>
</tr>
<tr>
<td>IntSource</td>
<td>MTS</td>
<td>$2303</td>
<td>Enables or disables certain interrupt sources.</td>
</tr>
<tr>
<td>InvalRect</td>
<td>WM</td>
<td>$3A0E</td>
<td>Accumulates a rectangle into the current window port's update region.</td>
</tr>
<tr>
<td>InvalRgn</td>
<td>WM</td>
<td>$3B0E</td>
<td>Accumulates a region into the current window port's update region.</td>
</tr>
<tr>
<td>InvertArc</td>
<td>QD</td>
<td>$6504</td>
<td>Inverts the pixels inside a specified arc.</td>
</tr>
<tr>
<td>InvertOval</td>
<td>QD</td>
<td>$5B04</td>
<td>Inverts the pixels inside a specified oval.</td>
</tr>
<tr>
<td>InvertPoly</td>
<td>QD</td>
<td>$6F04</td>
<td>Inverts a specified polygon.</td>
</tr>
<tr>
<td>InvertRect</td>
<td>QD</td>
<td>$5604</td>
<td>Inverts the pixels in the interior of a specified rectangle.</td>
</tr>
<tr>
<td>InvertRgn</td>
<td>QD</td>
<td>$7C04</td>
<td>Inverts the pixels in the interior of a specified region.</td>
</tr>
<tr>
<td>InvertRRect</td>
<td>QD</td>
<td>$6004</td>
<td>Inverts the pixels inside a specified round rectangle.</td>
</tr>
<tr>
<td>IsDialogEvent</td>
<td>DLM</td>
<td>$1015</td>
<td>Determines if an event should be handled as part of a dialog.</td>
</tr>
<tr>
<td>ItemID2FamNum</td>
<td>FM</td>
<td>$171B</td>
<td>Translates a menu item ID into a font family number.</td>
</tr>
<tr>
<td>KillControls</td>
<td>CM</td>
<td>$0B10</td>
<td>Disposes of all controls associated with a specified window.</td>
</tr>
<tr>
<td>Call</td>
<td>Tool</td>
<td>Call Number</td>
<td>Function</td>
</tr>
<tr>
<td>-------------</td>
<td>------</td>
<td>-------------</td>
<td>--------------------------------------------------------------------------</td>
</tr>
<tr>
<td>KillPoly</td>
<td>QD</td>
<td>$C304</td>
<td>Disposes of a specified polygon.</td>
</tr>
<tr>
<td>LEActivate</td>
<td>LE</td>
<td>$0F14</td>
<td>Highlights current selection range in specified text.</td>
</tr>
<tr>
<td>LEBootlnit</td>
<td>LE</td>
<td>$0114</td>
<td>Called at boot time by the Tool Locator.</td>
</tr>
<tr>
<td>LEClick</td>
<td>LE</td>
<td>$0D14</td>
<td>Using mouse clicks, draws a caret and highlights selected text.</td>
</tr>
<tr>
<td>LECopy</td>
<td>LE</td>
<td>$1314</td>
<td>Copies selected text into the LineEdit scrap.</td>
</tr>
<tr>
<td>LECut</td>
<td>LE</td>
<td>$1214</td>
<td>Removes selected text and places it in the LineEdit scrap.</td>
</tr>
<tr>
<td>LEDeactivate</td>
<td>LE</td>
<td>$1014</td>
<td>Unhighlights current selection range in specified text.</td>
</tr>
<tr>
<td>LEDelete</td>
<td>LE</td>
<td>$1514</td>
<td>Removes selected text and redraws the remaining text.</td>
</tr>
<tr>
<td>LEDispose</td>
<td>LE</td>
<td>$0A14</td>
<td>Releases the memory allocated for a specified edit record.</td>
</tr>
<tr>
<td>LEFromScrap</td>
<td>LE</td>
<td>$1914</td>
<td>Copies the desk scrap to the LineEdit scrap.</td>
</tr>
<tr>
<td>LeGetScrapLen</td>
<td>LE</td>
<td>$1C14</td>
<td>Returns the size of the LineEdit scrap in bytes.</td>
</tr>
<tr>
<td>LGetTextHand</td>
<td>LE</td>
<td>$2214</td>
<td>Returns a handle to the text of a specified edit record.</td>
</tr>
<tr>
<td>LGetTextLen</td>
<td>LE</td>
<td>$2314</td>
<td>Returns the length of the text of a specified edit record.</td>
</tr>
<tr>
<td>LEIdle</td>
<td>LE</td>
<td>$0C14</td>
<td>Places a blinking caret at the insertion point in a specified line.</td>
</tr>
<tr>
<td>LEInsert</td>
<td>LE</td>
<td>$1614</td>
<td>Inserts specified text into other text, and redraws the updated text.</td>
</tr>
<tr>
<td>LEKey</td>
<td>LE</td>
<td>$1114</td>
<td>Places a character in text and leaves an insertion point after it.</td>
</tr>
<tr>
<td>LENew</td>
<td>LE</td>
<td>$0914</td>
<td>Allocates text space and returns a handle to a new edit record.</td>
</tr>
<tr>
<td>LEPaste</td>
<td>LE</td>
<td>$1414</td>
<td>Replaces selected text with the contents of the LineEdit scrap.</td>
</tr>
<tr>
<td>LEReset</td>
<td>LE</td>
<td>$0514</td>
<td>Returns an error if LineEdit is active.</td>
</tr>
<tr>
<td>LEScrapHandle</td>
<td>LE</td>
<td>$1B14</td>
<td>Returns a handle to the LineEdit scrap.</td>
</tr>
<tr>
<td>LESetCaret</td>
<td>LE</td>
<td>$1F14</td>
<td>Sets the CaretHook field in the edit record to a specified pointer.</td>
</tr>
<tr>
<td>Call</td>
<td>Tool</td>
<td>Call Number</td>
<td>Function</td>
</tr>
<tr>
<td>-------------</td>
<td>------</td>
<td>-------------</td>
<td>---------------------------------------------------------------------------</td>
</tr>
<tr>
<td>LESetHiLite</td>
<td>LE</td>
<td>$1E14</td>
<td>Sets the HiliteHook field in the edit record to a specified pointer.</td>
</tr>
<tr>
<td>LESetJust</td>
<td>LE</td>
<td>$2114</td>
<td>Sets up the LineEdit Tool Set record for left, right, or center justification.</td>
</tr>
<tr>
<td>LESetScrapLen</td>
<td>LE</td>
<td>$1D14</td>
<td>Sets the size of the LineEdit scrap to a specified number of bytes.</td>
</tr>
<tr>
<td>LESetSelect</td>
<td>LE</td>
<td>$0E14</td>
<td>Sets the selection range in the specified text.</td>
</tr>
<tr>
<td>LESetText</td>
<td>LE</td>
<td>$0B14</td>
<td>Incorporates a copy of specified text into a specified edit record.</td>
</tr>
<tr>
<td>LEShutDown</td>
<td>LE</td>
<td>$0314</td>
<td>Shuts down the LineEdit Tool Set and discards the LineEdit scrap.</td>
</tr>
<tr>
<td>LEStartUp</td>
<td>LE</td>
<td>$0214</td>
<td>Initializes the LineEdit Tool Set and allocates a handle for the LineEdit scrap.</td>
</tr>
<tr>
<td>LEStatus</td>
<td>LE</td>
<td>$0614</td>
<td>Indicates whether or not the LineEdit Tool Set is active.</td>
</tr>
<tr>
<td>LETextBox</td>
<td>LE</td>
<td>$1814</td>
<td>Draws specified text in a specified rectangle.</td>
</tr>
<tr>
<td>LETextBox2</td>
<td>LE</td>
<td>$2014</td>
<td>Draws specified text in a specified rectangle.</td>
</tr>
<tr>
<td>LETextBox2</td>
<td>LE</td>
<td>$2014</td>
<td>Draws text in a specified rectangle, with specified justification.</td>
</tr>
<tr>
<td>LEToScrap</td>
<td>LE</td>
<td>$1A14</td>
<td>Copies the LineEdit scrap to the desk scrap.</td>
</tr>
<tr>
<td>LEVersion</td>
<td>LE</td>
<td>$0414</td>
<td>Returns version number of the LineEdit Tool Set.</td>
</tr>
<tr>
<td>Line</td>
<td>QD</td>
<td>$3D04</td>
<td>Draws a line from the current pen location to the specified displacements.</td>
</tr>
<tr>
<td>LineTo</td>
<td>QD</td>
<td>$3C04</td>
<td>Draws a line from the current pen location to a specified point.</td>
</tr>
<tr>
<td>ListBootInit</td>
<td>LM</td>
<td>$011C</td>
<td>Called at boot time by the Tool Locator.</td>
</tr>
<tr>
<td>ListReset</td>
<td>LM</td>
<td>$051C</td>
<td>Called when a system reset occurs.</td>
</tr>
<tr>
<td>ListShutDown</td>
<td>LM</td>
<td>$031C</td>
<td>Standard tool call.</td>
</tr>
<tr>
<td>ListStartUp</td>
<td>LM</td>
<td>$021C</td>
<td>Standard tool call.</td>
</tr>
<tr>
<td>ListStatus</td>
<td>LM</td>
<td>$061C</td>
<td>Returns a nonzero value indicating that the List Manager is active.</td>
</tr>
<tr>
<td>ListVersion</td>
<td>LM</td>
<td>$041C</td>
<td>Returns the version of the List Manager.</td>
</tr>
<tr>
<td>Call</td>
<td>Tool</td>
<td>Call Number</td>
<td>Function</td>
</tr>
<tr>
<td>----------------------</td>
<td>------</td>
<td>-------------</td>
<td>-----------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>LLDBitMap</td>
<td>PM</td>
<td>$1C13</td>
<td>Prints part or all of a specified QuickDraw II bit map.</td>
</tr>
<tr>
<td>LLDControl</td>
<td>PM</td>
<td>$1B13</td>
<td>Resets the printer and generates linefeeds and formfeeds.</td>
</tr>
<tr>
<td>LLDShutDown</td>
<td>PM</td>
<td>$1A13</td>
<td>Deallocates any memory allocated by LLDStartUp.</td>
</tr>
<tr>
<td>LLDStartUp</td>
<td>PM</td>
<td>$1913</td>
<td>Sets up the necessary environment for low-level drivers.</td>
</tr>
<tr>
<td>LLDText</td>
<td>PM</td>
<td>$1D13</td>
<td>Prints a stream of text using the native facilities of the printer.</td>
</tr>
<tr>
<td>LoadFont</td>
<td>FM</td>
<td>$121B</td>
<td>Finds a specified font, loads it, and makes it current.</td>
</tr>
<tr>
<td>LoadOneTool</td>
<td>TL</td>
<td>$0F01</td>
<td>Loads a specified tool from disk and checks its version.</td>
</tr>
<tr>
<td>LoadScrap</td>
<td>SK</td>
<td>$0A16</td>
<td>Reads the desk scrap from the scrap file into memory.</td>
</tr>
<tr>
<td>LoadSysFont</td>
<td>FM</td>
<td>$131B</td>
<td>Makes the system font current without requiring its font ID.</td>
</tr>
<tr>
<td>LoadTools</td>
<td>TL</td>
<td>$0E01</td>
<td>Loads specified RAM-based tool sets from disk into memory.</td>
</tr>
<tr>
<td>LocalToGlobal</td>
<td>QD</td>
<td>$8404</td>
<td>Converts a point from local coordinates to global coordinates.</td>
</tr>
<tr>
<td>Long2Dec</td>
<td>IM</td>
<td>$270B</td>
<td>Returns a string representing a 32-bit signed or unsigned integer.</td>
</tr>
<tr>
<td>Long2Fix</td>
<td>IM</td>
<td>$1A0B</td>
<td>Converts long integer to fixed.</td>
</tr>
<tr>
<td>Long2Hex</td>
<td>IM</td>
<td>$230B</td>
<td>Converts a 32-bit unsigned integer into a hexadecimal string.</td>
</tr>
<tr>
<td>LongDivide</td>
<td>IM</td>
<td>$0D0B</td>
<td>Divides two 32-bit inputs, producing a quotient and a remainder.</td>
</tr>
<tr>
<td>LongMul</td>
<td>IM</td>
<td>$0C0B</td>
<td>Multiplies two 32-bit inputs and produces a 64-bit result.</td>
</tr>
<tr>
<td>LoWord</td>
<td>IM</td>
<td>$190B</td>
<td>Returns the low-order word of a long input.</td>
</tr>
<tr>
<td>MapPoly</td>
<td>QD</td>
<td>$C504</td>
<td>Maps a polygon from a source rectangle to a destination rectangle.</td>
</tr>
<tr>
<td>MapPt</td>
<td>QD</td>
<td>$8A04</td>
<td>Maps a point from a source rectangle to a destination rectangle.</td>
</tr>
<tr>
<td>MapRect</td>
<td>QD</td>
<td>$8B04</td>
<td>Maps a rectangle from a source rectangle to a destination rectangle.</td>
</tr>
<tr>
<td>Call</td>
<td>Tool</td>
<td>Call Number</td>
<td>Function</td>
</tr>
<tr>
<td>-------------------</td>
<td>------</td>
<td>-------------</td>
<td>--------------------------------------------------------------------------</td>
</tr>
<tr>
<td>MapRgn</td>
<td>QD</td>
<td>$8C04</td>
<td>Maps a region from a source rectangle to a destination rectangle.</td>
</tr>
<tr>
<td>MaxBlock</td>
<td>MM</td>
<td>$1C02</td>
<td>Returns the size of the largest free block in memory.</td>
</tr>
<tr>
<td>MenuBootInit</td>
<td>MUM</td>
<td>$010F</td>
<td>Called at boot time.</td>
</tr>
<tr>
<td>MenuKey</td>
<td>MUM</td>
<td>$090F</td>
<td>Allows the user to type a character to select a menu item.</td>
</tr>
<tr>
<td>MenuNewRes</td>
<td>MUM</td>
<td>$290F</td>
<td>Restyles the menu after the screen resolution changes.</td>
</tr>
<tr>
<td>MenuRefresh</td>
<td>MUM</td>
<td>$0B0F</td>
<td>Called when the application is not using the Window Manager.</td>
</tr>
<tr>
<td>MenuReset</td>
<td>MUM</td>
<td>$050F</td>
<td>This call does nothing.</td>
</tr>
<tr>
<td>MenuSelect</td>
<td>MUM</td>
<td>$2B0F</td>
<td>Controls highlighting and pull-down action when an item is selected.</td>
</tr>
<tr>
<td>MenuShutDown</td>
<td>MUM</td>
<td>$030F</td>
<td>Closes the Menu Manager's port and frees any allocated menus.</td>
</tr>
<tr>
<td>MenuStartUp</td>
<td>MUM</td>
<td>$020F</td>
<td>Initializes the Menu Manager at application startup.</td>
</tr>
<tr>
<td>MenuStatus</td>
<td>MUM</td>
<td>$060F</td>
<td>Checks the current status of the Menu Manager.</td>
</tr>
<tr>
<td>MenuVersion</td>
<td>MUM</td>
<td>$040F</td>
<td>Returns the version of the Menu Manager.</td>
</tr>
<tr>
<td>MMBootInit</td>
<td>MM</td>
<td>$0102</td>
<td>Initializes the Memory Manager at boot time.</td>
</tr>
<tr>
<td>MMReset</td>
<td>MM</td>
<td>$0502</td>
<td>Used by the system at reset time.</td>
</tr>
<tr>
<td>MMShutDown</td>
<td>MM</td>
<td>$0302</td>
<td>An application makes this call when it is terminating.</td>
</tr>
<tr>
<td>MMStartUp</td>
<td>MM</td>
<td>$0202</td>
<td>An application makes this call when starting up.</td>
</tr>
<tr>
<td>MMStatus</td>
<td>MM</td>
<td>$0602</td>
<td>Returns status indicating the Memory Manager is active.</td>
</tr>
<tr>
<td>MMVersion</td>
<td>MM</td>
<td>$0402</td>
<td>Returns the version of the Memory Manager.</td>
</tr>
<tr>
<td>ModalDialog</td>
<td>DLM</td>
<td>$0F15</td>
<td>Repeatedly gets and handles events in a modal dialog’s window.</td>
</tr>
<tr>
<td>ModalDialog2</td>
<td>DLM</td>
<td>$2C15</td>
<td>Repeatedly gets and handles events in a modal dialog’s window.</td>
</tr>
<tr>
<td>Move</td>
<td>QD</td>
<td>$3B04</td>
<td>Moves the current pen location by specified X and Y displacements.</td>
</tr>
<tr>
<td>MoveControl</td>
<td>CM</td>
<td>$1610</td>
<td>Moves a specified control to a new location within its window.</td>
</tr>
<tr>
<td>Call</td>
<td>Tool</td>
<td>Call Number</td>
<td>Function</td>
</tr>
<tr>
<td>--------------------</td>
<td>------</td>
<td>-------------</td>
<td>----------</td>
</tr>
<tr>
<td><strong>MovePortTo</strong></td>
<td>QD</td>
<td>$2204</td>
<td>Changes the location of the current GrafPort’s PortRect.</td>
</tr>
<tr>
<td><strong>MoveTo</strong></td>
<td>QD</td>
<td>$3A04</td>
<td>Moves the current pen location to the specified point.</td>
</tr>
<tr>
<td><strong>MoveWindow</strong></td>
<td>WM</td>
<td>$190E</td>
<td>Moves a window to another part of the screen, not changing its size.</td>
</tr>
<tr>
<td><strong>MTBootInit</strong></td>
<td>MTS</td>
<td>$0103</td>
<td>Called at boot time.</td>
</tr>
<tr>
<td><strong>MTReset</strong></td>
<td>MTS</td>
<td>$0503</td>
<td>Clears the heartbeat task pointer and sets the mouse flag to &quot;not found.&quot;</td>
</tr>
<tr>
<td><strong>MTShutdown</strong></td>
<td>MTS</td>
<td>$0303</td>
<td>This call is not used in this tool set.</td>
</tr>
<tr>
<td><strong>MTStartUp</strong></td>
<td>MTS</td>
<td>$0203</td>
<td>This call is not used in this tool set.</td>
</tr>
<tr>
<td><strong>MTSTATUS</strong></td>
<td>MTS</td>
<td>$0603</td>
<td>Returns status indicating the Miscellaneous Tool Set is active.</td>
</tr>
<tr>
<td><strong>MTVersion</strong></td>
<td>MTS</td>
<td>$0403</td>
<td>Returns the version of the Miscellaneous Tool Set.</td>
</tr>
<tr>
<td><strong>Multiply</strong></td>
<td>IM</td>
<td>$090B</td>
<td>Multiplies two 16-bit inputs and produces a 32-bit result.</td>
</tr>
<tr>
<td><strong>Munger</strong></td>
<td>MTS</td>
<td>$2803</td>
<td>Manipulates bytes in a string of bytes.</td>
</tr>
<tr>
<td><strong>NewControl</strong></td>
<td>CM</td>
<td>$0910</td>
<td>Creates a control and returns a handle to it.</td>
</tr>
<tr>
<td><strong>NewDItem</strong></td>
<td>DLM</td>
<td>$0D15</td>
<td>Adds a new item to a dialog’s item list.</td>
</tr>
<tr>
<td><strong>NewHandle</strong></td>
<td>MM</td>
<td>$0902</td>
<td>Creates a new block and returns the handle to the block.</td>
</tr>
<tr>
<td><strong>NewList</strong></td>
<td>LM</td>
<td>$101C</td>
<td>Resets the list control according to a specified list record.</td>
</tr>
<tr>
<td><strong>NewMenu</strong></td>
<td>MUM</td>
<td>$2D0F</td>
<td>Allocates space for a menu list and its items.</td>
</tr>
<tr>
<td><strong>NewMenuBar</strong></td>
<td>MUM</td>
<td>$150F</td>
<td>Creates a default menu bar with no menus.</td>
</tr>
<tr>
<td><strong>NewModalDialog</strong></td>
<td>DLM</td>
<td>$0A15</td>
<td>Creates a modal dialog and returns a pointer to its port.</td>
</tr>
<tr>
<td><strong>NewModeless-Dial</strong></td>
<td>DLM</td>
<td>$0B15</td>
<td>Creates a modeless dialog and returns a handle to its port.</td>
</tr>
<tr>
<td><strong>NewRgn</strong></td>
<td>QD</td>
<td>$6704</td>
<td>Allocates space for a new region.</td>
</tr>
<tr>
<td><strong>NewWindow</strong></td>
<td>WM</td>
<td>$090E</td>
<td>Creates a window and returns a pointer to its GrafPort.</td>
</tr>
<tr>
<td><strong>NextMember</strong></td>
<td>LM</td>
<td>$0B1C</td>
<td>Searches a list record for a specified member and returns its value.</td>
</tr>
<tr>
<td>Call</td>
<td>Tool</td>
<td>Call Number</td>
<td>Function</td>
</tr>
<tr>
<td>-------------</td>
<td>------</td>
<td>-------------</td>
<td>--------------------------------------------------------------------------</td>
</tr>
<tr>
<td>NoteAlert</td>
<td>DLM</td>
<td>$1915</td>
<td>Performs the same functions as the Alert routine.</td>
</tr>
<tr>
<td>ObscureCursor</td>
<td>QD</td>
<td>$9204</td>
<td>Hides the cursor until the mouse moves.</td>
</tr>
<tr>
<td>OffsetPoly</td>
<td>QD</td>
<td>$C404</td>
<td>Offsets a polygon by specified X and Y displacements.</td>
</tr>
<tr>
<td>OffsetRect</td>
<td>QD</td>
<td>$4B04</td>
<td>Offsets a specified rectangle by specified displacements.</td>
</tr>
<tr>
<td>OffsetRgn</td>
<td>QD</td>
<td>$6F04</td>
<td>Moves a region a distance specified by X and Y displacements.</td>
</tr>
<tr>
<td>OpenNDA</td>
<td>DM</td>
<td>$1505</td>
<td>Opens a specified new desk accessory.</td>
</tr>
<tr>
<td>OpenPoly</td>
<td>QD</td>
<td>$C104</td>
<td>Opens a polygon structure for updating, and returns its handle.</td>
</tr>
<tr>
<td>OpenPort</td>
<td>QD</td>
<td>$1804</td>
<td>Initializes specified memory locations as a standard port.</td>
</tr>
<tr>
<td>OpenRgn</td>
<td>QD</td>
<td>$6D04</td>
<td>Allocates memory to hold information about a region being created.</td>
</tr>
<tr>
<td>OSEventAvail</td>
<td>EM</td>
<td>$1706</td>
<td>Accesses the next event of a given type but leaves it in the queue.</td>
</tr>
<tr>
<td>PackBytes</td>
<td>MTS</td>
<td>$2603</td>
<td>Packs bytes into a special format that uses less storage space.</td>
</tr>
<tr>
<td>PaintArc</td>
<td>QD</td>
<td>$6304</td>
<td>Paints the interior of an arc using the current pen state and pattern.</td>
</tr>
<tr>
<td>PaintOval</td>
<td>QD</td>
<td>$5904</td>
<td>Paints the interior of an oval using the current pen state and pattern.</td>
</tr>
<tr>
<td>PaintPixels</td>
<td>QD</td>
<td>$7F04</td>
<td>Transfers a region of pixels.</td>
</tr>
<tr>
<td>PaintPoly</td>
<td>QD</td>
<td>$BD04</td>
<td>Paints the interior of a polygon using the current pen state and pattern.</td>
</tr>
<tr>
<td>PaintRect</td>
<td>QD</td>
<td>$5404</td>
<td>Paints the interior of a rectangle using the current pen state and pattern.</td>
</tr>
<tr>
<td>PaintRgn</td>
<td>QD</td>
<td>$7A04</td>
<td>Paints the interior of a region using the current pen state and pattern.</td>
</tr>
<tr>
<td>PaintRRect</td>
<td>QD</td>
<td>$5E04</td>
<td>Paints the interior of a round rectangle using the current pen state and pattern.</td>
</tr>
<tr>
<td>PenNormal</td>
<td>QD</td>
<td>$3604</td>
<td>Sets the pen state to the standard state.</td>
</tr>
<tr>
<td>Call</td>
<td>Tool</td>
<td>Call Number</td>
<td>Function</td>
</tr>
<tr>
<td>------------------</td>
<td>------</td>
<td>-------------</td>
<td>----------</td>
</tr>
<tr>
<td>PinRect</td>
<td>WM</td>
<td>$210E</td>
<td>Pins a specified point inside a specified rectangle.</td>
</tr>
<tr>
<td>PMBootInit</td>
<td>PM</td>
<td>$0113</td>
<td>Called at boot time by the Tool Locator.</td>
</tr>
<tr>
<td>PMReset</td>
<td>PM</td>
<td>$0513</td>
<td>Internal routine called only at system reset.</td>
</tr>
<tr>
<td>PMShutDown</td>
<td>PM</td>
<td>$0313</td>
<td>Shuts down the Print Manager.</td>
</tr>
<tr>
<td>PMStartUp</td>
<td>PM</td>
<td>$0213</td>
<td>Initializes the Print Manager for use by an application.</td>
</tr>
<tr>
<td>PMStatus</td>
<td>PM</td>
<td>$0613</td>
<td>Indicates whether or not the Print Manager is active.</td>
</tr>
<tr>
<td>PMVersion</td>
<td>PM</td>
<td>$0413</td>
<td>Returns the version number of the Print Manager.</td>
</tr>
<tr>
<td>PosMouse</td>
<td>MTS</td>
<td>$1E03</td>
<td>Positions mouse at specified coordinates.</td>
</tr>
<tr>
<td>PostEvent</td>
<td>EM</td>
<td>$1406</td>
<td>Posts an event at the end of the event queue.</td>
</tr>
<tr>
<td>PPToPort</td>
<td>QD</td>
<td>$D604</td>
<td>Transfers pixels from a source pixel map to the current port.</td>
</tr>
<tr>
<td>PrChoosePrinter</td>
<td>PM</td>
<td>$1613</td>
<td>Displays a dialog for selecting a printer and port driver.</td>
</tr>
<tr>
<td>PrCloseDoc</td>
<td>PM</td>
<td>$0F13</td>
<td>Closes the GrafPort being used for printing.</td>
</tr>
<tr>
<td>PrClosePage</td>
<td>PM</td>
<td>$1113</td>
<td>Finishes the printing of the current page.</td>
</tr>
<tr>
<td>PrDefault</td>
<td>PM</td>
<td>$0913</td>
<td>Sets a print record to default values for the appropriate printer.</td>
</tr>
<tr>
<td>PrError</td>
<td>PM</td>
<td>$1413</td>
<td>Returns the result code left by the last Print Manager routine.</td>
</tr>
<tr>
<td>PrJobDialog</td>
<td>PM</td>
<td>$0C13</td>
<td>Displays a dialog for setting print quality, pages to print, and so on.</td>
</tr>
<tr>
<td>PrOpenDoc</td>
<td>PM</td>
<td>$0E13</td>
<td>Initializes a GrafPort for use in printing and returns its pointer.</td>
</tr>
<tr>
<td>PrOpenPage</td>
<td>PM</td>
<td>$1013</td>
<td>Begins a new page.</td>
</tr>
<tr>
<td>PrPicFile</td>
<td>PM</td>
<td>$1213</td>
<td>Prints a spooled document.</td>
</tr>
<tr>
<td>PrSetError</td>
<td>PM</td>
<td>$1513</td>
<td>Given an error number, performs a corresponding function.</td>
</tr>
<tr>
<td>PrStdDialog</td>
<td>PM</td>
<td>$0B13</td>
<td>Displays a dialog for inputting page setup information.</td>
</tr>
<tr>
<td>PrValidate</td>
<td>PM</td>
<td>$0A13</td>
<td>Checks if a print record is compatible with the Print Manager.</td>
</tr>
<tr>
<td>Call</td>
<td>Tool</td>
<td>Call Number</td>
<td>Function</td>
</tr>
<tr>
<td>--------------</td>
<td>------</td>
<td>-------------</td>
<td>---------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Pt2Rect</td>
<td>QD</td>
<td>$5004</td>
<td>Creates a rectangle using an upper left point and a lower right point.</td>
</tr>
<tr>
<td>PtInRect</td>
<td>QD</td>
<td>$4F04</td>
<td>Detects if a specified point is in a specified rectangle.</td>
</tr>
<tr>
<td>PtInRgn</td>
<td>QD</td>
<td>$7504</td>
<td>Determines where a specified point is within a specified region.</td>
</tr>
<tr>
<td>PtrToHand</td>
<td>MM</td>
<td>$2802</td>
<td>Copies a specified number of bytes from a source to a destination.</td>
</tr>
<tr>
<td>PurgeAll</td>
<td>MM</td>
<td>$1302</td>
<td>Purges all of the purgeable blocks for a specified user ID.</td>
</tr>
<tr>
<td>PurgeHandle</td>
<td>MM</td>
<td>$1202</td>
<td>Purges a specified purgeable handle.</td>
</tr>
<tr>
<td>PutScrap</td>
<td>SK</td>
<td>$0C16</td>
<td>Appends specified data to data in the scrap of the same type.</td>
</tr>
<tr>
<td>QDBootLnit</td>
<td>QD</td>
<td>$0104</td>
<td>Initializes QuickDraw II at boot time.</td>
</tr>
<tr>
<td>QDReset</td>
<td>QD</td>
<td>$0504</td>
<td>Resets QuickDraw II.</td>
</tr>
<tr>
<td>QDSHutDown</td>
<td>QD</td>
<td>$0304</td>
<td>Frees up any buffers allocated for QuickDraw II.</td>
</tr>
<tr>
<td>QDStartUp</td>
<td>QD</td>
<td>$0204</td>
<td>Starts up QuickDraw II.</td>
</tr>
<tr>
<td>QDStatus</td>
<td>QD</td>
<td>$0604</td>
<td>Returns if QuickDraw II is active.</td>
</tr>
<tr>
<td>QDVersion</td>
<td>QD</td>
<td>$0404</td>
<td>Returns the version of QuickDraw II.</td>
</tr>
<tr>
<td>Random</td>
<td>QD</td>
<td>$8604</td>
<td>Returns a pseudorandom number in the range -32768 to +32767.</td>
</tr>
<tr>
<td>Read Next</td>
<td>ST</td>
<td></td>
<td>Reads the next address pointed to by the GLU address register.</td>
</tr>
<tr>
<td>Read RAM</td>
<td>ST</td>
<td></td>
<td>Reads any specified Ensoniq RAM location.</td>
</tr>
<tr>
<td>Read Register</td>
<td>ST</td>
<td></td>
<td>Reads any register within the DOC.</td>
</tr>
<tr>
<td>ReadASCIITime</td>
<td>MTS</td>
<td>$0F03</td>
<td>Reads elapsed time since 00:00:00, Jan. 1, 1904.</td>
</tr>
<tr>
<td>ReadBParam</td>
<td>MTS</td>
<td>$0C03</td>
<td>Reads date from a specified parameter in battery RAM.</td>
</tr>
<tr>
<td>ReadBRam</td>
<td>MTS</td>
<td>$0A03</td>
<td>Reads 252 bytes of data, plus 4 checksum bytes, from battery RAM.</td>
</tr>
<tr>
<td>ReadChar</td>
<td>TT</td>
<td>$220C</td>
<td>Reads a character from an input text device; returns it on the stack.</td>
</tr>
<tr>
<td>Call</td>
<td>Tool</td>
<td>Call Number</td>
<td>Function</td>
</tr>
<tr>
<td>-------------------------</td>
<td>------</td>
<td>-------------</td>
<td>---------------------------------------------------------------------------</td>
</tr>
<tr>
<td>ReadKeyMicroData</td>
<td>ADB</td>
<td>$0A09</td>
<td>Receive data from the microcontroller.</td>
</tr>
<tr>
<td>ReadKeyMicro-Memory</td>
<td>ADB</td>
<td>$0B09</td>
<td>Reads a data byte from the microcontroller ROM.</td>
</tr>
<tr>
<td>ReadLine</td>
<td>TT</td>
<td>$240C</td>
<td>Reads an input string and writes it to a buffer.</td>
</tr>
<tr>
<td>ReadMouse</td>
<td>MTS</td>
<td>$1703</td>
<td>Returns mouse position, status, and mode.</td>
</tr>
<tr>
<td>ReadRamBlock</td>
<td>ST</td>
<td>$0A08</td>
<td>Reads any number of locations from DOC RAM into a buffer.</td>
</tr>
<tr>
<td>ReadTimeHex</td>
<td>MTS</td>
<td>$0D03</td>
<td>Returns current time in hexadecimal format.</td>
</tr>
<tr>
<td>ReAllocHandle</td>
<td>MM</td>
<td>$0A02</td>
<td>Reallocates a block that was purged.</td>
</tr>
<tr>
<td>RectlnRgn</td>
<td>QD</td>
<td>$7604</td>
<td>Checks whether a specified rectangle intersects a specified region.</td>
</tr>
<tr>
<td>RectRgn</td>
<td>QD</td>
<td>$6C04</td>
<td>Sets a specified region to a rectangle described by the input.</td>
</tr>
<tr>
<td>RefreshDesktop</td>
<td>WM</td>
<td>$390E</td>
<td>Redraws the entire desktop and all windows.</td>
</tr>
<tr>
<td>RemoveDItem</td>
<td>DLM</td>
<td>$0E15</td>
<td>Removes an item from a dialog and erases it from the screen.</td>
</tr>
<tr>
<td>ResetAlertStage</td>
<td>DLM</td>
<td>$3515</td>
<td>Resets a dialog so that its next stage is treated as its first stage.</td>
</tr>
<tr>
<td>ResetMember</td>
<td>LM</td>
<td>$0F1C</td>
<td>Searches a list record for a member and clears its select flag.</td>
</tr>
<tr>
<td>RestAll</td>
<td>DM</td>
<td>$0C05</td>
<td>Restores variables that were saved in calling a desk accessory.</td>
</tr>
<tr>
<td>RestoreBufDims</td>
<td>QD</td>
<td>$CE04</td>
<td>Restores QuickDraw’s internal buffers to the sizes described in a record.</td>
</tr>
<tr>
<td>RestoreHandle</td>
<td>MM</td>
<td>$0B02</td>
<td>Reallocates a purged handle.</td>
</tr>
<tr>
<td>RestScrn</td>
<td>DM</td>
<td>$0A05</td>
<td>Restores the screen area saved by the Desk Manager.</td>
</tr>
<tr>
<td>SANEBootInit</td>
<td>SAN</td>
<td>$010</td>
<td>Not used in this tool set.</td>
</tr>
<tr>
<td>SANEDecStr816</td>
<td>SAN</td>
<td>$0A0A</td>
<td>Contains numeric scanners and formatter.</td>
</tr>
<tr>
<td>SANEDecStr816</td>
<td>SAN</td>
<td>$0B0A</td>
<td>Contains elementary, financial, and random number functions.</td>
</tr>
<tr>
<td>SANEFP816</td>
<td>SAN</td>
<td>$090A</td>
<td>Contains basic arithmetic operations and IEEE auxiliary operations.</td>
</tr>
<tr>
<td>Call</td>
<td>Tool</td>
<td>Call Number</td>
<td>Function</td>
</tr>
<tr>
<td>-----------------</td>
<td>------</td>
<td>-------------</td>
<td>-----------------------------------------------------------</td>
</tr>
<tr>
<td>SANEReset</td>
<td>SAN</td>
<td>$050A</td>
<td>Not used in this tool set.</td>
</tr>
<tr>
<td>SANEShutDown</td>
<td>SAN</td>
<td>$030A</td>
<td>Zeros out the work area pointer for the SANE Tool Set.</td>
</tr>
<tr>
<td>SANESwap</td>
<td>SAN</td>
<td>$020A</td>
<td>Starts up the SANE Tool Set for use by an application.</td>
</tr>
<tr>
<td>SANESwap</td>
<td>SAN</td>
<td>$060A</td>
<td>Returns true, indicating the SANE Tool Set is active.</td>
</tr>
<tr>
<td>SANEVersion</td>
<td>SAN</td>
<td>$040A</td>
<td>Returns the version number of the SANE Tool Set.</td>
</tr>
<tr>
<td>SaveAll</td>
<td>DM</td>
<td>$0B05</td>
<td>Saves all variables preserved in activating a desk access</td>
</tr>
<tr>
<td>SaveBufDims</td>
<td>QD</td>
<td>$CD04</td>
<td>Saves QuickDraw II's buffer sizing information in an 8-byte record.</td>
</tr>
<tr>
<td>SaveScrn</td>
<td>DM</td>
<td>$0905</td>
<td>Saves the 80-column text screens in banks 00, 01, EO, and E1.</td>
</tr>
<tr>
<td>ScalePt</td>
<td>QD</td>
<td>$8904</td>
<td>Scales a point from a source rectangle to a destination rectangle.</td>
</tr>
<tr>
<td>SchAddTask</td>
<td>SK</td>
<td>$0907</td>
<td>Adds a task to Scheduler's queue.</td>
</tr>
<tr>
<td>SchBootLInit</td>
<td>SK</td>
<td>$0107</td>
<td>Initializes the flags and counters used by the Scheduler.</td>
</tr>
<tr>
<td>SchFlush</td>
<td>SK</td>
<td>$0A07</td>
<td>Flushes all tasks in the Scheduler's queue.</td>
</tr>
<tr>
<td>SchReset</td>
<td>SK</td>
<td>$0507</td>
<td>Reinitializes flags and counters.</td>
</tr>
<tr>
<td>SchShutDown</td>
<td>SK</td>
<td>$0307</td>
<td>Not used in this tool set.</td>
</tr>
<tr>
<td>SchStartUp</td>
<td>SK</td>
<td>$0207</td>
<td>Not used in this tool set.</td>
</tr>
<tr>
<td>SchStatus</td>
<td>SK</td>
<td>$0607</td>
<td>Returns true, indicating the Scheduler is active.</td>
</tr>
<tr>
<td>SchVersion</td>
<td>SK</td>
<td>$0407</td>
<td>Returns the version number of the Scheduler.</td>
</tr>
<tr>
<td>ScrapBootLInit</td>
<td>SK</td>
<td>$0116</td>
<td>Internal routine called at load time to initialize the Scrap Manager.</td>
</tr>
<tr>
<td>ScrapReset</td>
<td>SK</td>
<td>$0516</td>
<td>Internal routine to reset the Scrap Manager.</td>
</tr>
<tr>
<td>ScrapShutDown</td>
<td>SK</td>
<td>$0316</td>
<td>Shuts down the Scrap Manager.</td>
</tr>
<tr>
<td>ScrapStartUp</td>
<td>SK</td>
<td>$0216</td>
<td>Starts up the Scrap Manager.</td>
</tr>
<tr>
<td>ScrapStatus</td>
<td>SK</td>
<td>$0616</td>
<td>Always returns true; if the Scrap Manager is loaded, it is active.</td>
</tr>
<tr>
<td>Call</td>
<td>Tool</td>
<td>Call Number</td>
<td>Function</td>
</tr>
<tr>
<td>-----------------</td>
<td>------</td>
<td>-------------</td>
<td>--------------------------------------------------------------------------</td>
</tr>
<tr>
<td>ScrapVersion</td>
<td>SK</td>
<td>$0416</td>
<td>Returns the version number of the Scrap Manager.</td>
</tr>
<tr>
<td>ScrollRect</td>
<td>QD</td>
<td>$7E04</td>
<td>Scrolls a rectangle inside certain boundaries.</td>
</tr>
<tr>
<td>SDivide</td>
<td>IM</td>
<td>$0A0B</td>
<td>Divides two 16-bit inputs and produces two 16-bit signed results.</td>
</tr>
<tr>
<td>SectRect</td>
<td>QD</td>
<td>$4D04</td>
<td>Places the intersection of two rectangles in a third rectangle.</td>
</tr>
<tr>
<td>SectRgn</td>
<td>QD</td>
<td>$7104</td>
<td>Places the intersection of two regions in a third region.</td>
</tr>
<tr>
<td>SelectMember</td>
<td>LM</td>
<td>$0D1C</td>
<td>Selects a list member and scrolls the list so it is at the top.</td>
</tr>
<tr>
<td>SelectWindow</td>
<td>WM</td>
<td>$110E</td>
<td>Makes a specified window the active window.</td>
</tr>
<tr>
<td>SelIText</td>
<td>DLM</td>
<td>$2115</td>
<td>Sets the selection range or the insertion point for an EditLine item.</td>
</tr>
<tr>
<td>SendBehind</td>
<td>WM</td>
<td>$140E</td>
<td>Places a window behind a specified window, redrawing as appropriate.</td>
</tr>
<tr>
<td>SendInfo</td>
<td>ADB</td>
<td>$0909</td>
<td>Sends data to the microcontroller.</td>
</tr>
<tr>
<td>ServeMouse</td>
<td>MTS</td>
<td>$1F03</td>
<td>Returns the mouse interrupt status.</td>
</tr>
<tr>
<td>SetAbsClamp</td>
<td>MTS</td>
<td>$2A03</td>
<td>Sets clamp values for an absolute device to new values.</td>
</tr>
<tr>
<td>SetAbsScale</td>
<td>ADB</td>
<td>$1209</td>
<td>Sets up scaling for absolute devices.</td>
</tr>
<tr>
<td>SetAllSCBs</td>
<td>QD</td>
<td>$1404</td>
<td>Sets all scan-line control bytes (SCBs) to a specified value.</td>
</tr>
<tr>
<td>SetBackColor</td>
<td>QD</td>
<td>$A204</td>
<td>Sets a GrafPort's background color field to a specified value.</td>
</tr>
<tr>
<td>SetBackPat</td>
<td>QD</td>
<td>$3404</td>
<td>Sets the background pattern to a specified pattern.</td>
</tr>
<tr>
<td>SetBarColors</td>
<td>MUM</td>
<td>$170F</td>
<td>Sets the normal, inverse, and outline colors of the current menu bar.</td>
</tr>
<tr>
<td>SetBufDims</td>
<td>QD</td>
<td>$CB04</td>
<td>Sets the size of the QuickDraw II clipping and text buffers.</td>
</tr>
<tr>
<td>SetCharExtra</td>
<td>QD</td>
<td>$D404</td>
<td>Sets the chExtra field in the GrafPort to the specified value.</td>
</tr>
<tr>
<td>SetClip</td>
<td>QD</td>
<td>$2404</td>
<td>Copies a specified region into the ClipRgn.</td>
</tr>
<tr>
<td>SetClipHandle</td>
<td>QD</td>
<td>$C604</td>
<td>Sets the ClipRgn handle field in the GrafPort to a specified value.</td>
</tr>
<tr>
<td>Call</td>
<td>Tool</td>
<td>Call Number</td>
<td>Function</td>
</tr>
<tr>
<td>----------------------</td>
<td>------</td>
<td>-------------</td>
<td>---------------------------------------------------------------------------</td>
</tr>
<tr>
<td>SetColorEntry</td>
<td>QD</td>
<td>$1004</td>
<td>Sets the value of a color in a specified color table.</td>
</tr>
<tr>
<td>SetColorTable</td>
<td>QD</td>
<td>$0E04</td>
<td>Sets a color table to specified values.</td>
</tr>
<tr>
<td>SetContentDraw</td>
<td>WM</td>
<td>$490E</td>
<td>Sets the pointer to a routine that redraws a window’s content region.</td>
</tr>
<tr>
<td>SetContentOrigin</td>
<td>WM</td>
<td>$3F0E</td>
<td>Sets the origin of the window’s port when handling an update event.</td>
</tr>
<tr>
<td>SetCtLAction</td>
<td>CM</td>
<td>$2010</td>
<td>Sets a specified control’s CtlAction field to a new action.</td>
</tr>
<tr>
<td>SetCtLLcons</td>
<td>CM</td>
<td>$1810</td>
<td>Provides a handle to a specified new icon font.</td>
</tr>
<tr>
<td>SetCtlParams</td>
<td>CM</td>
<td>$1B10</td>
<td>Sets new parameters to a control’s definition procedure.</td>
</tr>
<tr>
<td>SetCtlRefCon</td>
<td>CM</td>
<td>$2210</td>
<td>Sets a specified control’s CtlReCon field to a new value.</td>
</tr>
<tr>
<td>SetCtlTitle</td>
<td>CM</td>
<td>$0C10</td>
<td>Sets a control’s title to a given string and redraws the control.</td>
</tr>
<tr>
<td>SetCtlValue</td>
<td>CM</td>
<td>$1910</td>
<td>Sets a control’s CtlValue field and redraws the control.</td>
</tr>
<tr>
<td>SetCursor</td>
<td>QD</td>
<td>$8E04</td>
<td>Sets the cursor to an image passed in a specified cursor record.</td>
</tr>
<tr>
<td>SetDAFont</td>
<td>DLM</td>
<td>$1C15</td>
<td>Sets the font of a given window’s port to a specified font number.</td>
</tr>
<tr>
<td>SetDAStrPtr</td>
<td>DM</td>
<td>$1305</td>
<td>Allows a program to change the built-in classic desk accessories.</td>
</tr>
<tr>
<td>SetDataSize</td>
<td>WM</td>
<td>$410E</td>
<td>Sets the height and width of the data area of a specified window.</td>
</tr>
<tr>
<td>SetDefButton</td>
<td>DLM</td>
<td>$3815</td>
<td>Sets the ID of the default button to a specified ID.</td>
</tr>
<tr>
<td>SetDefProc</td>
<td>WM</td>
<td>$320E</td>
<td>Sets the address of the routine that defines a window’s behavior.</td>
</tr>
<tr>
<td>SetDItemBox</td>
<td>DLM</td>
<td>$2915</td>
<td>Changes the display rectangle of an item to a new display rectangle.</td>
</tr>
<tr>
<td>SetDItemType</td>
<td>DLM</td>
<td>$2715</td>
<td>Changes the specified item to the new desired type.</td>
</tr>
<tr>
<td>SetDItemValue</td>
<td>DLM</td>
<td>$2F15</td>
<td>Sets the value of an item to a new value and redraws the item.</td>
</tr>
<tr>
<td>SetEmptyRgn</td>
<td>QD</td>
<td>$6A04</td>
<td>Sets a specified region to the empty region.</td>
</tr>
<tr>
<td>Call</td>
<td>Tool</td>
<td>Call Number</td>
<td>Function</td>
</tr>
<tr>
<td>------------------</td>
<td>------</td>
<td>-------------</td>
<td>--------------------------------------------------------------------------</td>
</tr>
<tr>
<td>SetErrGlobals</td>
<td>TT</td>
<td>$0B0C</td>
<td>Sets the global parameters for the error output device.</td>
</tr>
<tr>
<td>SetErrorDevice</td>
<td>TT</td>
<td>$110C</td>
<td>Sets the error output device to a specified type and location.</td>
</tr>
<tr>
<td>SetEventMask</td>
<td>EM</td>
<td>$1806</td>
<td>Sets the system event mask to the specified event mask.</td>
</tr>
<tr>
<td>SetFont</td>
<td>QD</td>
<td>$9404</td>
<td>Sets the current font to the specified font.</td>
</tr>
<tr>
<td>SetFontFlags</td>
<td>QD</td>
<td>$9804</td>
<td>Sets the font flags to the specified value.</td>
</tr>
<tr>
<td>SetFontID</td>
<td>QD</td>
<td>$D004</td>
<td>Sets the FontID field in the GrafPort.</td>
</tr>
<tr>
<td>SetForeColor</td>
<td>QD</td>
<td>$A004</td>
<td>Sets a GrafPort’s foreground color field to a specified value.</td>
</tr>
<tr>
<td>SetFrameColor</td>
<td>WM</td>
<td>$0F0E</td>
<td>Sets the color of a specified window’s frame.</td>
</tr>
<tr>
<td>SetGrafProcs</td>
<td>QD</td>
<td>$4404</td>
<td>Sets a GrafPort’s GrafProcs field to a specified value.</td>
</tr>
<tr>
<td>SetHandleSize</td>
<td>MM</td>
<td>$1902</td>
<td>Changes the size of a specified block.</td>
</tr>
<tr>
<td>SetHeartBeat</td>
<td>MTS</td>
<td>$1203</td>
<td>Installs a specified task into the heartbeat interrupt task queue.</td>
</tr>
<tr>
<td>SetInfoDraw</td>
<td>WM</td>
<td>$160E</td>
<td>Sets the pointer to a window’s information bar drawing procedure.</td>
</tr>
<tr>
<td>SetInfoRefCon</td>
<td>WM</td>
<td>$360E</td>
<td>Sets a value associated with a window’s information bar drawing routine.</td>
</tr>
<tr>
<td>SetInputDevice</td>
<td>TT</td>
<td>$0F0C</td>
<td>Sets the input device to a specified type and location.</td>
</tr>
<tr>
<td>SetIntUse</td>
<td>QD</td>
<td>$B604</td>
<td>Tells if the cursor should be drawn using scan-line interrupts.</td>
</tr>
<tr>
<td>SetIText</td>
<td>DLM</td>
<td>$2015</td>
<td>Fetches a string for an item that contains text and redraws the item.</td>
</tr>
<tr>
<td>SetlnGlobals</td>
<td>TT</td>
<td>$090C</td>
<td>Sets the global parameters for the input device.</td>
</tr>
<tr>
<td>SetMasterSCB</td>
<td>QD</td>
<td>$1604</td>
<td>Sets the master SCB to a specified value.</td>
</tr>
<tr>
<td>SetMaxGrow</td>
<td>WM</td>
<td>$430E</td>
<td>Sets the maximum values to which a window’s content region can grow.</td>
</tr>
<tr>
<td>SetMenuBar</td>
<td>MUM</td>
<td>$390F</td>
<td>Sets the current menu bar.</td>
</tr>
<tr>
<td>SetMenuFlag</td>
<td>MUM</td>
<td>$1F0F</td>
<td>Sets the menu to a specified state.</td>
</tr>
<tr>
<td>SetMenuID</td>
<td>MUM</td>
<td>$370F</td>
<td>Specifies a new menu number.</td>
</tr>
<tr>
<td>Call</td>
<td>Tool</td>
<td>Call Number</td>
<td>Function</td>
</tr>
<tr>
<td>----------------------</td>
<td>-------</td>
<td>-------------</td>
<td>--------------------------------------------------------------------------</td>
</tr>
<tr>
<td>SetMenuTitle</td>
<td>MUM</td>
<td>$210F</td>
<td>Specifies the title for a menu.</td>
</tr>
<tr>
<td>SetMItem</td>
<td>MUM</td>
<td>$240F</td>
<td>Specifies the name for a menu item.</td>
</tr>
<tr>
<td>SetMItemBlink</td>
<td>MUM</td>
<td>$280F</td>
<td>Determines how many times all menu items should blink when selected.</td>
</tr>
<tr>
<td>SetMItemFlag</td>
<td>MUM</td>
<td>$260F</td>
<td>Controls the style of an item's highlighting and underlining.</td>
</tr>
<tr>
<td>SetMItemID</td>
<td>MUM</td>
<td>$380F</td>
<td>Specifies the ID number of a menu item.</td>
</tr>
<tr>
<td>SetMItemMark</td>
<td>MUM</td>
<td>$330F</td>
<td>Sets a specified character to display or not display to the left of a menu item.</td>
</tr>
<tr>
<td>SetMItemName</td>
<td>MUM</td>
<td>$3A0F</td>
<td>Specifies the name for a menu item.</td>
</tr>
<tr>
<td>SetMItemStyle</td>
<td>MUM</td>
<td>$350F</td>
<td>Sets the text style for a specified menu item.</td>
</tr>
<tr>
<td>SetMouse</td>
<td>MTS</td>
<td>$1903</td>
<td>Sets the mode value for the mouse.</td>
</tr>
<tr>
<td>SetMTitleStart</td>
<td>MUM</td>
<td>$190F</td>
<td>Sets the starting point for the leftmost menu on the menu bar.</td>
</tr>
<tr>
<td>SetMTitleWidth</td>
<td>MUM</td>
<td>$1D0F</td>
<td>Sets the width of a title.</td>
</tr>
<tr>
<td>SetOrigin</td>
<td>QD</td>
<td>$2304</td>
<td>Sets the upper left corner of the PortRect to a given point.</td>
</tr>
<tr>
<td>SetOriginMask</td>
<td>WM</td>
<td>$340E</td>
<td>Specifies the mask used to put the horizontal origin on a grid.</td>
</tr>
<tr>
<td>SetOutGlobals</td>
<td>TT</td>
<td>$0A0C</td>
<td>Sets the global parameters for the error output device.</td>
</tr>
<tr>
<td>SetOutputDevice</td>
<td>TT</td>
<td>$100C</td>
<td>Sets the output device to a specified type and location.</td>
</tr>
<tr>
<td>SetPage</td>
<td>WM</td>
<td>$470E</td>
<td>Sets the number of pixels that define a &quot;page&quot; for scrolling.</td>
</tr>
<tr>
<td>SetPenMask</td>
<td>QD</td>
<td>$3204</td>
<td>Sets the pen mask to the specified mask.</td>
</tr>
<tr>
<td>SetPenMode</td>
<td>QD</td>
<td>$2E04</td>
<td>Sets the current pen mode to the specified pen mode.</td>
</tr>
<tr>
<td>SetPenPat</td>
<td>QD</td>
<td>$3004</td>
<td>Sets the current pen pattern to the specified pen pattern.</td>
</tr>
<tr>
<td>SetPenSize</td>
<td>QD</td>
<td>$2C04</td>
<td>Sets the current pen size to the specified pen size.</td>
</tr>
<tr>
<td>SetPenState</td>
<td>QD</td>
<td>$2A04</td>
<td>Sets the pen state in the GrafPort to the specified values.</td>
</tr>
<tr>
<td>SetPicSave</td>
<td>QD</td>
<td>$3E04</td>
<td>Sets the PicSave field to a specified value.</td>
</tr>
<tr>
<td>SetPolySave</td>
<td>QD</td>
<td>$4204</td>
<td>Sets the PolySave field to a specified value.</td>
</tr>
<tr>
<td>Call</td>
<td>Tool</td>
<td>Call Number</td>
<td>Function</td>
</tr>
<tr>
<td>------------------</td>
<td>------</td>
<td>-------------</td>
<td>---------------------------------------------------------------------------</td>
</tr>
<tr>
<td>SetPort</td>
<td>QD</td>
<td>$1B04</td>
<td>Makes the specified port the current port.</td>
</tr>
<tr>
<td>SetPortLoc</td>
<td>QD</td>
<td>$1D04</td>
<td>Sets the current port's map information structure.</td>
</tr>
<tr>
<td>SetPortRect</td>
<td>QD</td>
<td>$1F04</td>
<td>Sets the current port's rectangle to the specified rectangle.</td>
</tr>
<tr>
<td>SetPortSize</td>
<td>QD</td>
<td>$2104</td>
<td>Changes the size of the current GrafPort's PortRect.</td>
</tr>
<tr>
<td>SetPt</td>
<td>QD</td>
<td>$8204</td>
<td>Sets a point to specified horizontal and vertical values.</td>
</tr>
<tr>
<td>SetPurge</td>
<td>MM</td>
<td>$2402</td>
<td>Sets the purge level of a block specified by a handle.</td>
</tr>
<tr>
<td>SetPurgeAll</td>
<td>MM</td>
<td>$2502</td>
<td>Sets the purge level of all blocks for a specified user ID.</td>
</tr>
<tr>
<td>SetPurgeStat</td>
<td>FM</td>
<td>$0F1B</td>
<td>Makes a specified font in memory unpurgeable or purgeable.</td>
</tr>
<tr>
<td>SetRandSeed</td>
<td>QD</td>
<td>$8704</td>
<td>Sets the seed value for the random number generator.</td>
</tr>
<tr>
<td>SetRect</td>
<td>QD</td>
<td>$4A04</td>
<td>Sets a specified rectangle to specified values.</td>
</tr>
<tr>
<td>SetRectRgn</td>
<td>QD</td>
<td>$6B04</td>
<td>Sets a region to a specified rectangle.</td>
</tr>
<tr>
<td>SetRgnSave</td>
<td>QD</td>
<td>$4004</td>
<td>Sets the RgnSave field to a specified value.</td>
</tr>
<tr>
<td>SetSCB</td>
<td>QD</td>
<td>$1204</td>
<td>Sets the scan-line control byte (SCB) to a specified value.</td>
</tr>
<tr>
<td>SetScrapPath</td>
<td>SK</td>
<td>$1116</td>
<td>Sets the clipboard file pointer to the specified value.</td>
</tr>
<tr>
<td>SetScroll</td>
<td>WM</td>
<td>$450E</td>
<td>Sets the number of pixels that will be scrolled by scroll bar arrows.</td>
</tr>
<tr>
<td>SetSolidBackPat</td>
<td>QD</td>
<td>$3804</td>
<td>Sets the background pattern to a solid pattern using a certain color.</td>
</tr>
<tr>
<td>SetSolidPenPat</td>
<td>QD</td>
<td>$3704</td>
<td>Sets the pen pattern to a solid pattern using the specified color.</td>
</tr>
<tr>
<td>SetSoundMIRQV</td>
<td>ST</td>
<td>$1208</td>
<td>Sets the entry point into the sound interrupt handler.</td>
</tr>
<tr>
<td>SetSoundVolume</td>
<td>ST</td>
<td>$0D08</td>
<td>Changes the DOC registers' volume setting, or the system volume.</td>
</tr>
<tr>
<td>SetSpaceExtra</td>
<td>QD</td>
<td>$9E04</td>
<td>Sets the spExtra field in the GrafPort to the specified value.</td>
</tr>
<tr>
<td>SetStdProcs</td>
<td>QD</td>
<td>$8D04</td>
<td>Sets up a record of pointers for customizing QuickDraw II operations.</td>
</tr>
<tr>
<td>Call</td>
<td>Tool</td>
<td>Call Number</td>
<td>Function</td>
</tr>
<tr>
<td>--------------</td>
<td>------</td>
<td>-------------</td>
<td>--------------------------------------------------------------------------</td>
</tr>
<tr>
<td>SetSwitch</td>
<td>EM</td>
<td>$1306</td>
<td>Informs the Event Manager of a pending switch event.</td>
</tr>
<tr>
<td>SetSysBar</td>
<td>MUM</td>
<td>$120F</td>
<td>Sets a new system bar.</td>
</tr>
<tr>
<td>SetSysField</td>
<td>QD</td>
<td>$4804</td>
<td>Sets the SysField in the GrafPort to a specified value.</td>
</tr>
<tr>
<td>SetSysFont</td>
<td>QD</td>
<td>$B204</td>
<td>Sets a specified font as the system font.</td>
</tr>
<tr>
<td>SetSysWindow</td>
<td>WM</td>
<td>$4B0E</td>
<td>Marks a specified window as a system window.</td>
</tr>
<tr>
<td>SetTextFace</td>
<td>QD</td>
<td>$9A04</td>
<td>Sets the text face to the specified value.</td>
</tr>
<tr>
<td>SetTextMode</td>
<td>QD</td>
<td>$9C04</td>
<td>Sets the text mode to the specified value.</td>
</tr>
<tr>
<td>SetTextSize</td>
<td>QD</td>
<td>$D204</td>
<td>Call is not implemented at the time of this writing.</td>
</tr>
<tr>
<td>SetTSPtr</td>
<td>TL</td>
<td>$0A01</td>
<td>Call used to modify tool sets by installing patches.</td>
</tr>
<tr>
<td>SetUserField</td>
<td>QD</td>
<td>$4604</td>
<td>Sets the UserField in the GrafPort to a specified value.</td>
</tr>
<tr>
<td>SetUserSoundIRQV</td>
<td>ST</td>
<td>$1308</td>
<td>Sets the entry point for an application-defined interrupt handler.</td>
</tr>
<tr>
<td>SetVector</td>
<td>MTS</td>
<td>$1003</td>
<td>Sets the vector address for the specified vector reference number.</td>
</tr>
<tr>
<td>SetVisHandle</td>
<td>QD</td>
<td>$C804</td>
<td>Sets the VisRgn handle field in the GrafPort to a specified value.</td>
</tr>
<tr>
<td>SetVisRgn</td>
<td>QD</td>
<td>$B404</td>
<td>Copies a specified region into the VisRgn.</td>
</tr>
<tr>
<td>SetWAP</td>
<td>TL</td>
<td>$0D01</td>
<td>Sets the pointer to the work area for a specified tool set.</td>
</tr>
<tr>
<td>SetWFrame</td>
<td>WM</td>
<td>$2D0E</td>
<td>Sets the bit vector that describes a specified window’s frame type.</td>
</tr>
<tr>
<td>SetWindowIcons</td>
<td>WM</td>
<td>$4E0E</td>
<td>Sets the icon font for the Window Manager.</td>
</tr>
<tr>
<td>SetWRefCon</td>
<td>WM</td>
<td>$280E</td>
<td>Sets a window-record value reserved for an application’s use.</td>
</tr>
<tr>
<td>SetWTitle</td>
<td>WM</td>
<td>$0D0E</td>
<td>Updates the title of a specified window.</td>
</tr>
<tr>
<td>SetZoomRect</td>
<td>WM</td>
<td>$380E</td>
<td>Sets the rectangle used to calculate a window’s zoomed size.</td>
</tr>
<tr>
<td>SFAllCaps</td>
<td>SF</td>
<td>$0D17</td>
<td>Allows an application to display file names in all uppercase.</td>
</tr>
<tr>
<td>Call</td>
<td>Tool</td>
<td>Call Number</td>
<td>Function</td>
</tr>
<tr>
<td>------------------</td>
<td>------</td>
<td>-------------</td>
<td>---------------------------------------------------------------------------</td>
</tr>
<tr>
<td>SFBootlnit</td>
<td>SF</td>
<td>$0117</td>
<td>Initializes the Standard File Operations Tool Set at boot time.</td>
</tr>
<tr>
<td>SFGetFile</td>
<td>SF</td>
<td>$0917</td>
<td>Displays the Standard File Operations Tool Set's standard dialog; returns data about selected files.</td>
</tr>
<tr>
<td>SFPGetFile</td>
<td>SF</td>
<td>$0B17</td>
<td>Displays a custom dialog and returns information on selected files.</td>
</tr>
<tr>
<td>SFPPutFile</td>
<td>SF</td>
<td>$0A17</td>
<td>Displays a custom dialog and returns data on files to be saved.</td>
</tr>
<tr>
<td>SFPutFile</td>
<td>SF</td>
<td>$0A17</td>
<td>Displays a dialog and returns data about the file to be saved.</td>
</tr>
<tr>
<td>SFReset</td>
<td>SF</td>
<td>$0517</td>
<td>Resets the Standard File Operations Tool Set.</td>
</tr>
<tr>
<td>SFShutdown</td>
<td>SF</td>
<td>$0317</td>
<td>Shuts down the Standard File Operations Tool Set.</td>
</tr>
<tr>
<td>SFStartUp</td>
<td>SF</td>
<td>$0217</td>
<td>Starts up the Standard File Operations Tool Set.</td>
</tr>
<tr>
<td>SFStatus</td>
<td>SF</td>
<td>$0617</td>
<td>Tells if the Standard File Operations Tool Set is active.</td>
</tr>
<tr>
<td>SFVersion</td>
<td>SF</td>
<td>$0417</td>
<td>Returns the version number of the Standard File Operations Tool Set.</td>
</tr>
<tr>
<td>ShowControl</td>
<td>CM</td>
<td>$0F10</td>
<td>Makes a specified control visible.</td>
</tr>
<tr>
<td>ShowCursor</td>
<td>QD</td>
<td>$9104</td>
<td>Shows the cursor incrementing its level to 0, if necessary.</td>
</tr>
<tr>
<td>ShowDItem</td>
<td>DLM</td>
<td>$2315</td>
<td>Makes visible a specified item from a specified dialog.</td>
</tr>
<tr>
<td>ShowHide</td>
<td>WM</td>
<td>$230E</td>
<td>Shows or hides a window, depending upon a specified parameter.</td>
</tr>
<tr>
<td>ShowPen</td>
<td>QD</td>
<td>$2804</td>
<td>Increments the pen level.</td>
</tr>
<tr>
<td>ShowWindow</td>
<td>WM</td>
<td>$130E</td>
<td>Makes a specified window visible and draws it if it was invisible.</td>
</tr>
<tr>
<td>SizeWindow</td>
<td>WM</td>
<td>$1C0E</td>
<td>Sizes a window's port rectangle to a specified width and height.</td>
</tr>
<tr>
<td>SolidPattern</td>
<td>QD</td>
<td>$3904</td>
<td>Sets a specified pattern to a solid pattern using a specified color.</td>
</tr>
<tr>
<td>SortList</td>
<td>LM</td>
<td>$0A1C</td>
<td>Alphabetizes a list by rearranging the array of member records.</td>
</tr>
<tr>
<td>SoundBootlnit</td>
<td>ST</td>
<td>$0108</td>
<td>Called by the Tool Locator at initialization.</td>
</tr>
<tr>
<td>Call</td>
<td>Tool</td>
<td>Call Number</td>
<td>Function</td>
</tr>
<tr>
<td>----------------------</td>
<td>------</td>
<td>-------------</td>
<td>---------------------------------------------------------------------------</td>
</tr>
<tr>
<td>SoundReset</td>
<td>ST</td>
<td>$0508</td>
<td>Stops all generators that may be generating sound.</td>
</tr>
<tr>
<td>SoundShutdown</td>
<td>ST</td>
<td>$0308</td>
<td>Shuts down the Sound Manager.</td>
</tr>
<tr>
<td>SoundStartUp</td>
<td>ST</td>
<td>$0208</td>
<td>Initializes a work area to be used by the sound tools.</td>
</tr>
<tr>
<td>SoundToolStatus</td>
<td>ST</td>
<td>$0608</td>
<td>Returns status indicating whether the Sound Tool Set is active.</td>
</tr>
<tr>
<td>SoundVersion</td>
<td>ST</td>
<td>$0408</td>
<td>Returns the version of the Sound Tool Set.</td>
</tr>
<tr>
<td>SRQPoll</td>
<td>ADB</td>
<td>$1409</td>
<td>Adds a device to the SRQ list if the device exists.</td>
</tr>
<tr>
<td>SRQRemove</td>
<td>ADB</td>
<td>$1509</td>
<td>Removes a device from the SRQ list.</td>
</tr>
<tr>
<td>StartDrawing</td>
<td>WM</td>
<td>$4DOE</td>
<td>Makes a specified window the current port and sets its origin.</td>
</tr>
<tr>
<td>StartInfoDrawing</td>
<td>WM</td>
<td>$500E</td>
<td>Used for drawing outside a window's information bar procedure.</td>
</tr>
<tr>
<td>StatusID</td>
<td>MTS</td>
<td>$2203</td>
<td>Inquires whether or not a specified user ID is active.</td>
</tr>
<tr>
<td>StatusTextDev</td>
<td>TT</td>
<td>$170C</td>
<td>Executes a status call to a specified text device.</td>
</tr>
<tr>
<td>StillDown</td>
<td>EM</td>
<td>$0E06</td>
<td>Tests if the specified mouse button is still down.</td>
</tr>
<tr>
<td>StopAlert</td>
<td>DLM</td>
<td>$1815</td>
<td>Performs the same functions as the Alert routine.</td>
</tr>
<tr>
<td>StringBounds</td>
<td>QD</td>
<td>$AD04</td>
<td>Sets a specified rectangle to be the bounds of a specified string.</td>
</tr>
<tr>
<td>StringWidth</td>
<td>QD</td>
<td>$A904</td>
<td>Returns the width in pixels of a specified string.</td>
</tr>
<tr>
<td>SubPt</td>
<td>QD</td>
<td>$8104</td>
<td>Subtracts one point from another; leaves result in destination point.</td>
</tr>
<tr>
<td>SynchADBReceive</td>
<td>ADB</td>
<td>$0E09</td>
<td>Receive data from an ADB device.</td>
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<tr>
<td>SysBeep</td>
<td>MTS</td>
<td>$2C03</td>
<td>Calls the Apple II monitor entry point BEEL1.</td>
</tr>
<tr>
<td>SysFailMgr</td>
<td>MTS</td>
<td>$1503</td>
<td>Displays a system failure message and ends a program.</td>
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<tr>
<td>SystemClick</td>
<td>DM</td>
<td>$1705</td>
<td>Called when application detects a mouse down in a system window.</td>
</tr>
<tr>
<td>SystemEdit</td>
<td>DM</td>
<td>$1805</td>
<td>Passes standard menu edits to system windows.</td>
</tr>
<tr>
<td>Call</td>
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<td>Call Number</td>
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<tr>
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<td>-------------</td>
<td>--------------------------------------------------------------------------</td>
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<tr>
<td>SystemEvent</td>
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<td>$1A05</td>
<td>Entry point for the Event Manager into the Desk Manager.</td>
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<td>SystemTask</td>
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<td>Called periodically to support desk accessory actions.</td>
</tr>
<tr>
<td>TaskMaster</td>
<td>WM</td>
<td>$1D0E</td>
<td>Calls <code>getNextEvent</code> and then handles certain other events itself.</td>
</tr>
<tr>
<td>TestControl</td>
<td>CM</td>
<td>$1410</td>
<td>Tests which part of a control contains a specified point.</td>
</tr>
<tr>
<td>TextBootInit</td>
<td>TT</td>
<td>$010C</td>
<td>Called at boot time; sets up certain default device parameters.</td>
</tr>
<tr>
<td>TextBounds</td>
<td>QD</td>
<td>$AF04</td>
<td>Sets a specified rectangle to be the bounds of the specified text.</td>
</tr>
<tr>
<td>TextReadBlock</td>
<td>TT</td>
<td>$230C</td>
<td>Reads a block of input characters and writes it to a buffer.</td>
</tr>
<tr>
<td>TextReset</td>
<td>TT</td>
<td>$050C</td>
<td>Resets device parameters to the defaults.</td>
</tr>
<tr>
<td>TextShutDown</td>
<td>TT</td>
<td>$030C</td>
<td>A standard call that is unnecessary and performs no function.</td>
</tr>
<tr>
<td>TextStartUp</td>
<td>TT</td>
<td>$020C</td>
<td>A startup call that is unnecessary and performs no function.</td>
</tr>
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<td>TextStatus</td>
<td>TT</td>
<td>$060C</td>
<td>Returns $FFF, indicating the Text Tool Set is active.</td>
</tr>
<tr>
<td>TextVersion</td>
<td>TT</td>
<td>$040C</td>
<td>Returns the version of the Text Tool Set.</td>
</tr>
<tr>
<td>TextWidth</td>
<td>QD</td>
<td>$AB04</td>
<td>Returns the width of the specified text.</td>
</tr>
<tr>
<td>TextWriteBlock</td>
<td>TT</td>
<td>$1E0C</td>
<td>Writes a block of text to the output text device.</td>
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<tr>
<td>TickCount</td>
<td>EM</td>
<td>$1006</td>
<td>Returns the number of ticks since the system last started up.</td>
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<td>TLBootInit</td>
<td>TL</td>
<td>$0101</td>
<td>Initializes the Tool Locator and all other ROM-based tool sets.</td>
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<tr>
<td>TLMountVolume</td>
<td>TL</td>
<td>$1101</td>
<td>Displays a simulated dialog asking the user to mount a volume.</td>
</tr>
<tr>
<td>TLReset</td>
<td>TL</td>
<td>$0501</td>
<td>Initializes the Tool Locator and other ROM-based tool sets.</td>
</tr>
<tr>
<td>TLSHutDown</td>
<td>TL</td>
<td>$0301</td>
<td>Shuts down the Tool Locator when an application shuts down.</td>
</tr>
<tr>
<td>TLStartUp</td>
<td>TL</td>
<td>$0201</td>
<td>Starts up the Tool Locator when an application starts up.</td>
</tr>
<tr>
<td>TLDStatus</td>
<td>TL</td>
<td>$0601</td>
<td>Returns true, indicating the Tool Locator is active.</td>
</tr>
<tr>
<td>Call</td>
<td>Tool</td>
<td>Call Number</td>
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<td>TLTextMount-</td>
<td>TL</td>
<td>$1201</td>
<td>Displays a 40-column text window asking the user to mount a volume.</td>
</tr>
<tr>
<td>Volume</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TLVersion</td>
<td>TL</td>
<td>$0401</td>
<td>Returns the version of the Tool Locator.</td>
</tr>
<tr>
<td>TotalMem</td>
<td>MM</td>
<td>$1D02</td>
<td>Returns the size of all memory, including the main 256K.</td>
</tr>
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<td>TrackControl</td>
<td>CM</td>
<td>$1510</td>
<td>Follows mouse movements until the mouse button is released.</td>
</tr>
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<td>TrackGoAway</td>
<td>WM</td>
<td>$180E</td>
<td>Removes a window from the screen when the go-away box is clicked.</td>
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<td>TrackZoom</td>
<td>WM</td>
<td>$260E</td>
<td>Zooms a window when the mouse is clicked in the zoom box.</td>
</tr>
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<td>UDivide</td>
<td>IM</td>
<td>$0B0D</td>
<td>Divides two 16-bit inputs, producing a quotient and a remainder.</td>
</tr>
<tr>
<td>UnionRect</td>
<td>QD</td>
<td>$4E04</td>
<td>Places the union of two rectangles in a third rectangle.</td>
</tr>
<tr>
<td>UnionRgn</td>
<td>QD</td>
<td>$7204</td>
<td>Places the union of two regions in a third region.</td>
</tr>
<tr>
<td>UnLoadOneTool</td>
<td>TL</td>
<td>$1001</td>
<td>Unloads a specified tool from memory.</td>
</tr>
<tr>
<td>UnLoadScrap</td>
<td>SK</td>
<td>$0916</td>
<td>Writes the desk scrap to the scrap file, and releases its memory.</td>
</tr>
<tr>
<td>UnPackBytes</td>
<td>MTS</td>
<td>$2703</td>
<td>Unpacks data from the packed format used by PackBytes.</td>
</tr>
<tr>
<td>UpdateDialog</td>
<td>DLM</td>
<td>$2515</td>
<td>Redraws the part of a dialog that is in an update region.</td>
</tr>
<tr>
<td>ValidRect</td>
<td>WM</td>
<td>$3C0E</td>
<td>Removes a given rectangle from the current window's update region.</td>
</tr>
<tr>
<td>ValidRgn</td>
<td>WM</td>
<td>$3D0E</td>
<td>Removes a specified region from the current window's update region.</td>
</tr>
<tr>
<td>WaitMouseUp</td>
<td>EM</td>
<td>$0F06</td>
<td>Tests if the mouse button is still down.</td>
</tr>
<tr>
<td>WindBootInit</td>
<td>WM</td>
<td>$010E</td>
<td>Initializes the Window Manager at boot time.</td>
</tr>
<tr>
<td>WindDragRect</td>
<td>WM</td>
<td>$530E</td>
<td>Pulls around an outline of a rectangle, following mouse movements.</td>
</tr>
<tr>
<td>WindNewRes</td>
<td>WM</td>
<td>$250E</td>
<td>Called after the screen resolution is changed.</td>
</tr>
<tr>
<td>WindReset</td>
<td>WM</td>
<td>$050E</td>
<td>Resets the Window Manager.</td>
</tr>
<tr>
<td>Call</td>
<td>Tool</td>
<td>Call Number</td>
<td>Function</td>
</tr>
<tr>
<td>-----------------</td>
<td>------</td>
<td>-------------</td>
<td>----------</td>
</tr>
<tr>
<td>Wind ShutDown</td>
<td>WM</td>
<td>$030E</td>
<td>Shuts down the Window Manager.</td>
</tr>
<tr>
<td>Wind StartUp</td>
<td>WM</td>
<td>$020E</td>
<td>Initializes the Window Manager.</td>
</tr>
<tr>
<td>Wind Status</td>
<td>WM</td>
<td>$060E</td>
<td>Returns whether or not the Window Manager is active.</td>
</tr>
<tr>
<td>Wind Version</td>
<td>WM</td>
<td>$040E</td>
<td>Returns the version number of the Window Manager.</td>
</tr>
<tr>
<td>Write Next</td>
<td>ST</td>
<td></td>
<td>Writes 1 byte of data to the next DOC register or RAM address.</td>
</tr>
<tr>
<td>Write RAM</td>
<td>ST</td>
<td></td>
<td>Writes a 1-byte value to any specified Ensoniq RAM location.</td>
</tr>
<tr>
<td>Write Register</td>
<td>ST</td>
<td></td>
<td>Writes a 1-byte parameter to any register in the DOC chip.</td>
</tr>
<tr>
<td>Write BParam</td>
<td>MTS</td>
<td>$0B03</td>
<td>Writes data to a specified parameter in battery RAM.</td>
</tr>
<tr>
<td>Write BRam</td>
<td>MTS</td>
<td>$0903</td>
<td>Writes 252 bytes, plus 4 checksum bytes, to the battery RAM.</td>
</tr>
<tr>
<td>Write Char</td>
<td>TT</td>
<td>$180C</td>
<td>Writes a character to the output text device.</td>
</tr>
<tr>
<td>Write CString</td>
<td>TT</td>
<td>$200C</td>
<td>Writes a C-style string to the output text device.</td>
</tr>
<tr>
<td>Write Line</td>
<td>TT</td>
<td>$1A0C</td>
<td>Writes a string, plus a carriage return, to the output text device.</td>
</tr>
<tr>
<td>Write Ram Blkock</td>
<td>ST</td>
<td>$09080</td>
<td>Writes a specified number of bytes from system RAM into DOC RAM.</td>
</tr>
<tr>
<td>Write String</td>
<td>TT</td>
<td>$1C0C</td>
<td>Writes a string to the output text device.</td>
</tr>
<tr>
<td>Write Time Hex</td>
<td>MTS</td>
<td>$0E03</td>
<td>Sets the current time using hexadecimal format.</td>
</tr>
<tr>
<td>X2 Fix</td>
<td>IM</td>
<td>$200B</td>
<td>Converts extended to fixed.</td>
</tr>
<tr>
<td>X2 Frac</td>
<td>IM</td>
<td>$210B</td>
<td>Converts extended to fraction.</td>
</tr>
<tr>
<td>Xor Rgn</td>
<td>QD</td>
<td>$7404</td>
<td>Extend-ORs two regions and places the result in a third region.</td>
</tr>
<tr>
<td>Zero Scrap</td>
<td>SK</td>
<td>$0B16</td>
<td>Clears the contents of the scrap.</td>
</tr>
<tr>
<td>Zoom Window</td>
<td>WM</td>
<td>$270E</td>
<td>Zooms a window to its maximum size when the zoom box is clicked.</td>
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