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C Programming Techniques for the Macintosh®

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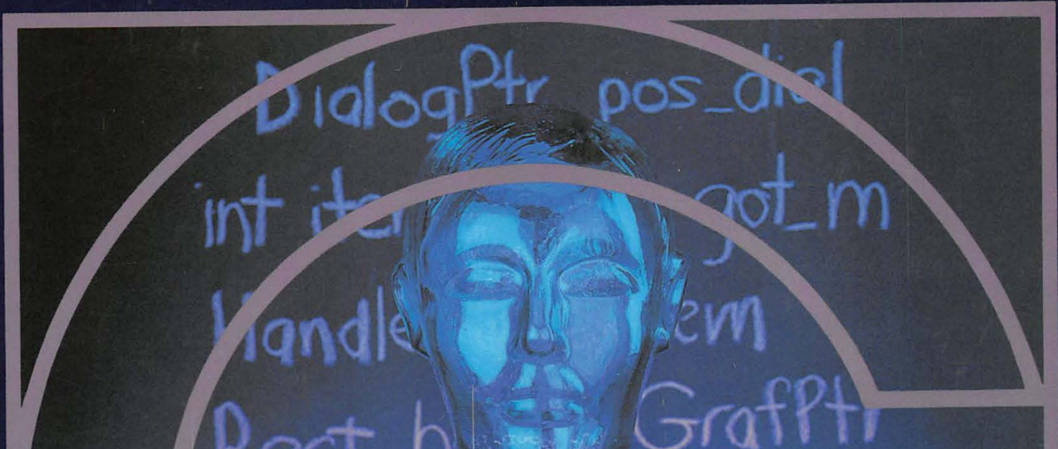

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Contents

Preface

Do you need this book?

This book is designed to break down barriers for a new breed of Macintosh user: the power user. Many power users reach a point at which it is no longer satisfying to be an expert user. If you are familiar with the Macintosh as a tool, and want to go beyond using the Macintosh to programming the Macintosh, you have reached that critical threshold.

You may be:

- A corporate MIS analyst considering using the Macintosh to provide better integration and ease-of-use for your user community. You need to provide your programmers with a detailed study of a complete Macintosh application.

- A vertical-market developer. You need to contain development costs. You need to know how to use the Macintosh Toolbox to give your products the same level of sophistication that companies like Lotus and Microsoft can provide in mass-market applications.

- A student in a course involving Macintosh programming. You need a practical guide to programming, so that you can devote more attention to computer-science issues.

- A software developer considering developing versions of your software for the Macintosh. You have heard that the Macintosh is hard to program. You need to know where the difficulties lie — and where benefits like ease-of-use come from.

What this book will tell you

If you want to start programming your Macintosh, this book will get you started faster and improve the chances that your first program will work.

The Macintosh has earned a reputation as a challenging machine to program. This is due, in part, to the Macintosh Toolbox. While it provides powerful routines for creating user interfaces, it also requires the programmer to be knowledgeable of and sensitive to the way Macintosh programs are written. Where other machines are vehicles for programs of almost any kind, the Macintosh is a highly integrated hardware/software system. If you are not programming for a living, and even if you are, you cannot afford to spend time making uninformed design decisions and painting yourself into corners. This book provides a clearly marked path for new Macintosh programmers:

- You will find how to convert you knowledge of other computer languages into expertise in C.

- You will be able to learn C quickly from this book if you already know Pascal or another block-structured language.

- If you already know C, your knowledge of the features of C that are commonly used in Macintosh programming will be strengthened.

- You will find out how the Macintosh graphics and windowing environment is put together.

- Your programs will not "sit on top of" the Macintosh Toolbox routines. There is an interplay between your programs and the rest of the Macintosh system. This book shows where your programs fit in and what the Macintosh will take care of for your programs.

- No program is flawless, and Macintosh programs can be challenging to debug as well as write. You will learn how to apply debugging tools in the Macintosh environment and what the commonest bugs and their symptoms are.

This book first presents a tutorial guide to programming the Macintosh. Beginning with the C language, continuing through the Macintosh development environment, and culminating in a detailed study of a complete Macintosh application, you will find all of the information a programmer with some experience with other computers needs in order to program for the Macintosh.

The second part of the book contains reference material on the portion of the Macintosh Toolbox required for applications programming. This reference section, which is written using C syntax, expands on the reference material that comes with most C compilers. In addition to the parameters and return values for the Toolbox routines, brief descriptions of the actions and side effects of these routines are provided.

Together, the two parts of this book speed up learning and programming. By enabling Macintosh programmers to get to work sooner, and by giving them reference material in a convenient format, the barriers to taking advantage of the Macintosh Toolbox are lowered.

Because of this focus on speeding up the learning process, it is impossible for this book to cover all aspects of the C language and

Macintosh programming:

- This is not an introductory programming book. If you have never written a program before, this book should be read after, or in conjunction with an introductory C programming book.

- This book does not cover Macintosh systems programming. Networking, file system utilities, and device drivers are all outside the scope of this book. The tutorial section does not cover the particulars of this type of programming, and the reference section does not document the low level routines used in Macintosh systems programming.

- This book is not a complete substitute for Inside Macintosh, Apple's documentation of the Macintosh Toolbox. While it will be possible to get along without for a while, Inside Macintosh will eventually be the key to some mystifying problem or question.

Thanks!

This book's technical accuracy and readability rest heavily on the contributions of the kind people who have given their time to review parts of the manuscript: Steve Golson, Herb Philpott, Bill Harrington, Charles von Rospach, Burt Sloan, Gill Pratt, Rachel Selig Greene, Clem Wang, John Cabot, Monty Solomon, Andrew Levin, Brian Delacey and all our colleagues at General Computer, Lotus Development and other companies who have provided feedback and a stimulating environment. We are forever in debt to David Eyes of Apple Computer for getting us into book writing and for his experienced hand in creating the framework of this book. Without David we would not have known where to begin.

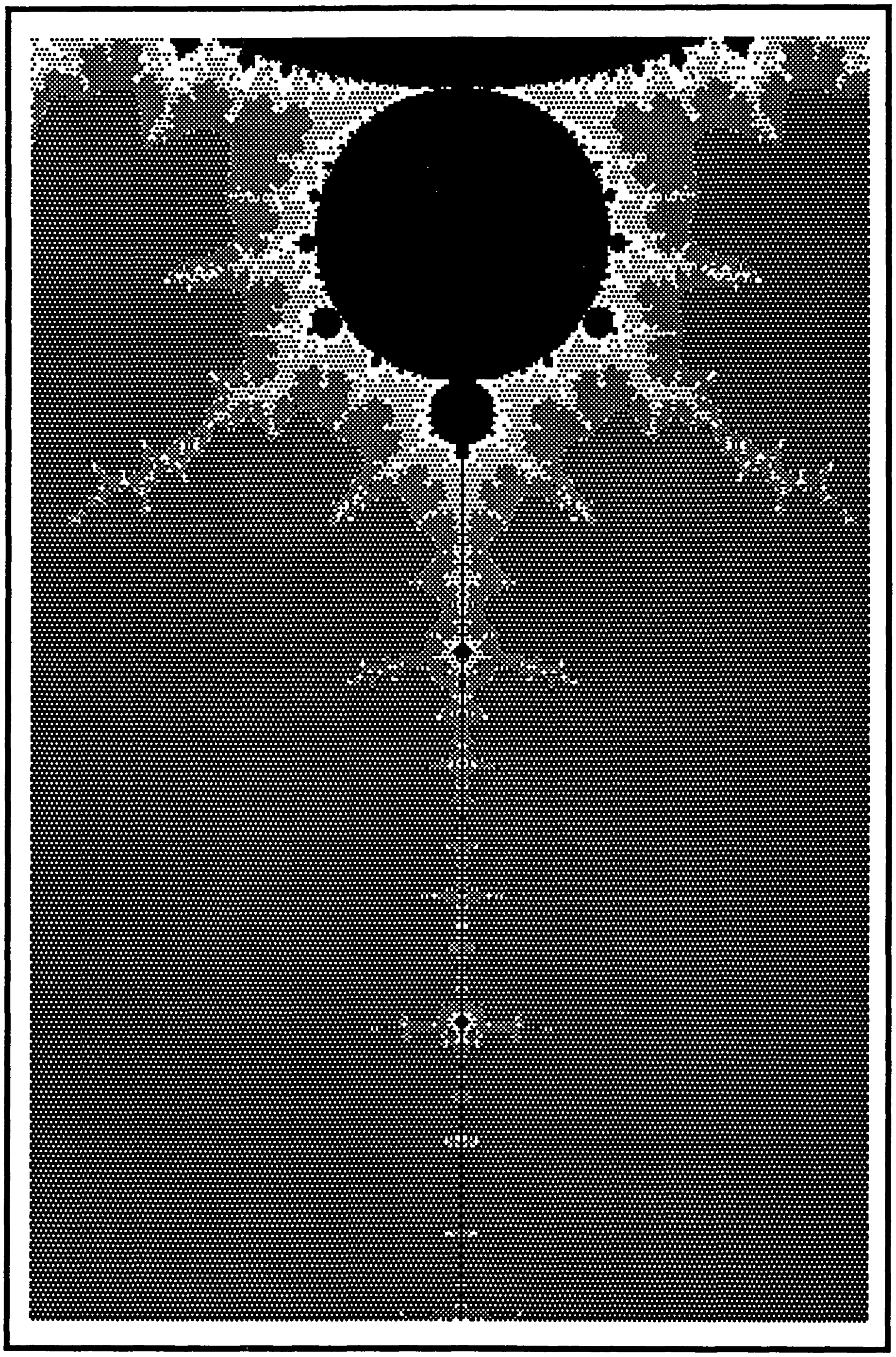
Updates in this printing

We have endeavored to improve this book for our readers, to whom we are grateful. We have corrected the book where we have found errors, and where errors have been pointed out to us. We have endeavored to make the book more readable through editing and through better production standards.

The most significant update concerns the creation of resources. Specifically, the discussions of the resource compiler "RMaker" are obsoleted by the fact that this program has been replaced by a new resource compiler named Rez, with vastly different syntax than RMaker. This raises a problem since Rez is part of Apple's development environment, which is too expensive for most students and hobbyists. We have kept our chapter on RMaker to illustrate resources in general, and we have updated our example programs to use ResEdit, a more widely available resource editor.

This book was intended to be a cookbook. And while the author of a book on Chinese cooking can't send you his dan-dan noodles so you can figure out where yours went wrong, we can now send you the example programs in this book, ready to run under the LightspeedC development environment. An order form appears in the back of this book. We hope that making our programs and code fragments completely compatible with this widely used compiler further reduces frustration for first time programmers.

Tutorial



1

Beginnings

- How C is related to other computer languages
- The origins of Unix and C
- The path C has traveled in Unix and other systems
- The path you will travel in the course of reading this book

The Macintosh is unlike any microcomputer that preceded it. C, on the other hand, has a long history on more traditional computers. This chapter traces the history of C up through the point where it has become the most popular language for developing Macintosh software. If you are choosing a language for your first major Macintosh program you may want to know the reasons for C's popularity, and the facts behind its suitability for Macintosh programming.

Origins

Nearly every book that discusses C and/or Unix begins with a brief history of these two intertwined pieces of software. This has led to a large body of apocrypha that would have one believe, among other things, that Unix was written as a prank to support a space-war game, or that it was all part of AT&T's coherent plan to become a significant player in the computer industry, or that Dennis Ritchie and Ken Thompson were fed up with the size and complication of the Multics system and wanted to show the world that something simpler would be better.

When Ken Thompson, one of the original principal authors of Unix, spoke at MIT in the spring of 1985, his responses to questions from the attendees about the origins of Unix shed some light on the actual circumstances and motivations that led to the creation of both Unix and C. Part of what Thompson said could be expected: Unix wasn't part of a grand design — neither AT&T's nor his own. Thompson and his colleague Dennis Ritchie had been working on the Multics project. Multics began as a huge project involving MIT, General Electric and Bell Laboratories. Although flawed, Multics was far ahead of any other operating system of its time and is still possibly the best software system for very large computers. So when Bell Labs withdrew from the Multics project, Ritchie and Thompson found themselves back in the computing stone age, where they had to submit "batch jobs" on decks of punched cards and wait a few hours or perhaps until the next day to see the results.

Thompson went on to describe how he and Ritchie tried to get their own computer that they could use interactively whenever they wanted to. Initially they wanted to buy a Digital Equipment Corporation PDP-10, a fairly large machine. In the end they got a PDP-7, a smaller machine — a "minicomputer." How different history might be had they succeeded in procuring the PDP-10, a machine with 36-bit words, 9-bit bytes, and 18-bit addressing yielding an address space of 256k 36-bit words! This machine seems odd compared to the processors that are prevalent today. Yet, at the time, there were no accepted byte-sizes, no expectations of a large address space, and usually nothing that deserved to be called an operating system available from the manufacturers of computers. Not only did Unix spawn C, the prevalence of hierarchical file systems, command processor "shells," and numerous other software design concepts, it also helped solidify the 8-bit byte as the atomic unit of addressing.

Implementations and implementation languages

Unix was first written in assembly language. Even before C was created, Unix had been ported across members of DEC's minicomputer product line. Still written in assembly language, it arrived on the PDP-11, DEC's last 16-bit computer. 8-bit bytes, general registers, and memory-mapped I/O are etched into the face of the Unix kernel code. Although Unix grew up portable, it did pick up some of the design philosophy of DEC minicomputers. Partly because of Unix, almost every 16-bit microprocessor is patterned after the PDP-11.

The first application of the Unix environment was the continued development of Unix. This development was greatly sped by "self-hosting," in which Unix development was done on Unix systems. The importance of self-hosted development cannot be overestimated. Systems without strong self-hosted development environments usually die from lack of applications software. With self-hosted development on Unix, the community of co-workers that Unix supported became a community of Unix developers — not just Unix users.

The appearance of C compilers on the Macintosh means that the Macintosh is now "self-hosted" for developing Macintosh software. The developer no longer needs two or more machines, and no longer needs to wait for downloading to write Macintosh software. Self-hosted development also means that user-programmers can afford to use the same tools professional developers use.

Unix development was self-hosted before C existed. The important Unix concepts of a hierarchical file system, of devices as nodes in the file system, of block and character devices, etc. were already implemented in the assembly-language versions of Unix. These concepts, and the interactive nature of Unix, were attractive enough that the initial community of Unix users began clamoring for a high level language — they wanted a "FORTRAN."

So, here we have it straight from Ken Thompson's mouth: C began as an effort to produce a dialect of FORTRAN for Unix. But one thing saved us from having just that: the address space of the machine Unix ran on allowed each program to occupy 64k bytes for both data and program instructions. There wasn't enough room to take into account all the special cases and "features" that FORTRAN has. So Ritchie began pruning and simplifying, so that all the things he really needed in a language could fit. The result is a spare language that relies on a standard library of routines where other languages would have things such as transcendental functions, heap management, and I/O built into the run-time environment. With the rigid constraints the PDP-11 address space placed on the size of the compiler, it is remarkable that C does not leave out any significant feature in the areas of flow control, data abstraction, or data-structure definition. The completeness of C and its suitability for nearly any programming task is illustrated by the fact that we are now in an era where C and Pascal are by far the two dominant languages in which new programs are written.

Capabilities

A complete set of capabilities is a key characteristic of C. Some computer languages, such as Pascal and Basic, hide the way the variables in a program are stored. C makes no attempt to *enforce* the abstraction of the computer your program is running on. Practically, this means that when you *must* reach right down to the hardware, to turn on a bit in a peripheral controller, you have all the capabilities of C at hand. You can use bit fields, data structures, defined data-types, symbolic constants, etc. to make the parts of your program that "touch" the hardware as readable, maintainable, and easy to write as the rest of your program — even while you are engaged in the down-and-dirty of bit twiddling. Of course, for most programming tasks, you can remain completely oblivious to where the compiler has set aside storage for your variables and subroutines. Few other languages give both the ability to ignore the hardware and hide it beneath abstractions and, alternatively, manipulate hardware while retaining all the power of high level language: type-checking, data structuring, and readable notation.

The availability of C to its initial user community at Bell Labs spurred the development of the full set of 300 or so Unix utility programs such as cat, ed, sed, grep, awk, etc. To be applied to the task of developing Unix utility programs, C had to generate fast code and carry no excess baggage in its run-time environment. These programs could be invoked quickly, run quickly, and not displace all the other programs running concurrently in the Unix environment. The ultimate test of C as a well-honed tool was the reimplementation of Unix itself in C. In transcribing Unix into C, C was proven as a system writing tool. C remains the only alternative to assembly-language for writing programs for micros — where performance, compactness, and access to hardware are critical. Unix was transformed from a toy Multics into a versatile operating system whose implementation one person could come to understand in a couple of months time.

Wherever C goes, there it is

C and Unix became intertwined and thrive together to this day. This is due in part to the popularity of Unix. C has also become more popular than any other "implementation" language for microprocessor work — it is more popular than languages (such as PL/M) that were created for that purpose. C has become a *lingua-franca* among computer science students. When you work in C you are assured of a steady supply of assistance from colleagues, of clever pieces of code to be gleaned from computer magazines, of compilers, debuggers, subroutine libraries, etc.

The popularity of C and Unix is a genuine groundswell rather than the result of a well executed marketing plan. Because AT&T was, at the time, enjoined from competing in the computer business, Unix was either given away to schools, or sold "as-is" for a fairly exorbitant price to ensure that it would not compete against other operating systems. Even though Unix was officially a non-product, both Unix and C were flattered by imitation. C compilers were written for the Z80, the 6809, and other microprocessors. Unix begat Uniflex, OS-9, and other operating systems that touted their resemblance to Unix.

C and microcomputer software

Even MS-DOS is an imitation of Unix. It is not surprising that C is a popular language for writing MS-DOS programs. C lets MS-DOS programmers easily port Unix programs to MS-DOS machines. C also allows access to low-level entities such as peripheral controller registers, so that PC programmers can take advantage of PC-specific hardware capabilities without resorting to assembly language. Microsoft, the publisher of MS-DOS, is strongly committed to C, and develops virtually all its products in C.

The popularity of C among Macintosh programmers is something of a puzzle, however. It caught Apple Computer's Developer Relations department by surprise. According to a survey taken by Developer Relations, about half the respondents are using C — a proportion that was expected to be much lower. It is easy to see why C is so popular for the IBM-PC: MS-DOS is overtly intended to be a scaled-down Unix. But the Macintosh could not be further from the design philosophy of both Unix and MS-DOS!

Partly, this popularity can be explained by availability. When the Macintosh came on the market, the prevalent use of the 68000 was in Unix supermicros. In its own way, the 68000 is also a descendant of the PDP-11. Many C compilers had already been written and exhaustively tested in the various Unix ports and derivatives running on 68000 based machines, so C compilers for the Macintosh can be expected to produce good code. C can also be more convenient for the developer who does not want a Lisa solely for writing Macintosh programs in the Lisa Pascal cross development environment. The Macintosh *allows* the choice of a minimal language like C that has no built-in facilities for modular or object oriented programming, unlike the Lisa which pretty much required the use of Clascal, an object-oriented Pascal.

Partly, C on the Macintosh is a popular development environment due to the use of the Macintosh in universities. Students at universities where the use of a Macintosh is encouraged (or required) do not, in general, even have the choice of using the Lisa Pascal cross-development system. Because Unix is popular among universities, students are predisposed to C. At Stanford, the University's long exposure to Unix manifested itself in "SUMACC" — the Stanford Unix Macintosh C Compiler, a Unix-to-Macintosh cross compiler for C.

Lastly, C is a wonderful and productive language with no artificial constraints, no excess baggage, and all the significant features needed to create readable, debuggable, and maintainable programs. C is an excellent choice on its own merits.

Breaking down barriers

So, if the 68000 is the modern equivalent of the PDP-11, and if C works so well on the 68000, and if the Macintosh represents the next wave in microcomputing, and if about half the professional developers of Macintosh software have already decided that C is the best development tool for their work, what problem remains? What obstacles lie between the Macintosh and a large following of user-programmers?

In short, the answer is unfamiliarity. The engineer who used a PDP-11 in his lab in college might find the 8088-based MS-DOS computers more familiar. The Z80 microcomputer veteran will certainly find the 8088 instruction set and the notion of a ROM-BIOS more familiar than the Macintosh's "Toolbox." The Unix programmer will have to get used to an environment that encourages a combination of big, heavily used, and highly interactive applications the user might keep running for hours on end and "desk accessories" that can be quickly invoked for short operations, whereas the Unix environment he is familiar with is based almost entirely on programs that start quickly, run for a short while, and then give way to the next command the user types.

Where to go now

The rest of this book addresses the nature of the Macintosh — it tells you why the Macintosh is the way it is, how to take advantage of it, and how to carry any knowledge of C programming in other computing environments over to the Macintosh environment. Overcoming this unfamiliarity is important to creating software that doesn't chafe against the interface style Macintosh users have come to expect from experience with the Finder, MacWrite and MacPaint.

By the time you are done with this book you will know the mechanics of programming in C in the Macintosh environment. You will also know how to make design decisions in harmony with the decisions made by the designers of the Macintosh. As a result of knowing both these disciplines, your programs will look just as beautiful and stylish as the programs written by Microsoft or Lotus, and without significant extra work on your part. Giving every program that you, the user-programmer, write a professional level of polish is not practical in any other computer system — not Unix, not MS-DOS, nor any other popular system.

Mastering the Macintosh means more than overcoming the differences between Macintosh and the microcomputers that came before it. It means becoming completely comfortable with the design decisions that went into the Macintosh. It means *being* inside Macintosh.

POINTS TO CONSIDER

1. The following computers are all very successful: Macintosh, IBM-PC, Apple][, IBM 370, DEC VAX. Why are they successful?

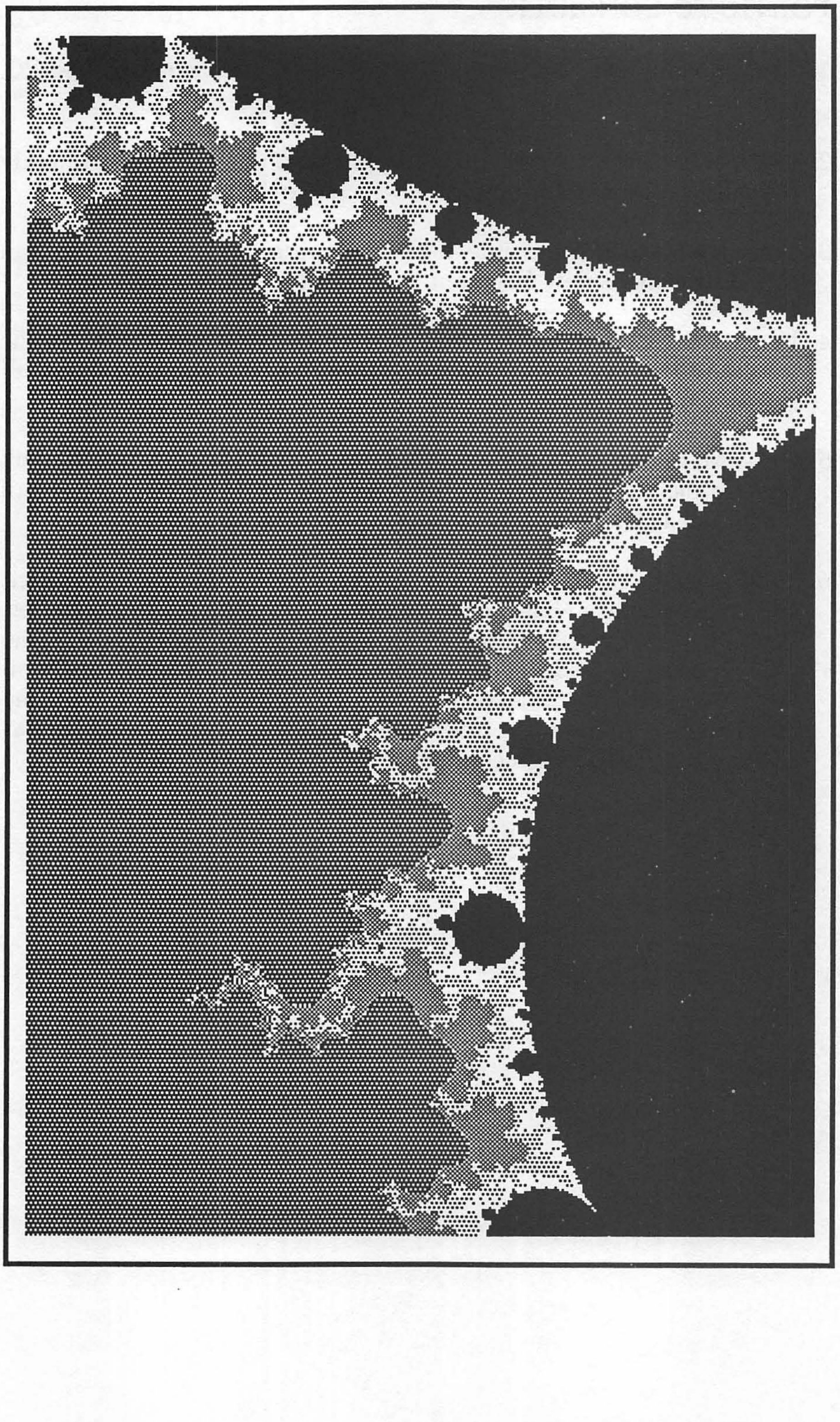
2. In the above group of successful computers, only two occupy roughly the same position in the market — which two? Why?

3. You may have, at some time, used a computer system that has fallen into disuse and is now forgotten. Why did that product fail?

4. Users are demanding more and more ease-of-use and polish in the programs they are willing to use. What does this mean to the small software developer?

5. Of GEM, Microsoft Windows, and Topview, which do you think will become the standard IBM-PC window system? What is the effect of the lack of a standard user interface on MS-DOS and Unix software?

6. Unix gained popularity because it was given away to universities, and Unix became a widely cited example in computer science courses. With the University Consortium, Apple has established the Macintosh as the leading microcomputer in many important universities. As you read this book and as you learn more about the Macintosh, keep asking yourself "How can the Macintosh be used as an example of good engineering?"



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C and Other Languages

- How C is related to other computer languages
- How C is different
- How to transfer your experience in other languages to C
- Why everyone ends up putting features of the C language in their language
- Why Pascal has no advantage over C for Macintosh programming

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Where you are going

If you are approaching this book knowing some other language than C, you may be wondering just what C is, what C programmers think it is, and where C fits in the spectrum of languages.

Where you are

We will take a broad approach to the question of the nature of C. C is not very different from other block structured languages like Pascal, Algol, SPL, Ratfor, PL/1, etc. If you know one of these languages stepping into C should not be difficult. If you are an assembly-language programmer, you can think of C as a convenient notation for structuring data, calling functions, and specifying arithmetic operations and control flow. Only if your experience in programming was acquired in an interpretive language like LOGO, APL, or Basic will you have to learn some really new ways of working to use C effectively.

What you will need to get there

If you are a member of the group of people coming to C from an interpretive language environment, you may want to read a tutorial on C before going on. If you have experience in a compiled, block-structured language already, you may want to have a C reference at hand. And if you are a C programmer, you may want to brush up on function pointers, pointers to pointers, and defined data types, because these are all heavily used in Macintosh programming.

Familiar tools and new tools

Computer languages are like tools in a Toolbox. You may have already chosen C as the tool you will be using to program the Macintosh. If you are not an experienced C programmer, that decision was made without complete knowledge of what you are getting into. A computer language is just a tool and is inherently less important than the job itself. You may be tempted to just get to work and use C syntax with the style and conventions you used in Pascal or whatever language you are familiar with. Certainly no one cares whether you push or pull on the handle of a wrench, whether you grip a screwdriver overhand or underhand. But in programming, style is important if anyone other than yourself is going to comprehend your programs. C is particularly susceptible to quirky programming since there are no style rules built into the language.

The rest of this chapter compares the facilities other languages provide for writing good programs with the facilities provided in C.

Abstraction

Abstraction is the ability to hide the details of an operation from the programmer. Because of the abstraction built into Pascal, Pascal is widely thought to be a superior language for the programmer who is not going to make a career of programming. Standard Pascal, as it was conceived by Niklaus Wirth, can be taught to a student as a set of rules. Students of Pascal can become proficient without knowing what a register is, whether structures are passed on the stack below a certain size and passed indirectly if they are larger than that size, how a data structure is laid out in memory, etc. If you follow the rules of Pascal, your programs will work, and you will not need to know *how* the machine is actually doing it.

For instance, if a Pascal programmer wants to write a procedure with a side effect, he or she would declare a "VAR" parameter — a parameter that is passed "by reference." So when an assignment is made to that parameter in the routine, the variable "passed by reference" to the routine will reflect the result of that assignment. In contrast, a C programmer would have to be aware that in order to have a procedure modify a variable local to its caller, the procedure will have to take a pointer to that variable as a parameter, and all the modifications will have to go through that pointer. This is one case where Pascal provides an abstraction, and C provides a general mechanism for achieving the same result.

The following code fragments show the way a "VAR" parameter is used in Pascal, and an equivalent procedure coded in C. This is an example of one instance of Pascal abstracting and C requiring the programmer to specify an action explicitly. Both routines do exactly the same thing. First the Pascal version:

```
procedure Assign (VAR to : INTEGER; from : INTEGER);

  {Assign the value of "from" to the variable "to."}

  begin {Assign}

    to := from;

  end {Assign}
```

And the C version of the same procedure:

```
/* Put the value of "from" into "to." */
assign(to, from)
       int *to;
       int from;
{
       *to = from;
}
```

In this case the C programmer has to know that in order to change some non-local value whose location is not globally known, the procedure has to have a pointer to that location passed as a parameter. The Pascal programmer can achieve the same effect knowing only the rule: If you want to "permanently" change the value of a parameter, you have to declare it "VAR."

The cost of the more-general approach

It is impossible to become an expert C programmer without knowing that you cannot, in general, find the address of a register, that strings are conventionally null terminated, that data structures are laid out in the order they are defined, that odd addresses can only point to one-byte objects on machines based on the 68000, etc. It is hard to write good C programs without being an expert. Fortunately C, like Pascal, is a small, simple language. It is not much more difficult to become an expert at C than it is to become proficient in the rules of Pascal programming.

Some other languages, like Pascal, were designed to hide the details of data storage and access; C was not. If you are familiar with a block structured language that abstracts more than C does, you will find a C reference manual that details the way data storage and scope is treated handy.

Hiding data

If you are writing a large program and you want to avoid naming conflicts, or if you are working with other programmers on a large project, you will want to "hide" data from code that should not be modifying that data.

C provides about the same facilities for hiding data as the typical assembler and some additional capability that lets you "hide" variables inside procedures. Like most assemblers, you can declare a data object "external" — meaning it is defined in some other file. The linker resolves references to external objects. You can also declare global variables "static," which means they will never be touched by code in another file. If a local variable is declared static, it will not be allocated on the stack when the procedure it is declared in is called. Instead, it will be allocated in the global data area of the program, but only the code in the procedure it was declared in will be able to access it. Static local variables retain their value across invocations of that procedure, and they always occupy space — even when the procedure they are declared in is not being executed. Procedures can also be declared static — in which case they cannot be directly called from outside the file they are defined in.

Normal local variables are allocated on the stack, and disappear when the procedure they are declared in returns. These variables are only directly accessible from code in the procedure they are declared in.

The following code fragment illustrates C's data-hiding capabilities:

```
static int this_file_only;      /* Available only to this file */
extern int somewhere_else;      /* Defined in some other file */

/* call a routine that accumulates values to accumulate two
 * numbers, then call it with a value of 0 and put
 * the return value in the variable "total"
 */
main()
{
      int a_local, another_local, the_total;

      a_local = 1;
      accumulate(a_local);
      another_local = 4;
      accumulate(another_local);
      the_total = accumulate(0);
}

/* A routine callable only from code in this file */
 static
accumulate(value)
{
      static int accumulator = 0;

      accumulator += value;
      return accumulator;
}
```

C does not have the elaborate "scope rules" of Algol, where, in certain cases, variables in a routine's caller are available, along with local and global variables. But by using the static storage class and by dividing large programs into separately compiled modules, you can do an effective job of organizing your program's data, and hiding data from code that has no business modifying it.

Program structure

C programs are generally organized "top-down," no matter what order they are written or designed in. When you look at a C program listing you will generally see the "main" procedure near the top, the high level procedures next, and the lowest level procedures either following the higher level procedures they support or at the end of the listing. This is exactly the opposite of the way most Pascal, Algol, and APL programs are organized. In these languages, the lowest level procedures come first, conventionally or compulsorily before the procedures that call them.

Languages that promote "bottom-up" order in listings do so because their development environments may provide an interpreter that needs routines defined before they can be called, or because they have no way of declaring return values other than in procedure definitions. In some languages there may be no real need to order programs bottom-up — it may just be customary.

C does not require any particular order. C compilers can determine the data type of return values either from procedure definitions or from declarations. Whether or not there is some intrinsic value to top-down program organization, most C programmers expect programs to be organized this way. If you want to take advantage of the advice of experienced C programmers it is a good idea to lay out your programs the way they would.

In addition to this stylistic convention, you only need to follow common sense and the requirements of the language in laying out your programs. You have to define data structures, variables, and preprocessor macros before you use them. Preprocessor macros are used throughout the file, so they ought to come at the beginning (this is a flexible maxim, and if common sense dictates defining a macro near the other entities it refers to instead of at the top of the file, follow common sense). After the preprocessor macros come the data structure definitions, the enumerated constants, and the defined data types. They must precede the global data declarations where their definitions are used. Following the global data declarations, the procedures that make up the program are defined.

Structuring data

The data structuring capabilities of a computer language are a major determining factor in the expressive power of that language. Roughly speaking, there are low-powered languages like Basic and Fortran at one end of this spectrum, C, Pascal, Algol, PL/1, and other block-structured languages in the middle, and Lisp, Modula-2, Smalltalk, and the granddaddy of modular languages, Simula, at the high end of the data structuring spectrum. Because C is found in the middle of this spectrum, as is Pascal, C can replace Pascal as a programming tool without too much disruption, kludging, or violation of language rules.

C data structures are bit-for-bit equivalent to Pascal records. The differences amount to that C provides bit-fields and Pascal has a more convenient way of expressing multiple interpretations of the structure of the same piece of memory. That C and Pascal structure data in about the same way is a fortunate circumstance: it means that all of the data structures that the Macintosh Toolbox uses can be defined and accessed in C without any tricks or hacks whatsoever. Because of this, it is possible to write C programs for the Macintosh that are every bit as enmeshed in the Macintosh environment as any Pascal or assembly language program.

The languages that fall below C and Pascal in data structuring capability, such as Basic and Fortran, prevent programs written in those languages from taking full advantage of the Toolbox software. Conversely, languages that offer a great deal more data structuring power than C either make it difficult to do low-level "bit-twiddling," or require a cumbersome runtime environment, or have no way of specifying structured data in a way that has a predictable layout in memory, or some combination of these hindrances.

Number crunching

C is not the best language for number crunching. It isn't bad if all you need are double-precision floating point numbers. But single precision floating point is all but useless in C, because single precision floating point numbers are converted to double precision before any operations are performed on them. This means there is no performance gain to be had by using single precision floating point numbers, even when they are sufficient for the application.

Some C compilers violate the C standard and provide completely single-precision operations, or IEEE standard floating-point numbers, or both. Adding floating point data types is a fairly innocuous way of fudging the C standard because C programmers can define new data types themselves. If you plan to use a lot of floating point arithmetic, you may want to look for a C compiler that has additional floating point data types.

The Macintosh Toolbox software provides fixed-point arithmetic, but the cost of calling a routine to do a single fixed-point operation is greater than the cost of executing the in-line code for double-precision floating-point arithmetic.

Extensibility

C provides two forms of extensibility: New data types may be defined, as in Pascal, and new types of constants may be defined. C also has a macro-preprocessor which should not be used to extend the language. While it is true that you could make C look a lot like Pascal through creative use of preprocessor macros, you should not expect anyone but yourself to be able to read such code!

Although C and Pascal have virtually identical capabilities for defining new data types, C programmers use that facility a great deal less than Pascal programmers. While every pointer used by Toolbox software has a defined data type associated with it, C programs seldom have data types defined for pointers, since C notation for declaring pointers is so simple and terse. In the examples in this book, we will use the defined pointer types provided by the Toolbox because all of the Apple documentation and other Pascal oriented documentation refers to those data types. For pointers to objects of our own creation, we will follow the usual practice of omitting to define new data types for pointers and structures.

Macros

Unlike most other languages, C has a macro-expander associated with it. The macro expander is a separate step in compilation, so you can be sure that all macro expansion is done before any C expression parsing has taken place. The C preprocessor is a "token-oriented" macro expander, which means that it operates on the same chunks of characters that the C parser does.

C's token-oriented macro expander can be contrasted with the string-oriented macro expander "m4" which comes standard with most Unix systems. The m4 macro-expander can be used to glue tokens together and pull them apart — something that can't (well, shouldn't) be done with the C preprocessor.

The C preprocessor is used to associate names with constants, so when you write:

```
#define FOO 5

bar = 3 + FOO;
```

The C compiler proper sees:

```
bar = 3 + 5;
```

The preprocessor has substituted the token "5" for the token FOO.

Most Macintosh C compilers use the preprocessor for Toolbox constants because most C programmers do not use enumerated constants, and because preprocessor symbols can stand for all types of C tokens. Also, some compilers do not have enumerated types.

Why Macintosh programming really ought to be done in C

Because Apple had to extend Pascal to include features that are part of standard C (most notably casting operations), the Pascal used to develop Macintosh applications has lost its advantage of hiding the facts of life about data storage from the programmer. One consequence of these extensions is that Inside Macintosh, Apple's reference manual for Macintosh programmers,has to cover the non-standard extensions to Pascal and their use in Macintosh programming, in addition to being a reference document for the Macintosh Toolbox. Programmers that have learned standard Pascal, or some other extended variant of Pascal will need to learn the language features added to Macintosh Pascal. Also, most Pascal manuals and tutorials do not cover these added features.

The result of these extensions is a Pascal that can do most — not all — of the things C can do, without the advantage of hiding details of data storage from the programmer. When you cast one type to another, you have to be aware of how those data types are stored. So instead of keeping track of data storage as part of the rules of C, you have to keep track of a set of violations to the rules of standard Pascal. On the Macintosh, there is no substantial difference in the effort expended on the part of the Pascal programmer compared with that expended by the C programmer. Programmers might as well take advantage of the added features of C. (Though, to be fair, the extensions in Macintosh Pascal are quite cleanly designed, and do not detract from the readability of programs.)

Since Macintosh Pascal is not standard Pascal, the amount of help available to the Pascal programmer from tutorials and other books on Pascal is diminished. On the other hand, in a well designed C development system for the Macintosh, you will not have to learn new language features.You will have to change the way you think about program design, and you will find yourself using some features of C that are seldom used in other environments. In Macintosh programming, the rules are the same, but the style of the game is different.

Choosing your tools

LightspeedC was used for the examples contained in this book. LightspeedC provides an integrated development environment that takes advantage of the Macintosh user interface to make compiling, assembling, and linking, painless and easy. All of the phases of compiling a program are rolled into one program — even the program editor is integrated into the LightspeedC environment. This degree of integration provides two advantages: If a syntax error is discovered in your program, the file in which the error occurred is placed right there in an editor window, with cursor in the offending line of code, ready for you to fix. The other advantage of LightspeedC is speed. LightspeedC is the fastest available C compiler for the Macintosh. If used with a hard disk, it is faster than compiling on all but the fastest mini and mainframe computers.

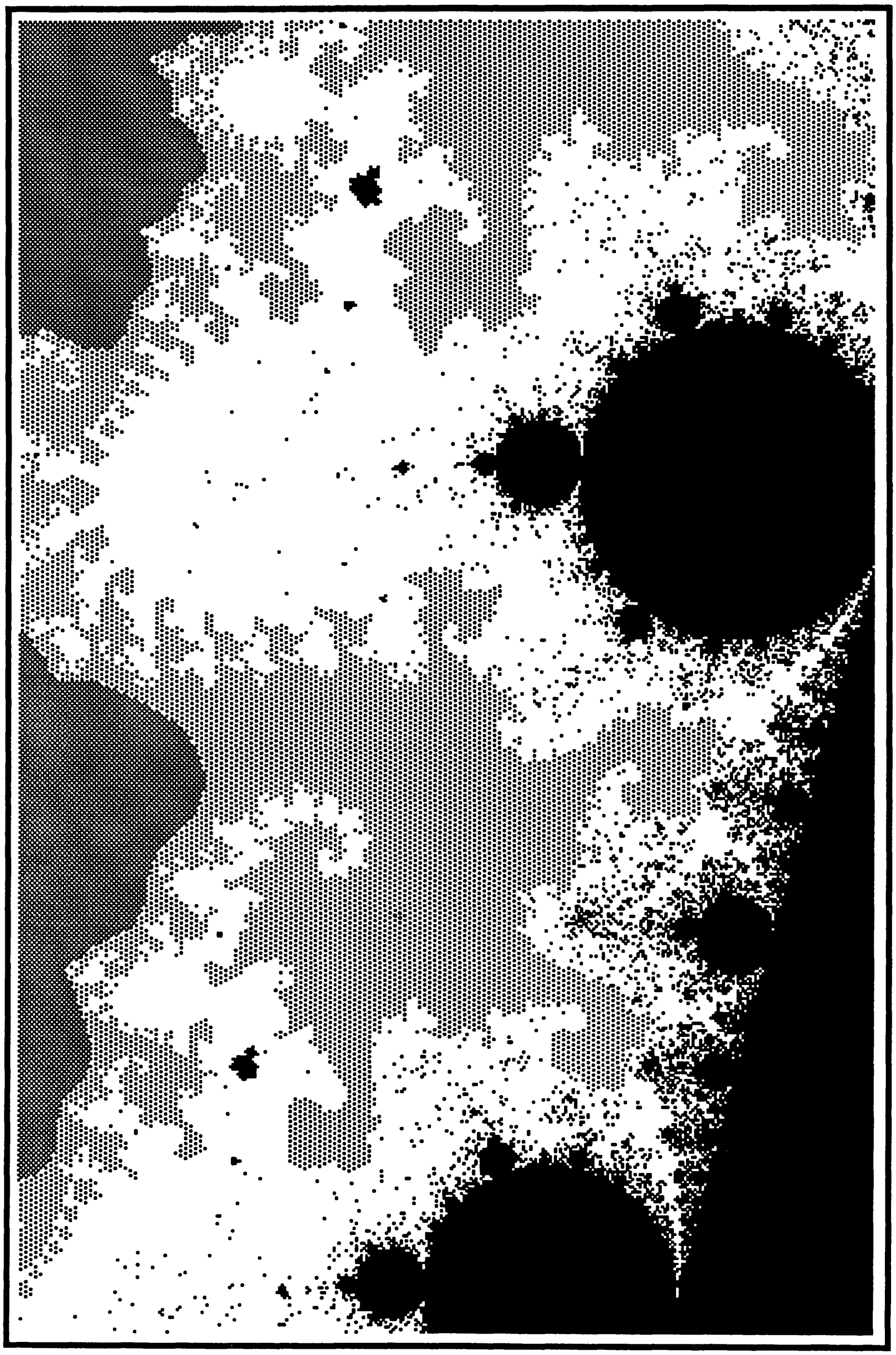
LightspeedC is designed to conform to the way Apple's Macintosh Programmer's Workbench (MPW) Pascal interfaces with the Toolbox. Integers and other related data types in LightspeedC are the same size as those in MPW Pascal, and calling sequences for Toolbox routines are the same as well. No "glue" or interface code separates your program from the Toolbox, and no implicit data conversion is done in passing parameters to Toolbox routines. In terms of conforming to the Pascal Toolbox interface conventions, LightspeedC is superior to MPW C, which performs potentially confusing data conversions when string and integer parameters are passed to Toolbox routines.

Compilers that insulate you from the Macintosh Toolbox or that attempt to maintain Unix programming idioms in the Macintosh milieu make it much more difficult to tap the technical information available in Apple's documentation, technical journals, and users' group newsletters. Insulating you from the "native" Toolbox interface also takes code, which increases the size of your applications without increasing their power.

If you are considering using a compiler not specifically mentioned in this book, you should look for one that has the fewest embellishments over and above the standard Macintosh Toolbox interface. New compilers are appearing all the time, and it is certain that some of the new compilers will be at least as good as LightspeedC. Selecting a compiler is a difficult judgment to make. Contact your local user's group if you need more technical information on which to base your decision.

POINTS TO CONSIDER

1. Why did you choose C for programming the Macintosh?
2. What obstacles did you foresee in using C?
3. How does C differ from other languages you know? Is the difference greater or smaller than you expected?
4. What other languages would you consider using? Why?



3

Knowing C, Thinking C

- Whether you can learn C in one chapter
- A description of the C language
- What is good C style
- How to read Pascal and think C

Ready?

To keep this chapter manageable, we do not attempt to do what others do in an entire book. You will need to ask yourself whether you can learn C in a single chapter, or whether you should augment this chapter with a C tutorial. If you are familiar with a block-structured language, and if you have written enough code in that language to have faced the following issues, you can probably pick up C from this description of the language. Here are the issues you should have faced:

- Calling procedures written in other languages — the practical implications of "call by value" and "call by reference."
- Defining data structures to match structured data from external sources such as networks, data files produced by other systems, or data structures used by library procedures written in languages other than the one you use.
- The scope and visibility of local variables.
- The use of "bit-masks."
- Formatting your programs according to accepted practice.

If you are well-versed in these issues then you can probably go on to pick up C from the rest of this chapter. If you feel you might be left adrift by a description of the C language that omits extensive tutorial examples and exercises, there are many books that teach C with plenty of depth and tutorial assistance.

Which C

This description of the C language is derived from the draft ANSI standard for C. This is the subset of that standard that is compatible with the current AT&T Unix C compiler. We will be presenting C in three parts. First, the C preprocessor will be described: it is what gives C constants and macros. Then the C language proper will be described in terms of its data types and operators.

The preprocessor

The C preprocessor is a language in itself. In some implementations of C, the preprocessor is made available in stand-alone form so it can be applied to files in languages other than C. In all implementations, the preprocessor can be considered a separate "pass." The compiler only sees code after the preprocessor has finished operating on it.

The language of the preprocessor enables you to specify that some token in a program be replaced by some other token(s). One function of the preprocessor is the creation of symbolic constants ("equates," in assembly language). Most symbolic constants in C programs are preprocessor constants — these are replaced by numeric constants before the C language parser sees them. In Pascal, symbolic constants are part of the language itself. There is little practical difference between these two approaches.

Preprocessor statements have two parts. The left side of a preprocessor statement specifies a token,or a macro with a list of parameters. The right side specifies what will replace the left side. Preprocessor statements generally end at the end of the line. When more than one line is required, a backslash placed at the end of the line indicates that the next line is also part of the preprocessor statement.

Simple preprocessor statements

This is the syntax of preprocessor statements:

```
#define identifier [any-token...]
```

The basic preprocessor statement associates `identifier` with one or more tokens. Before the C parser sees the tokens that make up the C program, the preprocessor will have replaced `identifier` with the tokens to the right of it. If no tokens are given, then the `identifier` is removed from the program.

A program with the following statement in it would have all instances of the token "FOO" replaced with the number "3:"

```
#define FOO 3
```

Preprocessor statements with parameters

In addition to an identifier that names a preprocessor macro, a macro can have a list of parameters, enclosed in parentheses, following the macro-name. If these parameters are used anywhere in the body of the macro definition, they will be replaced by whatever tokens appear in the parameter list when the macro is used.

```
#define identifier (identifier [, identifier...]) [any-to-
ken...]
```

Macro parameters are like procedure parameters. When a macro is used, the parameters of the definition are replaced by "actual parameters." A macro that looks like a procedure-call can replace procedure-calls with in-line code, increasing the efficiency of critical sections of programs.

The opposite of a macro definition

```
#undef identifier
```

This preprocessor directive causes the preprocessor to forget about `identifier`.

Including files

```
#include <name-of-file>
#include "name-of-file"
```

These two statements cause the contents of another file to be included into the the file being processed. The first form looks for files in a predetermined list of directories, the second uses only files found in the local directory.

Conditional compilation

```
#ifdef identifier
#ifndef identifier
#if constant-expression
#endif
```

These are the preprocessor's conditional statements. Lines between an opening conditional statement and a closing `#endif` statement are conditionally included in the file being processed. The first two forms of preprocessor conditions test for the existence or non-existence of preprocessor macros. The identifier may be the name of a macro with no right side — no tokens that would replace occurrences of the identifier in the file. The third form of condition includes the entire constant expression syntax of C. If the expression has a non-zero value, the condition is true.

This facility of the C preprocessor corresponds to the conditional assembly facility of most assemblers.

```
#else
```

This preprocessor statement divides conditionally included lines into two groups: The lines before the `#else` remain in the file being processed if the condition of the conditional inclusion statement is true. The lines following the `#else` and before the `#endif` are included if the condition is not true.

Support for program generators

The `#line` statement is not properly part of the preprocessor. The purpose of the `#line` statement is to inform the compiler's error-notification system what line the real source code is on. Preprocessors like the C preprocessor, m4, YACC, LEX, or any of the other macro processors and program generators that are commonly used in conjunction with C often change the number of lines the compiler sees after the source code has been processed. These preprocessors insert `#line` statements so that the compiler does not report incorrect and confusing line numbers when compiling preprocessed code.

```
#line integer [name-of-file]
```

Program-generating-programs insert `#line` statements in their output — seldom would you have any reason to type in a line statement yourself.

Preprocessor Example

The following code fragment is an example of conditional compilation:

```
#if DEBUG_LEVEL > 3

/* Some highly detailed debugging code... */

#endif
#if DEBUG_LEVEL > 2
```

```
/* Some less detailed debugging code... */

#endif
```

The syntax of C — what the C parser sees

The rest of this chapter describes the syntax that the C parser recognizes. Whether a particular compiler is implemented this way or not, you can think of a C program as being free of preprocessor statements by the time it reaches the C parser.

While reading this description of C, you may want to keep your thumb on a page with a sample program on it, to see examples of the syntax being described. A small sample program appears at the end of this chapter, and later chapters contain much larger examples illustrating Macintosh programming.

Simple variables — storage classes and data types

A fundamental part of many computer languages is a facility for setting aside space for variables. Using the following syntax you can set aside space in units fundamental to C:

```
[storage-class] [data-type] identifier
    [= initializer][, identifier [= initializer]...];
```

Storage classes determine how a variable is stored. Data types tell how the bits in a variable are used and the size of the variable. The identifier gives the variable a name. The initializer determines the initial value of the variable. Any number of variables of the same type and storage class can be declared,with storage set aside for them, in a single statement.

The following storage classes are available:

`static`

If this storage class is specified for a global variable (a variable declared outside any function or procedure), the variable is made unavailable outside the file it is declared in. If the static storage class is specified for a variable local to a procedure, then that variable will be allocated in the *global* data area of the program and the variable will retain its value across invocations of that procedure it is local to. Because the variable is local to a procedure, no other procedure will be able to access it. Procedures can be declared static as well, hiding them from other files. The static storage class is used to make programs more modular and to avoid naming conflicts among global variables.

extern

The `extern` storage class tells the compiler that storage for this variable has been allocated elsewhere but that its data type is the one specified with the name of the variable. The `extern` storage class is used when the compiler needs to know the size and/or type of a variable whose storage has been set aside in some other module of the program.

auto

The `auto` storage class signifies that a variable is to be allocated "automatically," on the stack, when a program block is entered, and de-allocated when the block is exited. This is the default storage class for local variables.

register

The `register` storage class advises the C compiler to place variables local to procedures in the registers of the processor. Using register variables can greatly speed-up the execution of a program.

The following data types are predefined in C:

int

The `int` (integer) data type is the fundamental data type in C. Integers are meant to reflect the architecture of the machine the compiled program will run on. In the case of the Macintosh, integers are 16 bits wide.

short

The `short` data type is never bigger than an integer, but it can be smaller. The choice of size for a `short` is up to the compiler implementor. On the Macintosh, short integers are not too useful — if you need an 8-bit quantity use a `char` because all compilers have an 8-bit `char` data type. On machines where integers are 32 bits wide, the `short` data type provides a way of working with 16 bit integers.

long

The `long` data type is 32 bits wide on the Macintosh. It is never smaller than an `int`. On most 32 bit machines, it is the same size as an `int`.

`char`

The char data type is used to reflect the unit of storage used to hold characters on a machine. On a Macintosh, and most other machines, it is 8 bits wide. Arithmetic operations can be performed on `char` variables in the same way as on `int`, `long` and `short` variables.

`unsigned int`

Unsigned integers have no sign-bit, and so can hold numbers twice the magnitude of signed integers.

`unsigned short`

Just like a `short` but no sign-bit.

`unsigned long`

Just like a `long` but no sign-bit.

`float`

The `float` data type may sound as though it is the fundamental floating point type in C, but it is not. All float variables are converted to `double` before being operated on. Unless you are storing floating point numbers in arrays big enough to cause a space crunch, using the `double` type will make your programs execute faster.

There are no standards specifying sizes, or even relative sizes for floating point types in C. Some Macintosh C compilers use Apple's Standard Apple Numerics Environment, a library that conforms to the IEEE floating point standard, and some do not. Some compilers omit floating point altogether. Some compilers allow the programmer to specify that `float` types are not to be converted to double before arithmetic operations.

`double`

This is the real fundamental floating point type in C. On the Macintosh, a `double` typically occupies 10 bytes.

An example: Simple declarations

The following declarations create simple variables:

```
/* Double-precision X and Y velocities are initialized
 * to 0
 */
```

```
double x_velocity = 0, y_velocity = 0;

/* The local variable in this procedure retains its
 * value across calls, and is zero before the first
 * call to this routine.
 */
int running_total(add_in)
{
      static subtotal = 0;
      /* Initially zero */

      subtotal += add_in;
      return subtotal;
}
```

Data structures and arrays

Data structures and arrays are the two means of aggregating variables in C.

Arrays can have multiple subscripts, but they must be contiguous in memory. Subscripts are always integers. Negative subscripts indicate a negative offset from the beginning of an array. On a Macintosh, you can use subscripts to access elements of one-dimensional arrays of 2^{15} items or less.

This is not to say that you cannot deal in tracts of memory larger than this — you will just have to do the pointer arithmetic yourself.

Array declarations have a syntax that is a minor variation on that used for simple variables:

```
[storage-class] [data-type]
     identifier[[bounds]][[bounds]...]
          [= initializer][, identifier [= initializer]...];
```

Array bounds can be expressed as any constant expression. C does no bounds checking and bounds are optional for one dimensional arrays. Omitting array bounds or ignoring preestablished bounds can be useful for working with variable length arrays.

Data structures are a way of grouping declarations under a single umbrella declaration. In Pascal, the equivalents of structures are called records.

This is the syntax of C data structures:

```
struct [identifier] { declaration; [declaration;...] }
     [identifier];
```

Data structures are like cookie cutters, and memory is like a sheet of dough: if you leave off the last optional identifier you have made a cookie cutter, but no cookies. If you include the last identifier, you have made a cookie cutter and one cookie. If you plan to use a data structure cookie cutter elsewhere, you will have to name it by including the optional identifier just after the `struct` keyword.

Named structure definitions can be used just like predefined data types. Any place where the name of a data type is used, the keyword struct can be used followed by the name of a previously defined structure.

Unions

Unions are like structures except that unions do not lay items end to end as structures do — unions lay the items they contain on top of each other. So if you need a name for a piece of memory that could hold two or more structures, indeed any number of types of variables, you would declare a union containing members of all the types that could be put in that space. The syntax of union declarations is almost identical to that of structures:

```
union [identifier] { declaration; [declaration;...] }
     [identifier];
```

As with structures, the result of declaring a union is a "cookie cutter" that cuts out pieces of memory that are the size of the largest element in the union. If the union can hold the largest member of the union, it can hold any member of the union.

Defined data types

C has a means of defining new data types. This mechanism is similar in syntax and in usage to Pascal's defined data types. The greatest difference is that defined data types are seldom used in C, though some books that teach C strongly advocate their use.

Defined data types are widely used in the Toolbox interface. Even if you have not used defined data types extensively in C programs you may have written, you will need to be familiar with them for programming the Macintosh.

This is the syntax of data type definition:

```
typedef abstract-declaration identifier;
```

An abstract declaration is a declaration without the name of the variable. So instead of creating a variable of a given type and a given name, an abstract declaration simply provides information about size and type. Defined types use this information, because the newly defined type inherits the characteristics, like size, structure element names, etc. from the data types used in the abstract declaration. The name of the defined data type is given as an identifier. That identifier can then be used like any other data type name — anywhere when you can use "int," you can use a defined data type.

Enumerated constants

Enumerated constants are the "other" way of creating symbolic constants in C. Enumerated constants are like Pascal sets. Not only do you create symbolic constants when you with define enumerated constants, you can, at the same time, create a class of variables to hold those constants.

Creating enumerated data types provides a means of enforcing the correct use of enumerated constants only in situation where they ought to be used. They will not properly "fit" in variables of other types and a good compiler will warn you of abuse of enumeration types and constants.

This is the syntax of enumerated constant declarations:

```
enum [identifier] { [identifier [= initializer]][,
          [identifier [= initializer]]... };
```

The identifier that may appear just after the enum keyword names an enumerated type for variables that can hold only the constants named in the list between the braces. To declare a variable of a class defined in an enum declaration, use the following syntax:

```
enum identifier [= initializer];
```

Aggregate declarations: an example

The following declaration creates an array of structures. The structure is called `ball` and the array is called `in_play`.

```
/* At most three balls can be in play */
struct ball
{      int x_position;
       int y_position;
       double x_velocity;
       double y_velocity;
       int mass;
} in_play[3];
```

Pointer declarations

Pointers are variables that hold the addresses of other variables. In C, pointer declarations are syntactically variations of the declarations of the variables they can point to.

In pointer declarations, the identifier naming the pointer is preceded by an asterisk. Asterisk, when used as a unary operator, is the dereferencing operator. Dereferencing is the action that takes place when a pointer is followed to the object it points to — this is also called indirection.

This is the syntax of pointer declarations:

```
data-type *identifier [= initializer];
```

This is the declaration for a pointer to an integer:

```
int *ptr_to_a_number;
```

Operators

The C language has a rich enough set of operators to perform almost any arithmetic or logical operation supported by hardware primitives in most computers.

Operators are evaluated in a predetermined order. Several operators may be at the same level in this order, in which case they are evaluated from left to right. Unary operators are an exception, evaluating right to left.

The operators that operate first are responsible for delivering values to operate on to other operators. These include subscripting, the dot operator between a structure-variable name and the name of an element in that kind of structure, the "arrow" between a pointer to a structure and the name of a structure element, the square braces around subscripts, the parentheses around parameter lists in procedure calls, and the parentheses used to group other operators. In the case of parentheses and the square braces around subscripts, which can be nested, the order of evaluation is left-to right and inside-to-outside.

The reason operators which yield structure elements and array subscripts are evaluated first is that they work on names. They turn combinations of structure-variable names, array names, structure element names, and array subscripts into operands for other operators.

The following table summarizes the operators that form the primary expressions in C — expressions delivering values for other C operators to work on. The following operators have the highest evaluation priority. If they are not explicitly grouped using parentheses, they evaluate in left-to-right order.

- `()` Parentheses can be used to group operators and their operands so that the default order of evaluation is overridden. Parentheses also enclose the arguments of a procedure call.
- `.` The dot operator selects an element, named to the right of the dot, from the structure-variable, named on the left of the dot.
- `->` The "arrow" operator selects an element, named to the right of the arrow, from the structure, whose location is specified to the left of the arrow.
- `[]` Square braces enclose expressions that yield array subscripts. Array subscripts are always integers.

The rest of the operators in C fall into several groups. Order of evaluation never crosses the borders of these groups. Therefore knowing what these groups are makes it much easier to remember the order of evaluation of all the operators in C.

Just as there is a group of operators that yield operands for the rest of the operators in the language, there are groups of operators that: have only one operand, perform multiplicative operations, perform additive operations, perform bit-shift operations, perform relational and equality comparison, perform bit-wise "and" and bit-wise "or" operations, perform logical "and" and logical "or" operations, perform the conditional operation, perform assignment, and concatenate expressions.

Unary operators in C are evaluated right after the above group of operators that operate on names to produce operands. Unary operators are the common-sense next step in evaluating expressions: After an operand is arrived at, one or more unary operators may modify it before it is combined with other operands.

Unary operators differ from most other C operators (except for assignment operators) in that they are all evaluated from right to left (if not explicitly grouped). Think of this as an order of evaluation where the operator closest to the operand operates first, and then the next closest, and so on. There are no other rules for grouping in the use of unary operators.

C has the following unary operators:

- `*` Asterisk is the C indirection operator. Applied to a pointer, the result is the value stored in the location being pointed to.
- `&` Ampersand is the C address operator. Any entity that has storage associated with it, and is in the machine's address space (not, for instance, in the 68000's registers) can have the address operator applied to it, yield-

	ing a pointer to that entity.
sizeof	`Sizeof` yields the size, in bytes, of its operand. This is not to be confused with library functions that measure the length of null-terminated strings. `Sizeof` gets its information from the data type of its operand.
`(type-name)`	A type-name enclosed in parentheses is the C cast operator. In C, casting not only changes the type of the entity being cast, it may also convert the entity. It is beyond the scope of this chapter to enumerate all of the things that can happen when casting from any type to any other type.
-	Unary minus yields the arithmetic negative of its operand.
!	Exclamation point yields the logical negative of its operand. In C, logical "true" is any non-zero value, including negative values, and "false" is represented only by zero.
~	Tilde is the bit-wise negation operator. The result is a value in which every corresponding bit in the operand is inverted.
++	The increment operator can be placed before or after its operand. Placed before an operand it yields a value one unit greater than the operand. In addition to yielding this value, the operand is immediately updated to have this new value as well. Placed after an operand, the result is simply the value of the operand. After the value is copied from the operand, the operand itself gets a new value one unit greater than it had before.
--	The decrement operator operates similarly to the increment operator, except that it decrements where the increment operator would increment.

Using unary operators: an example

The following code fragment assigns the complement of an array element to `test` and bumps the pointer to point to the next element:

```
test = ~*thing_ptr++;
```

Even though the ++ operator is the leftmost unary operator, and so evaluated first, it still "post-increments" the pointer. That is, it has no effect until after the expression is evaluated.

Binary operators

Unlike the unary operators, which are all evaluated in right-to-left order, binary operators have an inherent precedence in which some operators will be evaluated before others, no matter what order they appear in. Thus binary operators are not all part of the same group. This inherent order of evaluation is overridden, when necessary, by the use of parentheses.

The binary operators are presented here from highest to lowest precedence. The first operators presented are the first to be evaluated. When several binary operators have the same precedence, they are evaluated from left to right, just as they would be read aloud. Where it makes sense to do so, precedence rules follow those typically used in mathematics. The exception to left to right order is the order of evaluation for assignment operators, which are evaluated right to left. So, when two or more assignments take place in a single expression, the right side is evaluated before the left side, just as in the case of a statement with a single assignment operation.

The binary operators with the highest precedence are the multiplicative operators that multiply, divide, and yield remainders. These operators have the same precedence and are evaluated left to right:

*	An asterisk used between two operands is the multiplication operator. This is the same symbol as the indirection operator, but the syntax of the language prevents confusion — there is no situation in which an asterisk meant to multiply two operands would be taken for an indirection operator.
/	Virgule (or slash) is the division operator. The result is the quotient, and, in the case of integer operands, the remainder is unavailable.
%	Percent-sign is the modulus operator, yielding the remainder of a division operation rather than the quotient. The modulus operator cannot be applied to floating point numbers.

Following the multiplicative operators, in precedence, are the additive operators:

+	Plus-sign is the addition operator in C. It yields the sum of its two operands.

- Minus-sign is the subtraction operator. It yields the difference of its two operands.

C evaluates its arithmetic operators first among its binary operators. Transcendental functions are usually available is the library(s) of functions that come with most C compilers. C does have a rich set of logical and bit-wise logical operators, so that almost any operation a processor can perform with a single instruction, such as shifting, masking, oring, etc. can be specified directly in C.

The logical operators come after the arithmetic operators in precedence, and are divided into several groups, some containing only one operator. The logical operators with the highest precedence are the shift operators. They are evaluated left to right:

>> This is the shift-right operator. The right operand is converted, if need be, to an integer. The result is the value of the left operand shifted right as many bits as is specified by the right operand.

<< This is the left-shift operator. It operates the same way as the right shift operand, but shifts the left operand left.

Following the shift operators in precedence, are the relational operators. The relational and equality operators are all ahead of the logical operators because relational results are often combined by logic.

The relational operators are evaluated left to right. The result you get by concatenating relational operations is legal, but not very useful. The result of a relational operation is one if the relation is true and zero if it is not — not a useful result for use in other relational operations.

> This is the greater-than operator. It yields one if the left operand is greater than the right operand, otherwise zero.

< This is the less-than operator. It yields one if the left operand is less than the right operand, otherwise zero.

>= This is the greater-than-or-equal-to operator. It yields one if the left operand is greater than or equal to the right operand, otherwise zero.

<= This is the less-than-or-equal-to operator. It yields one if the left operand is less than or equal to the right operand, otherwise zero.

The equality operators follow the relational operators, in precedence, and they share the properties of the relational operators in the usefulness of cascading them:

`==` This is the C equality operator. It yields one if the operands are equal, otherwise zero.

`!=` This is the C inequality operator. It yields one if the operands are not equal, otherwise zero.

Following the equality operators are the bit-wise operators. These come one to a group.

The bit-wise operator with the highest precedence is the bit-wise "and" operator:

`&` When used as a binary operator, ampersand is the bit-wise "and" operator. If the corresponding bit of both operands is one, then the corresponding bit in the result is one, otherwise zero.

After the bit-wise "and" operator comes the bit-wise exclusive-or operator:

`^` Carat is the bit-wise exclusive-or operator. If the corresponding bit of either operand, but not both, is one, then the corresponding bit in the result is one, otherwise zero.

And after the bit-wise exclusive-or operator comes the bit-wise inclusive-or operator:

`|` The vertical bar is the bit-wise inclusive-or operator. If the corresponding bit of either operand is one, then the corresponding bit in the result is one, otherwise zero.

The logical operators in C operate values where non-zero values mean "true" and zero means "false." The logical operators, like the bit-wise logic operators, come in groups of one. The and operator is evaluated before the or operator.

Unlike the relational and equality operators, it does make sense to cascade logical operators. Cascaded "or" operators and cascaded "and" operators are both evaluated left to right.

`&&` This is the logical "and" operator. If both operands are non-zero, then the result is one, otherwise zero.

Following the logical "and" operator, in precedence, is the logical " or" operator:

|| This is the logical "or" operator. If either operand is non-zero, or if both operands are non-zero, then the result is one, otherwise zero.

After the logical operators comes the conditional operator. The conditional operator is C's only ternary operator. The conditional operator is documented here, among C's binary operators, because it has higher precedence than some binary operators, namely the assignment operators and the comma operator. Cascaded conditional operators are evaluated right to left. Additionally, the conditional operator never produces an lvalue.

? : This is the conditional operator. The three operands of the conditional operator are located (first) before the question mark, (second) between the question mark and the colon, and (third) after the colon. If the value of the first operand is non-zero, the result is the value of the second operand, otherwise it is the value of the third operand.

The conditional operator may seem to be much like an "if statement," but an if statement does not produce a value as a result.

After the conditional operator come the assignment operators. In addition to an operator that assigns the value of the right operand to the left operand, C has assignment operators that perform the functions of most of the binary operators (except for the Boolean logical operators). In the combination assignment operators, the value of the left operand and the right operand are used as operands of the binary operator that the assignment is combined with. The result is then assigned to the left operand. Cascaded assignment operators are evaluated right to left.

= This is the assignment operator. The left operand gets the value of the right operand.

*= Multiplication and assignment.

/= Division and assignment.

%= Modulus and assignment.

+= Addition and assignment.

-= Subtraction and assignment.

`<<=`	Shift-left and assignment.
`>>=`	Shift-right and assignment.
`&=`	Bit-wise "and" and assignment.
`^=`	Bit-wise exclusive-or and assignment.
`|=`	Bit-wise inclusive-or and assignment.

Strangely, perhaps, assignment operators do not have the lowest precedence in C. That honor belongs to the comma operator:

`,`	The comma operator is a binary operator that yields the value of the second operand as a result. This is not the same as the comma that is part of a "for" statement.

Control flow statements

Control flow statements determine a program's path of execution. C has five control-flow statements and two keywords that modify the behavior of the control flow statements.

This is the syntax of C's control flow statements:

```
while ( expression ) statement

do statement while ( expression );

for ( [expression] ; [expression] ; [expression] )
     statement

switch ( expression ) statement
```

A statement may be an expression followed by a semicolon, a block enclosed in braces, or a control flow statement.

In switch statements, statements within the statement may be labeled with a case label:

```
case constant-expression:
```

The constant expression must have a unique value in the switch statement it is part of. If the constant expression's value matches that of the expression enclosed in parentheses at the top of the `switch` statement, then control will pass to the expression immediately after the `case` label when the `switch` statement is reached.

While statements and do while statements repeatedly return control flow to the statement that is the body of the loop, until the expression in parentheses has a value of zero.

For statements have three expressions, separated by semicolons, in parentheses. The first expression is evaluated only once, before the first time through the body of the loop. The second expression is evaluated before each time through the loop, just as the expressions in while and do while statements are; if it has the value zero, the loop body is not executed and control is passed to the statement following the for statement. The last expression in parentheses is evaluated after each time through the body of the loop.

Two keywords are used to modify the behavior of control flow statements. The continue keyword modifies the behavior of the loop statement it is in. When a statement consisting of the continue keyword is evaluated, control passes to the point just before the end of the loop body, skipping over the rest of the statements in the loop body.

The break keyword modifies all of the control flow statements. When a statement consisting of the break keyword is evaluated, control passes to the statement following the control flow statement where the break keyword is encountered.

Procedures

C programs consist of global declarations and procedure definitions. Procedures have a return type, local storage, and statements. Procedures that return a value have return statements that contain an expression that yields the return value.

This is the syntax of C procedure definitions:

```
[return-type] procedure-name
     ( [parameter-name][, parameter-name]...) statement
```

An example program

```
#include <quickdraw.h>              /* Include the macros and
                                     * declarations associated with
                                     * quickdraw
                                     */
int a_global;                       /* A global variable */

/* With the following union, a 32 bit long can be treated as
 * two 16 bit ints. The long and the structure containing
 * the two integers would occupy the same storage in a
 * variable of this type.
 */
typedef union              /* Make a defined type */
{   struct                 /* One member is a structure... */
    {   int a;             /* With ints a and b as elements */
```

```
        int b;
    } halves;
    long longword;      /* The other member is a long */
} split_long;           /* call the type "split_long" */

/* The main routine */
main(argc, argv)
    char *argv[];       /* A vector of character ptrs */
{
    int a_local;        /* A local variable */

    switch (argc)
    {   case 1:                 /* In case argc is one... */
            p_to_c(argv[0]);    /* Pass the first ptr in argv */
            break;
        default:                /* The default case */
            a_global = do_default();
    }
}

/* Process an element of argv */
p_to_c(string)
    char *string;
{
    int i, length = string[0];

    if (string)         /* If this pointer is not null */
    {   /* In this example we convert a Pascal style string
         * into a C style string with no length byte at the
         * beginning and a null at the end.
         */
        for (i = 1, i <= length; i < length; i++)
            string[i - 1] = string[i];
    }
}

/* Do a few things that illustrate some arithmetic
 * operators in C.
 */
do_default()
{
    /* a local variable */
    long a_value = 0xd2d7;      /* initialize to hex d2d7 */

    a_value *= 17;              /* Multiply it by 17 */

    /* Here we cast a_value to the split_long type, take the
     * high word and assign the value to a_value. We
     * parenthesize the cast operation because unary
     * operators have a lower precedence than the operations
     * that pick out structure and union members.
     */
    a_value = ((split_long)a_value).halves.b;
}
```

The meaning and use of style

The style conventions used in this book are the generally accepted conventions used widely in Macintosh, Unix and MS-DOS programming. No major changes in C style have to be made to accommodate the Macintosh Toolbox interface.

In companies and school that use and teach C you will find both stricter and more relaxed standards. In this book we strive for readability without sacrificing performance. If you are considering writing programs to sell to others, we encourage you to adhere to style conventions at least as strictly as we do. Software publishers often review the software offered to them to assess the cost of maintaining it and fixing any bugs that may turn up. The clarity of your code may make the difference between selling and not selling your program.

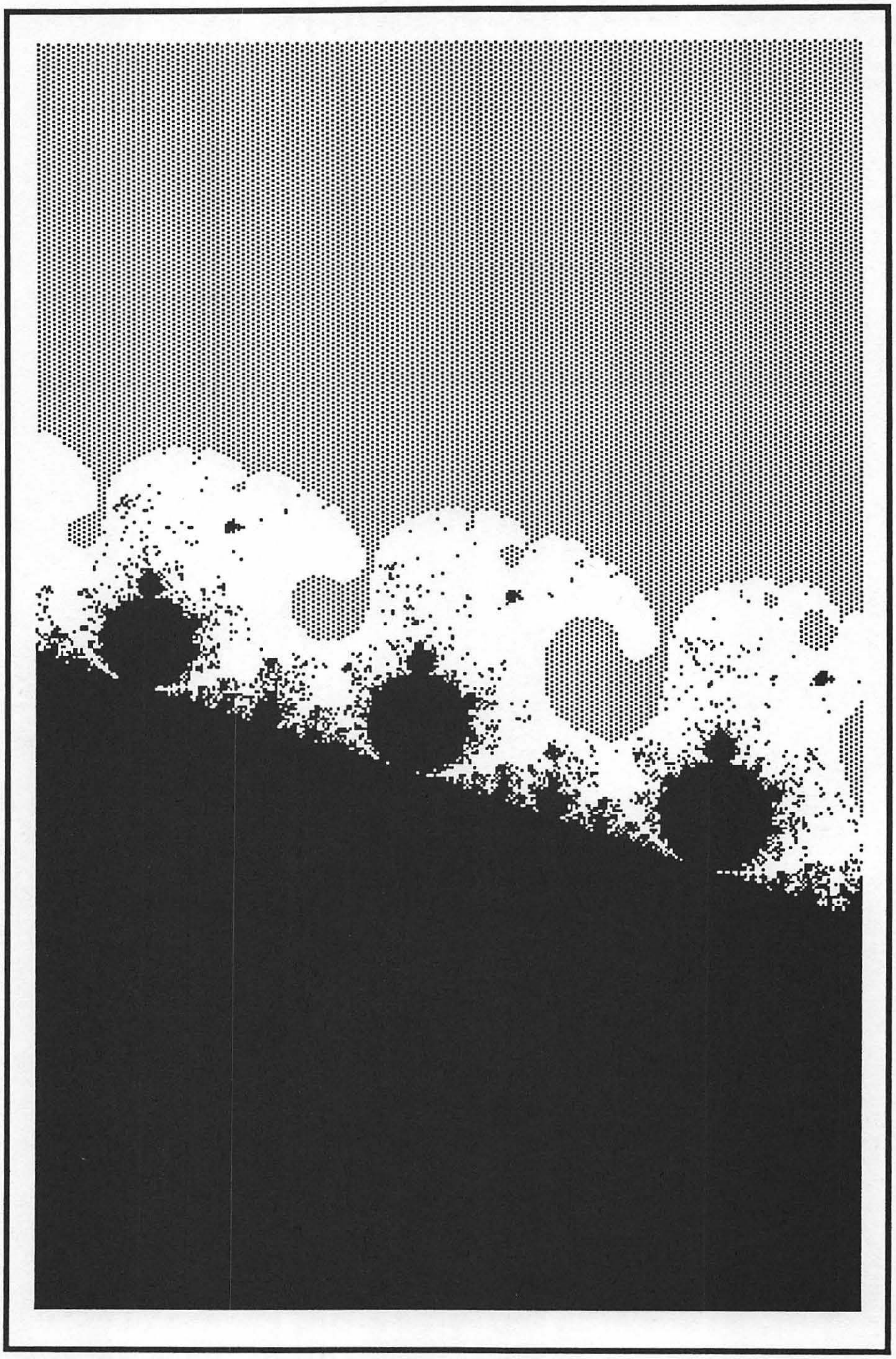
POINTS TO CONSIDER

1. Why do assignment operators have such low precedence? What would happen if they were evaluated *before* arithmetic operators?

2. What is wrong with the following `if` statement:

```
if (value = INVALID)
        report_error();
```

3. Most compilers come with example programs. Compile a short example and disassemble the program. Match the lines of the source program up to the instructions in the disassembled object code.



4

QuickDraw and Windows

- The system of GrafPort environments used by QuickDraw to support drawing in windows
- The coordinate system used by QuickDraw
- GrafPort regions, which are used to limit the area drawn in
- How the Window Manger, in concert with QuickDraw, manages graphics updates
- How applications can use GrafPort regions to "clip "

This chapter covers the two parts of the Toolbox ROM most responsible for giving the Macintosh its unique character. Windowing and event-driven programming are intertwined and form the foundation of all Macintosh applications. The operating principals behind windowed, event-driven applications presented here will prepare you to design and program your own interactive applications.

This chapter brings together concepts from the Window Manager and QuickDraw so that you understand the relationship between these two distinct Toolbox managers. Only those aspects of QuickDraw and the Window Manager that support windowing will be discussed here. Both of these managers have features that are not part of the Macintosh's windowing support. *Inside Macintosh* gives a thorough explanation of *all* the features of both these Toolbox managers, and a summary of their features is found in the reference section of this book.

The obvious and subtle parts of QuickDraw

QuickDraw is the basis of all activity on the Macintosh screen. The obvious part of this activity is QuickDraw painting bits on the screen in response to requests that characters or lines or patterns be drawn. QuickDraw also performs the graphics calculations that are the basis of the Macintosh window system.

The Window Manager is the Toolbox manager that applications call when they want to create windows, move windows, and change which window is the active window. QuickDraw supports the Window Manager by helping it maintain the illusion that the application has several small screens that can be moved around the Macintosh screen.

QuickDraw provides numerous drawing routines that draw lines, fill areas, copy bits from one place to another (while stretching or shrinking the image painted in those bits), draw characters, scroll, etc. QuickDraw also provides routines that perform calculations on points, lines, rectangles, areas, etc. Using QuickDraw, an application can, for example, determine whether objects overlap, it can set up the GrafPort so that the overlapped region is clipped, and draw those objects so that one appears to be "in front" of the other.

The Window Manager uses the calculation routines in QuickDraw to create the desktop. Without QuickDraw, the Window Manager would be a hopeless kludge, and without the Window Manager, QuickDraw could not provide enough support for windowing. Working together, these two Toolbox managers provide both high level support for windows, such as the code that automatically draws the frames of windows as needed, and low level support for drawing in windows. The low level support that an application uses to draw what it wants displayed in its windows is the same as what the Window Manager uses to draw window frames.

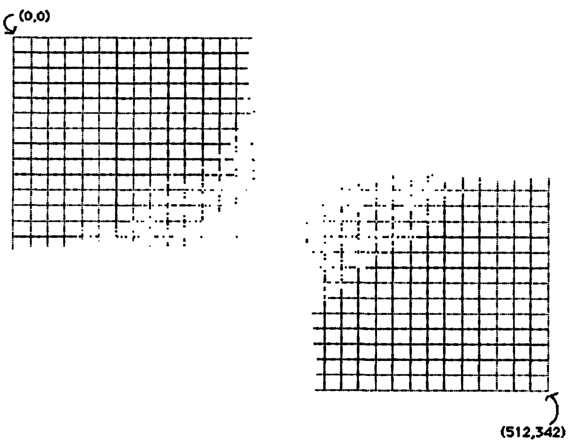
Starting with QuickDraw coordinates, we will see how windows and the Window Manager are built on QuickDraw. Using this information, you will be better able to manage the contents of your applications' windows.

QuickDraw coordinates

All the drawing and calculating on the Macintosh is done in a coordinate system that needs to be understood before QuickDraw can be used effectively. Many of the errors encountered during the development of a Macintosh program have to do with being one bit off of the desired place when drawing, erasing or scrolling.

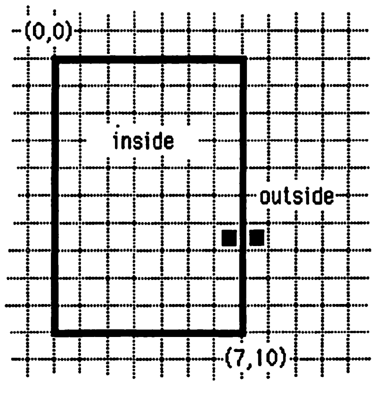
The QuickDraw coordinate system is the basis of the algorithms embodied in QuickDraw, and knowing the coordinate system and the conventions used in it lets you predict what QuickDraw will do. Otherwise you may waste a lot of time in trial and error.

Drawing is done at a location, or between two locations, or in the space enclosed by several locations connected together. Locations in QuickDraw are positions on a lattice that *runs between the pixels.* Two parts of a QuickDraw coordinate system are depicted below:



Keeping this lattice in mind helps to avoid confusion: If you picture a lattice running between pixels, rather than pixels with row and column addresses, there is no confusion over whether a rectangle includes or excludes a pixel, because the rectangle runs between, and not on top of, the pixels. Because the points on the lattice are infinitely small, the size of a pixel and how much of its area is on one side or the other of a bounding line never enters into QuickDraw calculations.

Depicted below is a QuickDraw rectangle. The coordinates of the rectangle are (0,0) and (7,10). One of the two black pixels is inside, and the other is outside. If the rectangle were filled with black, only the pixels inside the rectangle's boundary would be black. Since the rectangle itself is *not* a graphic, and it has no visible boundaries that occupy pixels themselves, what is meant by "inside" is unambiguous.



The QuickDraw coordinate system is not just a mathematical basis for thinking about QuickDraw: The fact that QuickDraw coordinates are integers and the lines in the QuickDraw lattice are infinitely thin means that integer arithmetic yields the correct results. No rounding is required to decide whether a pixel falls on one side of a line or the other. This makes QuickDraw quick.

The GrafPort: an environment for drawing

Macintosh windows are built on GrafPort environments. GrafPort environments are individual, self-contained drawing environments. The Macintosh screen is where GrafPort bit maps are almost always located, but a GrafPort may be associated with bit maps anywhere in memory. The Macintosh screen is distinguished only by the fact that if drawing is done in a GrafPort that uses the Macintosh's screen-memory for its "bit map," the drawing is rendered visible by the Macintosh's video hardware.

Apart from a pointer to its bit map, a GrafPort holds all the other information that pertains to painting bits in the GrafPort bit map. This information ranges from the current typeface for the GrafPort to the foreground and background colors for the GrafPort to a list of customized routines for drawing in the GrafPort.

This is the data structure that holds GrafPort information:

```
typedef struct
{    int device;
     BitMap portBits;
     Rect portRect;
     RgnHandle visRgn;
     RgnHandle clipRgn;
     Pattern bakPat;
     Pattern fillPat;
     Point pnLoc;
     Point pnSize;
     int pnMode;
     Pattern pnPat;
     int pnVis;
     int txFont;
     Style txFace;
     int txMode;
     int txSize;
     int spExtra;
     long fgColor;
     long bkColor;
     int colrBit;
     int patStretch;
     QDHandle picSave;
     QDHandle rgnSave;
     QDHandle polySave;
     QDProcsPtr grafProcs;
} GrafPort;
```

While the GrafPort does hold all the information associated with drawing in a bit map, the memory that is drawn in is pointed to by the portBits part of the GrafPort, and is not part of the structure. The GrafPort structure associated with the Macintosh screen could be anywhere in memory, but the memory for the GrafPort bit map has to be where the video hardware can access it.

GrafPort structures contain numerous fields for storing the state of the GrafPort. The field that determines where the GrafPort is is the portRect field. When a window is moved around the Macintosh screen, all that happens to the GrafPort structure is that the portRect field is changed. The portRect is defined in terms of the bit map.

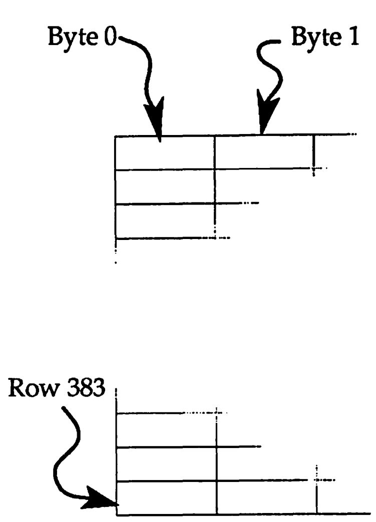
Bit maps

Bit maps are a way of describing a piece of memory used for drawing in. This is the bit map data structure:

```
typedef struct
{    QDPtr baseAddr;
     int rowBytes;
     Rect bounds;
} BitMap;
```

The baseAddr field of a bit map points to the first location of memory to be drawn in. The rowBytes field holds information about how many bytes wide the bit map is. The width of the bit map of the Macintosh screen is 512 bits, or 64 bytes, a number constrained by the hardware that displays the bit map on the video display. Memory set aside for a bit map by an application can have any byte width that fits in the amount of memory set aside an integral number of times. The bounds rectangle is always anchored at the top left corner above the topmost, leftmost bit in the bit map. The bottom right corner can be anywhere in the bit map. Typically the bounds rectangle encloses all of the bits in the bit map.

The following diagram illustrates a BitMap with 64 bytes in each row and 384 rows, the same dimensions as the Macintosh screen



The `baseAddr` field of a `BitMap` structure hold the location of byte 0 of the memory associated with the bit map. To allocate a bit map yourself, you need to allocate both the `BitMap` structure that describes the bit map, and the array of bytes to be drawn in.

`GrafPort` regions: support for windows

`GrafPort` environments alone would let an application create rectangles on the screen that would act something like windows. Several `GrafPort` environments often share the bit map that is the Macintosh screen. By moving the `portRect` of a `GrafPort` around, the location where drawing takes place in that `GrafPort` changes. But there still is quite a bit missing: There is no notion of one `GrafPort` being in front of another, no way of telling the user which is the active `GrafPort`, and no facility for keeping track of which parts of the screen need updating. To provide complete windowing, the Window Manager uses regions to add the ability to hide parts of windows behind other windows.

Regions are a QuickDraw structure that describe arbitrarily shaped areas. You do not have to know how regions work in order to use them, but their underlying structure is interesting: The documented part of region structures consists of a word containing the size of the region data structure and a boundary rectangle. If the region is more complex than a rectangle, additional information following the first two fields of the region structure describe the region. This information consists of lists of coordinates of the apexes of the region: One vertical coordinate is followed by all of the horizontal coordinates that share that vertical coordinate.

Since C does not check for accesses beyond the ends of data structures or arrays, variable size object are easy to manipulate in C programs.

Regions can describe areas that are convex, concave, areas that have holes in them, and even areas that are not contiguous. If you are interested in studying how Macintosh regions are used by QuickDraw routines that fill them in or perform calculations using them, the process underlying operations on regions is called "scan conversion."

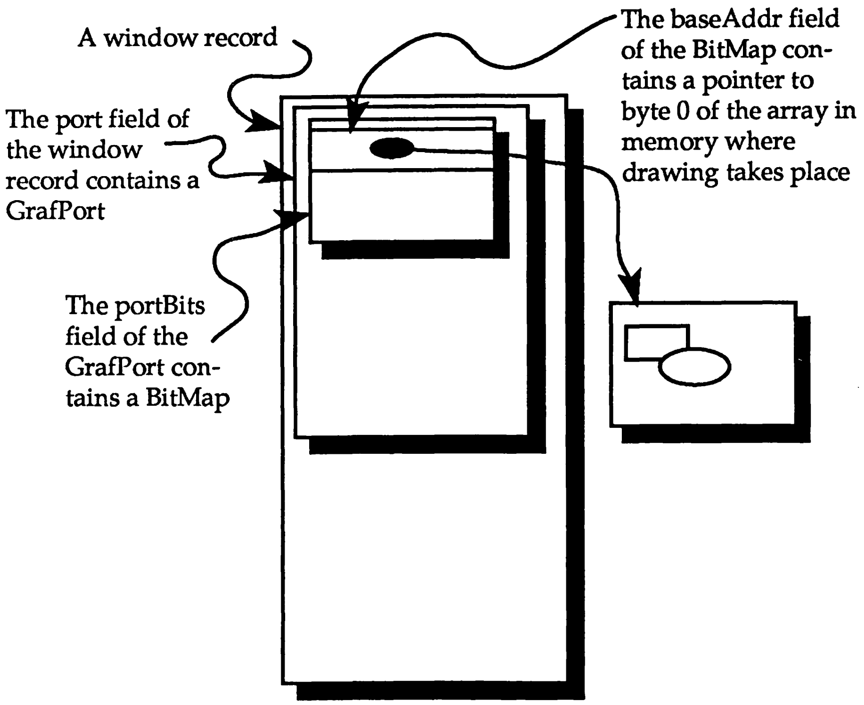
The Window Manager

The Window Manager builds on QuickDraw's `GrafPort` structure. This is the window structure:

```
typedef struct
{    GrafPort port;
     int WindowKind;
     BOOLEAN visible;
     BOOLEAN hilited;
     BOOLEAN goAwayFlag;
     BOOLEAN spareFlag;
     RgnHandle structRgn;
     RgnHandle contRgn;
     RgnHandle updateRgn;
     Handle windowDefProc;
     Handle dataHandle;
     StringHandle titleHandle;
     int titleWidth;
     ControlHandle controlList;
     WindowPeek nextWindow;
     PicHandle windowPic;
} WindowRecord;
```

The window record structure

The window record structure is the highest level of the three structures we have covered in this chapter. The window record subsumes a `GrafPort`, which, in turn, subsumes a `BitMap`, which, in turn points to the actual bits in memory where drawing takes place. The following diagram shows the relationship of these objects in memory:


A window record
The port field of the window record contains a GrafPort
The portBits field of the GrafPort contains a BitMap
The baseAddr field of the BitMap contains a pointer to byte 0 of the array in memory where drawing takes place

Creating the desktop metaphor

The Window Manager manipulates `GrafPort` environments to create the impression of overlapping pieces of paper on a desktop. To do this the Window Manager manipulates the `visRgn` field of the `GrafPort`. Whenever the windows on the Macintosh screen are moved, grown or shuffled, the Window Manager makes sure the `visRgn` is the region of each of the windows the part that would be "visible" if windows are to behave like pieces of paper on a desktop. The `visRgn` is one of two regions associated with each `GrafPort`.

The other region associated with the `GrafPort` is the `clipRgn` (clip region). The purpose of the clip region is to limit the part of the `GrafPort` where drawing takes place. The clip region is used like masking tape, when an application finds that it is more convenient to issue QuickDraw calls to draw an entire object and when it is appropriate for only part of that object to appear on the screen. This usually happens when objects are near the scroll bars of a window, as we shall see in the example program.

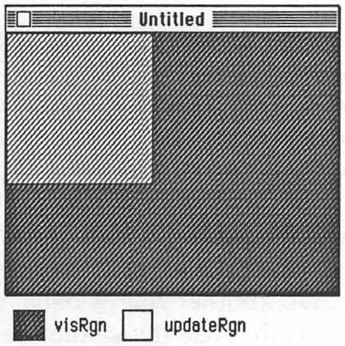
The Window Manager maintains a region, the "update region," associated with each window that describes the part of the window that needs updating. Applications can use the Window Manager routines `InvalRgn` and `InvalRect` to add areas to the update region. In this way the update region collects all the areas that need updating because of both Window Manager related activity and because of the application changing its display.

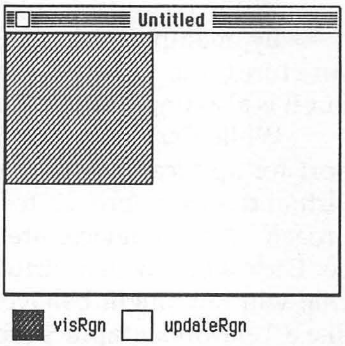
When the update region is not empty, an *update event* is posted. Handling an update event consists of three steps: 1) Calling `BeginUpdate`; 2) Drawing (at least) the objects that fall inside the area that needs updating; 3) Calling `EndUpdate`. Calling `BeginUpdate` causes the Window Manager to temporarily change the `visRgn` of the window being updated to consist of the intersection of the update region and the previous `visRgn`. This leaves the `clipRgn` free for the application to use. Calling `EndUpdate` restores the `visRgn` to its previous value.

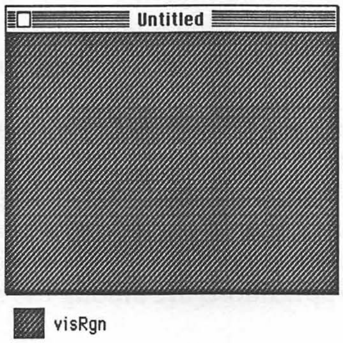
Update events are the most important part of creating interactive Macintosh applications. Few computer systems tell applications running on them which part of the screen needs updating. The Macintosh takes care of this for applications. This is convenient for the user and it is also one important mechanism behind the uniformity of Macintosh user interfaces.

Stepping through an update event

The following diagrams show how regions are manipulated by the application and by the window system while updating a window:







Drawing from applications

If the Macintosh's Window Manager only lets areas that need updating be drawn in, how does an application draw on the screen? Applications need to declare parts of the screen "invalid" before they can be drawn in. Regions can be declared valid as well. This gives applications two options for updating the screen: 1) An application can declare a region invalid, draw in it, and then declare it valid. 2) It can declare a region invalid, update its internal representation of what is on the screen, get an update event, and redraw the the invalid region then. The second approach has the advantage that any other objects lying in the invalid region would be updated as well.

The Active Window

Another important type of event is the "activate event." The activate event means that the window the the event pertains to is now being activated or deactivated (these events come in pairs). Activate events tell an application absolutely nothing about updating. Although activation and updating often happen together, separate events are used to signal activation and updating. The active window is a way for the user to tell where he is. Since one keyboard is used to enter information in possibly a large number of windows, the active window, with the highlighted title-bar, is the one that actually is receiving information.

What windows are not

By manipulating the `visRgn` and `clipRgn` fields of `GrafPort` structures, the Window Manager gives life to the "desktop metaphor." But it is also important to know what windows do not do, and why.

While QuickDraw and the Window Manager provide a lot of support for applications, they stop short of providing virtual devices. The virtual device approach to window systems is another widely used approach. Virtual devices are pretty much what they sound like they might be: Each window in a virtual device system behaves like a "real" device. One window might behave like a vt100 terminal, another might behave like a Tektronix graphics scope. Window systems that use the virtual device approach are common among Unix workstations. The purpose of those window systems is to provide a windowed environment for applications that were written with the assumption that they had the whole terminal to themselves.

Since the Macintosh does not provide virtual devices, it is difficult to port Unix and MS-DOS application to the Macintosh. Such "quick and dirty" ports would look impoverished next to applications that take full advantage of the mouse, menus, windows, dialogs and QuickDraw. Because it isn't convenient to do a poor job of porting a program to the Macintosh, Macintosh applications are among the most polished and easy to use.

POINTS TO CONSIDER

1. Unix programs that read characters from an input and write characters to an output while performing some transform on them are called "filters." Some kinds of programs, like compilers, sort programs and search programs, fit the filter model well. How would you port a typical Unix filter to the Macintosh? What would you use the display for? How would you have the user specify input and output?

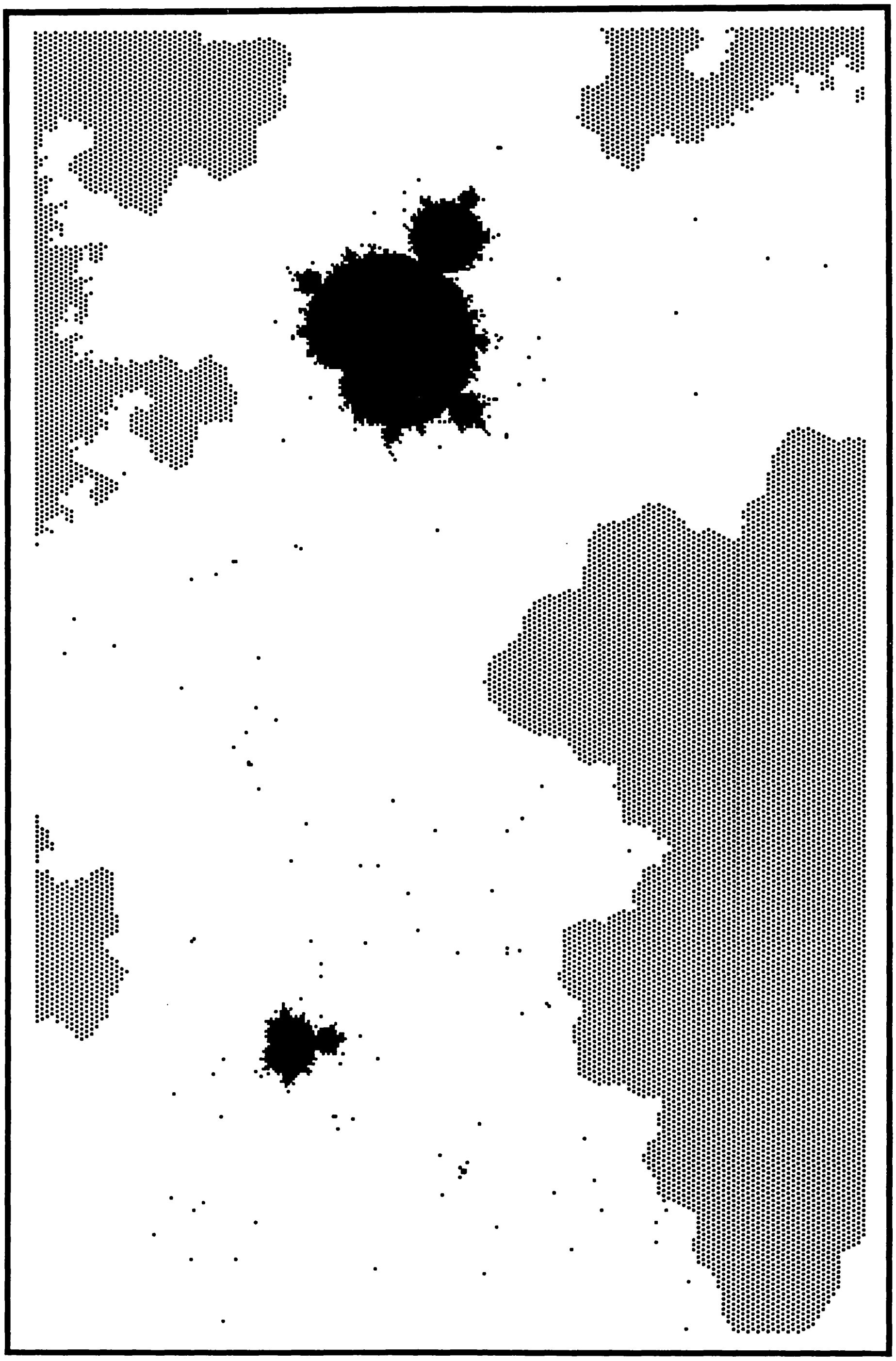
2. Some programs, like text processors, spreadsheets, and project management programs do not fit the filter model well at all. Why is this so? What does this mean to Unix? To the Macintosh?

3. What tasks is the Macintosh user interface style ill suited for? What, if anything, can be done about it?

4. What is the difference between the Macintosh window environment and a "virtual terminal" system? What are the advantages? The disadvantages?

5. On paper, apply the `FrameRect` call to the rectangle depicted near the beginning of this chapter. Where are the framing lines drawn?

6. Take a piece of graph paper and look at the descriptions of QuickDraw routines in the reference section of this book. Walk through the operation of some QuickDraw Toolbox traps by drawing what they would draw on the graph paper.



5

Revolutionary Software, Classical Microcomputer Hardware

- The Macintosh runs some of the most advanced systems software in existence
- Macintosh hardware is relatively simple
- An overview of the 68000 instruction set to help you use a debugger or disassembler
- The Macintosh software developer can count on a large base of installed machines that have capabilities that would cost hundreds of dollars to add to computers that lacked them
- The Macintosh hardware is always hidden behind at least one layer of Toolbox software
- Although the Macintosh is a closed box, the Macintosh is an expandable system
- How Macintosh hardware affects the applications writer (you)

The Macintosh's system software has its roots in the Xerox Alto and the Lisa computers' window-oriented user interfaces and simple, pared-down operating systems. Despite the fact that the Macintosh is a far less expensive machine than its workstation predecessors, it is in many ways more polished and sophisticated. The level of sophistication has to do with the fact that the Macintosh was designed by experienced designers working for a company that knew that to fall slightly short, as Apple did with the Lisa, would be disastrous. The low cost of the Macintosh is due to the simplicity of the Macintosh's hardware.

In this chapter we will look at the Macintosh's hardware. Although it is always hidden beneath a layer of software, the Macintosh's hardware has a strong influence on what a Macintosh is. It would be difficult to move the Macintosh's software over to a machine that did not strongly resemble the Macintosh.

The Macintosh and the Apple][

There are few computers that are as different as the Macintosh and the Apple][. The Apple][is the traditional microcomputer. Inexpensive to build, and hence inexpensive to buy, the Apple][is the mainstay of educational computing in elementary schools, is a workhorse in homes and small businesses, and plays a key role in the hobbyist market — a market it helped establish.

When the Apple][was introduced, software had little to do with its attractiveness to hobbyists who bought it in order to write programs in the Apple]['s 6502 assembly language. At a time when disk controllers cost around a thousand dollars, condemning hobbyists to use cassette tapes to store their work, the Apple][was a real disk-based computer that almost any hobbyist could afford. The Apple][was also the first computer with affordable color graphics. Today, now that color and disk drives are commonplace, the Apple]['s simplicity and low cost have made it the standard for elementary schools and home and small business accounting and word-processing. The Apple][has *evolved* from a machine bought largely due to the value and merits of its hardware to a machine that is bought mostly due to the power and simplicity of the huge library of educational and business software that runs on it.

In the case of the Macintosh, software has had everything to do with the machine's success. The Macintosh has attracted two groups of buyers: The biggest group is novice computer user who never liked obscure command languages and the lack of system-wide integration found in most microcomputers. The Macintosh has also attracted a loyal following among knowledgeable, experienced computer users and programmers because Macintosh software is as sophisticated and powerful as that found on workstation computers that cost many times the price of a Macintosh.

The Macintosh *had* to be much more sophisticated than the Apple][because hardware alone will no longer make a successful computer. Computer engineering has progressed, and more significantly, the potential computer buyer's expectations are much higher now than at the birth of the microcomputer industry. People rightly expect a complete computer system when they buy a microcomputer. The Apple][had many years to evolve into a comprehensive system — the Macintosh had to be born as a system.

Yet the Macintosh and the Apple][have a common heritage and have similarities at the hardware level. Both machines are a carefully chosen collection of parts that deliver features and performance that cost a lot more in other computers. Just as the Apple][was has the least expensive color graphics and disk interfaces available, the Macintosh is still the only microcomputer that has an inexpensive network interface built into every machine. At its introduction, the Macintosh was the only microcomputer to have wholly abandoned the "character-only" display in favor of a bit-map display. The Macintosh uses the same simple, inexpensive floppy-disk interface used in the Apple][. In the Macintosh, this interface is contained in two chips. Every Macintosh comes with a completely indispensable mouse. All of the features of the Macintosh, including the power-supply and monitor electronics, are implemented entirely on two fairly small printed circuit cards. The simplicity of the Macintosh hardware means that it is unlikely that the Macintosh will be outmoded anytime soon. Apple discovered that the Apple][is "forever," but the Macintosh was designed that way.

You can count on Macintosh features

Software developers benefit from the Macintosh's built-in features. Every music program for the Macintosh can count on the Macintosh's sound-generating hardware. Every multi-user database can count on every Macintosh to have the same network hardware built in. Despite the fact that there are far fewer Macintoshes out in the world than there are IBM-PC compatibles, the Macintosh software developer can count on every Macintosh to have the same basic capabilities. For programs that require sound, or a network, or a mouse, or high-speed serial ports, there is a far greater base of Macintoshes capable of running those programs than any other computer. The lack of graphics, sound, and networking standards impede the development of networked applications for other computers. No such obstacles exist for the Macintosh.

The major players on the Macintosh logic board

The logic board of the Macintosh has remarkably few parts on it. Some of these parts perform numerous and/or powerful functions that make the Macintosh hardware what it is. Understanding what these parts do will enable you to know what the Macintosh is capable of.

The Motorola M68000

The Motorola 68000 processor is, of course, central to what a Macintosh is. Unlike microprocessors with smaller address spaces, Macintosh users almost never need to be aware of what kind of processor is executing instructions in their computers. Although you may never need to write any code in assembly language, chances are you will do some debugging with only a disassembler available to tell you what code is being executed. Therefore an overview of the 68000 instruction set will arm you with the knowledge you need to keep track of where your program is when you trace its execution with a debugger. If you are completely unfamiliar with assembly language conventions, you will want a copy of *M68000 16/32-bit Microprocessor Programmer's Reference Manual,* by Motorola, Inc. (Prentice-Hall, publisher).

In the following table, the details of the instructions' operations are left out. Most 68000 instructions do exactly what you would expect them to do from reading the mnemonics. Instructions peculiar to the 68000 are briefly explained. Only the basic operations are listed. Variations of these operations, like immediate, byte, and longword variations are not listed separately.

Move instructions

`MOVE`	Move.
`EXG`	Exchange the contents of two registers.
`SWAP`	Swap words in a register.
`LEA`	Load effective address (perform address arithmetic — load the address, not the data at the address).
`PEA`	Push effective address.

Logic instructions

`AND`	And.
`OR`	Or.
`EOR`	Exclusive or.
`NOT`	Not.
`S`*`cc`*	Set byte according to condition code.
`CLR`	Clear.

Bit manipulation instructions

`BSET`	Test, then set a bit.
`BCLR`	Test, then clear a bit.
`BCHG`	Test, then complement a bit.
`BTST`	Test a bit.
`TAS`	Test a bit, while setting high order bit. Uninterruptable.

Shift instructions

`LSL`	Logical shift left.
`LSR`	Logical shift right.
`ASR`	Arithmetic shift right.
`ROL`	Rotate left.
`ROR`	Rotate right.

Comparison instructions

`TST`	Test.

`CMP`	Compare.
`CHK`	Bounds-check. Causes a trap if it fails.

Arithmetic instructions

`ADD`	Add.
`SUB`	Subtract.
`MUL`	Multiply.
`DIV`	Divide.
`NEG`	Negate.
`EXT`	Sign-extend.

BCD arithmetic

`ABCD`	Add BCD numbers.
`SBCD`	Subtract BCD numbers.
`NBCD`	Negate BCD numbers.

Control transfer instructions

`BRA`	Branch always (up to 64k displacement).
`B`*`cc`*	Branch on condition code (up to 64k displacement).
`BSR`	Branch to subroutine (up to 64k displacement).
`JMP`	Jump.
`JSR`	Jump to subroutine.
`RTE`	Return from exception.
`RTS`	Return from subroutine.
`TRAP`	Initiate exception opportunity. Trap *macros* are not `TRAP` instructions — they are unimplemented instructions.

Stack frame maintenance

`LINK`	Push an address register on the stack; store the stack pointer's value in the saved register; bump the stack pointer to allocate space for local variables.
`UNLK`	Undo a `LINK` instruction.

Processor control

`STOP`	Load status register and stop until an interrupt, exception, or reset occurs.
`RESET`	Reset *external* devices.
`NOP`	Sit one out.

Most of the instructions that move information around and perform logic and arithmetic operations can operate on three different sizes of operands: 8-bit bytes, 16-bit words, and 32-bit "longwords." To specify the size of the operands of an instruction, a suffix is appended to the instruction: `.b` means byte operands, `.w` means word operands, and `.l` means longwords. Word operands are the default, and the 68000 is at its most efficient when dealing with 16-bit words.

The 68000 was designed from a pragmatic point-of-view. It provides 32-bit capabilities in a comparatively simple design. It does not provide the high degree of *orthogonality* found in the PDP-11 or the National Semiconductor 32016. The 68000 cannot apply the same addressing modes to every operand of every instruction. This means that in order to write 68000 code, you will probably have to keep a reference manual handy — not all the instruction variations apply to all the instructions. If you are reading 68000 code, like the disassembled code of one of your C programs, you may never notice the restrictions placed on 68000 instructions,because most instructions and their permitted addressing modes do most of the things a C compiler, or an assembly language programmer, would like done. In most practical situations, the 68000 performs at least as well as its more elegant competitors.

The other specialized parts in the Macintosh are less visible to the programmer than the microprocessor. But these parts, and the functions they perform, may inspire you to develop unusual applications based on untapped abilities in the Macintosh.

The Synertek SY6522 Versatile Interface Adapter

The one small, inexpensive device performs an astounding range of functions with the Macintosh. The VIA is responsible, in whole or in part, for controlling sound generation and sound volume in two separate modes, for controlling disk-drive motor speed, for generating interrupts when keys are pressed or the mouse is moved, and providing an interface to the real-time clock. A shift register on the VIA is used to serialize output to the keyboard and optional keypad and to parallelize input from the keyboard and keypad.

The VIA is involved in so many functions because it can interrupt the processor when interesting events in other parts of the Macintosh have occurred. Interrupts are generated by the VIA when either of two timers on the VIA time out, when the one-second clock ticks, when the keyboard interface requires attention, and when the vertical blanking interval begins. The VIA also controls memory mapping in the Macintosh that temporarily maps the ROM into low memory on power-up so that the initialization code executes.

One Toolbox manager involved in the operation of the VIA is the Task Manager, also known and the Vertical Retrace Manager because it enables code to be run while the electron-gun that paints bits on the video tube is returning to the top of the video tube. The vertical retrace interval of the Macintosh display is useful for applications, such as games, that move a lot of graphics around the screen and want that movement to appear as smooth as possible. By updating the display during the vertical retrace interval, half-updated objects will never be visible to the user.

The Zilog Z8530 Serial Communications Controller

The Zilog SCC controls the two serial ports on the Macintosh. Together with the 26LS30 differential driver and 26LS32 receiver, it implements RS422 serial ports and the AppleTalk network ports. The SCC connectors on the back of the Macintosh may be used as either serial ports or network ports. Interrupts that signal mouse movement are generated by the SCC, but the mouse and keyboard input is handled primarily though the VIA, leaving the SCC to deal with modem, printer, terminal line, and network connection options.

An interesting artifact in the SCC's control register addressing is that word accesses to any of the SCC's registers shifts the system clock's phase by 128 nanoseconds. This "phase-space" access is used at system startup time to synchronize the RAM memory to the processor. Buggy programs that spuriously access phase-space may cause the Macintosh's memory to be clocked out-of-phase with the processor, causing "rain" on the screen. "Rain" — random bits on the screen winking on and off — looks like a hardware problem, and is in most instances the manifestation of a hardware bug. But on the Macintosh rain is almost always a symptom of buggy code.

The Macintosh Toolbox includes a serial driver, a Printing Manager that uses the serial driver to talk to serial printers, and an AppleTalk Manager. All of these modules use the SCC.

The Integrated Woz Machine

The Integrated Woz Machine (IWM) is a single chip that implements the same style of floppy disk interface found in the Apple][. Because of the simplicity of the IWM disk interface, the disk-drive port of the Macintosh can be used as a general purpose high-speed serial port. The Apple Hard Disk 20 connects to the Macintosh through the floppy disk port and uses it simply as a serial connection.

If you are interested in writing a program that uses the IWM port of the Macintosh, some information on the timing and protocols used in the IWM are contained in an Apple Technical Note about the Hard Disk 20. Apple technical notes are available from the Developer Relations department of Apple, and can also be found through users groups.

The NCR SCSI host adapter

Although it doesn't look like much — you can't open the Macintosh up and look at rows of connectors inside, the SCSI adapter found in the Macintosh Plus does provide true, general purpose, expandability for the Macintosh. The SCSI standard was designed to accommodate a wide variety of peripherals. SCSI addressing supports up to 2^{32} separate disk-blocks or other addressable entities in peripherals. Integrated SCSI controllers in disks, tape drives, and other peripherals mean that the Macintosh does not need an expansion bus in order to talk to these peripherals. The SCSI interface allows up to eight peripherals to be connected externally to the Macintosh Plus model.

The Macintosh Plus is the first inexpensive computer to utilize the SCSI standard. As with the Appletalk network, the wide availability of the SCSI interface will spur development of products that take advantage of it.

How closed is it?

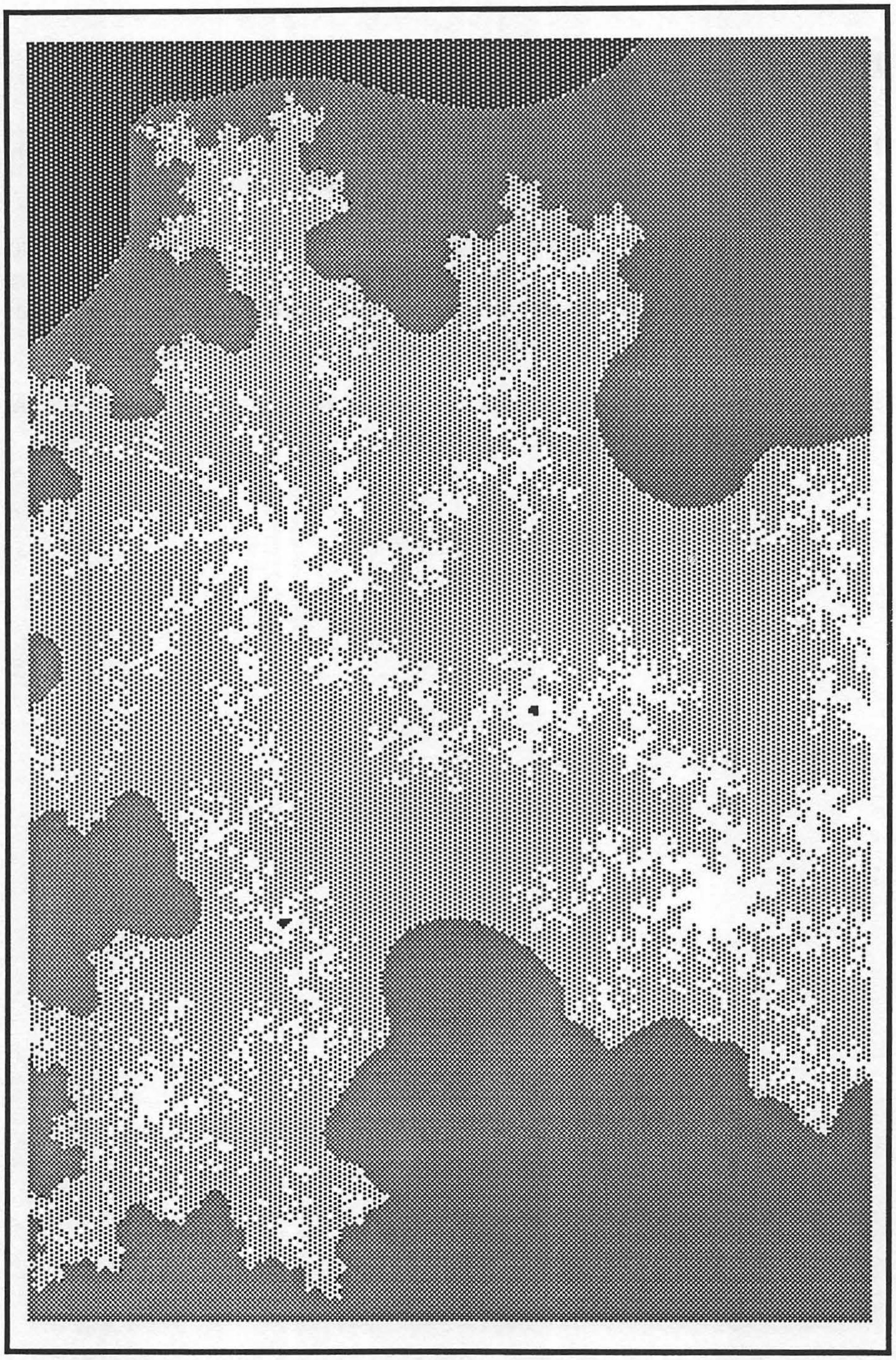
The Macintosh comes in a sealed box. But Macintosh system software always allowed for expansion. It is beyond the scope of this book to discuss writing Macintosh system software, but it is important to note that the Macintosh has software features, like loadable device drivers, that support expansion.

POINTS TO CONSIDER

1. What other computers have a user interface comparable to the Macintosh? How much do they cost in a usable configuration?

2. Because the Macintosh provides a "free" network, network applications are no longer limited to expensive workstation computers. What kind of business applications could make good use of a network? What kind of educational applications could use a network?

3. What kind of peripheral device would be uniquely suited to the Macintosh?



6

The Resource Compiler

- What a resource compiler is
- The reason for using resources
- The extent to which resources permeate Macintosh toolkit software
- A tutorial example of resource compiler use
- A reference that covers the syntax of current resource compilers
- When to use resource *editors* instead of the resource compiler

A consistent way of initializing Macintosh data structures

Resources are part of every well made Macintosh application. They make life easier for the program developer, the program publisher, and the user of the program. The user can change patterns, icons, and other parameters stored in the resource fork to suit his taste if the ones used by the developer do not suit him or her. The program publisher can translate a program's menu entries, window titles, and dialogs and other strings into foreign languages without touching the source code or troubling the developer. The messages a program displays on the screen are more closely related to documentation than to the code in a program, and the resource compiler lets nonprogrammers, such as technical writers, change these parts of a program and cooperate in the development of applications. The way resources benefit the developer is quite down to earth: A change in the resource fork of an application is much easier to make than a change to the code itself. In many cases, the resource compiler does not need to be used to modify a resource fork: Small changes to a resource fork, or changes that need to be made by non-programmers, can be made through the use of a resource editor that interactively edits items in the resource fork of Macintosh files.

Resources are data: A pattern — like the gray pattern the desktop is usually covered by — is simply a data structure stuffed with the bits that determine a pattern. Somehow, the bits that spell out a particular pattern of bits on the screen must be put in the data structures that you have allocated space for in your program. A resource can be used to fill in that data structure. Resources are stored in the resource fork of a Macintosh file, read in by the Resource Manager, and are used by many of the most important and visible parts of the Macintosh system.

Resources and Toolbox Managers

When a program creates a window on the screen, it passes the window manager a pointer to a structure that has been filled with data describing the new window. There are several ways for a program to fill in that structure: The structure could be initialized global data; The structure could be allocated at run-time and filled in, member by member, by a subroutine in the program; Or, it could be filled in by reading a resource from a file's resource fork into the space occupied by the data structure. This last approach is aided by Toolbox routines geared toward looking in the resource forks for resources to be used in initializing data structures.

The Window Manager contains the `GetNewWindow` function which takes as arguments the resource ID (a 16-bit number used to identify resources) of a window resource and a `WindowPtr`, a pointer to a window data structure where the data from that window resource will be deposited. In a single step, using `GetNewWindow`, your program has filled in all the information about the window's size, location, type, and features, and has informed the Window manager that a new window, with these attributes, is to be created.

Nearly every Toolbox manager has one or more routines that use the Resource Manager to simplify initialization of data structures. Some do so overtly, like the Window Manager, and some, like the font manager, use the resource manager internally and have their own way of identifying their resources and retrieving them from resource forks. The font manager,for instance, imposes a special structure on the resource ID of a font, encoding both the font number and the point-size of the font in the resource ID.

Your Own Resources

You aren't limited to using the resource fork to store information in formats that the various Toolbox managers already know about. You can create your own resource types and you can build up composites of existing resource types. The Macintosh system uses some resource types that cannot be defined by resource compiler input. Even 68000 instructions are a kind of resource. The output of any Macintosh compiler is a file with a resource fork full of compiled code. The type for this resource is "CODE."

Example: Designing a dialog

The Dialog Manager makes the most use of resources. A dialog box, which is a kind of window, and which may have controls, editable text, icons, static text, pictures, etc. in it can be described in its entirety in the resource compiler input file. The following resource compiler input describes a dialog box:

```
* A resource compiler template for a dialog box:
Type DLOG
      ,256
      100 100 200 250
      Visible 1 NoGoAway 0
      270

Type DITL
      ,270
      2
      BtnItem Enabled
      60 10  80 70
      Resume
      StatText Disabled
      A sample dialog box
```

Starting at the top of this resource compiler input, there is a comment line preceded by an asterisk. Asterisk is the resource compiler's comment character. Then there is a `Type` keyword that begins the definition of a resource of type DLOG — a dialog box. The ID number of this dialog box is 256, it has the bounds 100 100 200 250, it is visible, its `procId` is 1, its `refCon` is 0, and it has an item list with an ID of 270. The item list describes two items that will appear inside this dialog box: A button labeled "Resume" and a static, uneditable string reading "A sample dialog box."

The ID numbers are the way your application accesses resources, and the way resources are tied together in the resource compiler input file. Except for fonts, which have their own conventions for numbering, your own resources should have IDs that start somewhat above 0 — in the examples here, we will generally start numbering our resources from 256. Resources of different types can reuse resource IDs. That is, the window resource numbered 256 is not going to be confused with the dialog numbered 256. Resource IDs are 16 bit number ad so have to be less than 65535.

Resource Compiler Syntax

The resource compiler compiles a language, like any computer language. Like the best purpose-built languages, the resource compiler's syntax is simple.

Lines with asterisks at the right margin are comments:

```
*This is a resource file comment line
```

Comments on the same line as other resource compiler directives are preceded by two semicolons:

```
A resource compiler statement          ;;another comment
```

Resource compiler lines that need to be folded in order to fit in your editor's windows can use the resource compiler continuation characters which are two plus signs:

```
This is a long resource compiler input, perhaps a long ++
string that would not fit within your editor's window
```

Ascii characters, particularly non-printing control characters may be entered as 8-bit hexadecimal numbers preceded by a backslash:

```
\0A          ;; This is control-J
```

The header of a resource compiler input file

Resource compiler input files start with two lines that tell the resource compiler what name and what file type it's output will have. The first line specifies the output file. If the first line begins with an exclamation point, the output of the resource compiler is added to an existing file. The second line specifies the type, typically `APPL`, for applications, and the creator of the file. The "creator" is not the resource compiler, but the application that the output file is associated with.

```
Sample
APPLMANX
```

The above two lines begin a resource compiler input that would create a file called Sample that has the `APPL` type, and is identified as having been created by MANX. The name of the compiler, in this case the Aztec C compiler by Manx Software, is used as the creator of this file because the primary use of the resource compiler is to add resources to a program emitted by a C compiler.

There are more than 35 different predefined types of resources, and future versions of the resource compiler may define more. Some 27 of these resources types are significant in that extant versions of the resource compiler provide a syntax for specifying the template information that goes into these resources. The rest of the resources are simply read from other files and included into the resource fork of the resource compiler's output. For example, the CODE resource type is used to include a compiler's output in the resource fork of your program. This is how the resources you specify in resource compiler format are combined with the 68000 instructions emitted by the compiler to form the complete resource fork of your program.

The general format of resource specifications

Predefined resources that can be described through resource compiler input take on the following broad format:

```
TYPE [your-type =] type
[file-name!resource-name],ID [(attribute)]
data-for-this-resource
```

Characters in boldface (**TYPE, !, (,), =,** and **,**) are literally part of a resource specification, brackets mean that the enclosed part of a resource specification is optional — brackets are not part of the resource compiler syntax, and words in plain typeface describe what goes in those positions in actual resource specifications. To see where these characters are used in a resource definition match this general description up with the actual specification for a dialog given above.

Window resources

The window manager is supported by a syntax that enables the creation of data to fill in window structures. The order of the items in a window resource specification roughly corresponds to the order of structure members in a window structure. The keywords used in the window manager specification, and in other resource specifications, roughly correspond to the names of the constants defined in the include files associated with the manager that the resource supports.

The following is a window definition commented to explain the resource compiler syntax specific to this type of resource:

```
Type WIND                   ;;WIND specifies a resource for windows
      ,256                  ;;no name, ID is 256
      A Good Window Title   ;;The title to appear in the
                            ;;title bar
      50 50 150 210         ;;top, left, bottom, right
                            ;;coordinates
      Visible NoGoAway      ;;Is visible, no go away box
      0                     ;;ProcID (The function that draws it)
      0                     ;;RefCon (A slot for storing things)
```

Dialogs and item lists

Dialogs and alerts, being a specialized types of windows, have resource compiler syntax similar to windows:

```
Type DLOG                    ;;A Dialog Box
      ,256                   ;;ID #256
      100 100 200 250        ;;The dialog's rectangle
      Visible 1 NoGoAway 0   ;;It's visible, has ProcId, no go away
      270                    ;;ID of its item list
```

Dialogs have an item list, identified by resource ID. The item list describes the features of the dialog box. There are nine types of items that can be included in dialogs, including a user defined type of dialog item. One feature of all dialog item specifications is the ability to determine whether the item will be initially enabled or disabled. If an item is disabled it will not respond to mouse clicks. This enabled or disabled state applies only to the dialog manager and determines whether the dialog manger notifies your application of mouse clicks in dialog items. It does not affect the way those items are displayed. For instance, to give a visual indication that a control is disabled, you would still have to call `HiliteControl`.

```
Type DITL                    ;;A dialog's item list
      ,270                   ;;ID #270
      5                      ;;Five items in the list

      StatText Disabled      ;;Uneditable text, not mouse
                             ;;sensitive
      20 40 35 180           ;;The text's rectangle
      A sample dialog box    ;;The text

      BtnItem Enabled        ;;A button, mouse sensitive
      50 10 70 70            ;;The button's rectangle
      Resume                 ;;The button's label

      ResCItem Enabled       ;;A control item
      70 10 120 26           ;;The rectangle for this control
      257                    ;;The resource ID of the control

      IconItem Disabled      ;;An icon
      40 150 72 182          ;;A 32x32 rectangle
      257                    ;;Resource ID of the icon

      UserItem Disabled      ;;An application's own item
      80 40 120 230          ;;The rectangle it will be
                             ;;displayed in
```

In addition to the `StatText` type of dialog item, there is a similar `EditText` item type that defines a possibly empty string of text that is edited with TextEdit. In addition to `BtnItem`, `RadioItem` and `ChkItem` types are available for defining check-boxes and radio buttons. In addition to the `IconItem` type, a `PictItem` can be specified for including pictures.

Icon Resources

Icons are 32-pixel by 32-pixel entities supported by a couple of QuickDraw calls that look for items in resource forks and draw them. Icons are used where symbols in a typeface like the Cairo font are insufficient and where QuickDraw pictures are overkill. Icons are defined in the the Resource Compiler input file as 32 lines of two 4-digit hex numbers.

```
Type ICON           ;;An icon definition
 ,256               ;;Its resource ID
0F0F 0F0F           ;;32 lines like this one
0F0F 0F0F           ;;to enter each bit of the icon
0F0F 0F0F           ;;in a compact but still fairly
0F0F 0F0F           ;;readable form.
F0F0 F0F0           ;;
F0F0 F0F0           ;;This icon looks like a checkerboard
F0F0 F0F0           ;;with squares 4 pixels on a side.
F0F0 F0F0           ;;
0F0F 0F0F           ;;Since the Macintosh has a one-to-one
0F0F 0F0F           ;;aspect ratio, you can design your
0F0F 0F0F           ;;icon on graph paper before entering
0F0F 0F0F           ;;it in hexadecimal.
F0F0 F0F0
F0F0 F0F0
F0F0 F0F0
F0F0 F0F0
0F0F 0F0F
0F0F 0F0F
0F0F 0F0F
0F0F 0F0F
F0F0 F0F0
F0F0 F0F0
F0F0 F0F0
F0F0 F0F0
0F0F 0F0F
0F0F 0F0F
0F0F 0F0F
0F0F 0F0F
F0F0 F0F0
F0F0 F0F0
F0F0 F0F0
```

Icons can also be defined in the resource compiler file in a list of icons. The resource type of an item list is `ICN#`. The format of an icon list is the same as that of an icon resource specification, except that a count of icons in the list precedes the rest of the data in the specification, and after that, instead of the data for one icon, there is the data for however many there are in the list. Icon lists are used mostly to create desktop icons, which are actually icon lists of two icons.

Cursors

Cursors can be defined in the resource compiler file. A cursor consists of two 16-bit by 16-bit images and a "hot spot." The hot spot is the point inside the cursor that is used in determining exactly where mouse related events have occurred. Cursor resources consist of two lines of 64 hexadecimal digits that define the "data" and "mask" components of the cursor and one line that specifies the location of the hot spot in two 4 digit hexadecimal numbers.

The cursor data is an 16-bit by 16-bit image that defines the basic shape of the cursor. The mask is another such image that describes how that cursor gets displayed. For bits that are set to 1 in the cursor data, they will be displayed as black if the corresponding mask bit is 1, or as the inverse of the pixel under that bit if the mask bit is 0. For 0 bits in the cursor data, if the mask is 1, then that bit will be displayed as white; if the mask bit is 0, then that pixel will be transparent — it will always display the pixel under that part of the cursor unchanged.

The last part of the description of a cursor is the specification of its "hot spot" — the point relative to the upper left hand corner of the cursor that is the actual pixel being pointed at by the cursor. For example, the default arrow cursor has a hot spot of (0,0). The crosshairs style cursor that the Control Panel desk accessory uses has its hot spot at (8,8), in the center of the crosshairs.

There is no more convenient a way to specify a cursor than through resources. If you use more than just the standard arrow cursor in your applications, you will probably define the cursors in the resource fork. The following example shows a cursor somewhat like the I-beam cursor used in most text editing situations:

```
Type CURS
  ,256
  0FF801C000800080008000800080008000800080008000800080008001C00FF8
  0080008000800080008000800080008000800080008000800080008000800080
  0008 0002
```

Patterns

Not surprisingly, patterns are 8-bit by 8-bit patterns. Patterns are used to fill areas of the screen — they are backgrounds. The desktop is generally filled with a fine checkerboard pattern that looks gray. The patterns your application uses to fill in areas of the screen around controls, behind windows, and other areas on the screen are a large factor in determining the look of application. If you use attractive, pleasing patterns, you can create the illusion of texture and depth. Patterns are specified in much the same way that icons and cursors are:

```
Type PAT
```

```
  ,256
  FF00FF00FF00FF00 ;; A pattern of horizontal lines
```

Patterns can also come in pattern lists, similar in form to icon lists. In addition to the components of a pattern specification, a pattern list has a length that is specified before the list of patterns:

```
Type PAT#
  ,256
  2                          ;; Two patterns in this list
  FF00FF00FF00FF00 ;; A pattern of horizontal lines
  AAAAAAAAAAAAAAAA ;; A pattern of vertical lines
```

Pattern lists are useful when you are using so many patterns that you don't want to have to clutter the resource compiler file with lots of separate pattern specifications.

Strings

String resources are important for two reasons: First, string resources allow Macintosh applications to be translated into foreign languages without recompiling the application's code. This means that the people who are experts at translating documentation can translate the program itself. It also means that since the program itself remains undisturbed, there is less likelihood that something might be broken by the translation process. This ease with which properly constructed Macintosh applications can be translated significantly reduces the barriers to entering foreign markets.

The use of string resources enables non-programmers, like technical writers, to compose the messages the user sees. It is easy to see why writers ought to be writing the English that goes into a product and programmers ought to be writing the code.

String resources give you — for free — a valuable tool for reducing the size of your programs. If you do not use all the strings in your program frequently, the seldom used ones can be brought in if and when they are needed, and purged from memory if they are no longer required. Many programmers have been forced to resort to this technique to fit a big powerful program in a microcomputer's memory. The Macintosh provides a uniform way of doing this as well as all the routines that perform resource retrieval and memory management, giving every program writer a solution to the space crunch.

String resources have an added attraction to C programmers: One of the most common errors encountered by beginning Macintosh C programmers — even those who are highly experienced Unix or MS-DOS C programmers — is passing a null-terminated C-style string to a Toolbox routine that is expecting a Pascal string with a length-byte at the beginning. By using string resources, you can keep your strings in a form that the Toolbox will accept, thereby avoiding string conversion errors.

String resources have a simple format: The string corresponding to this resource is typed, on one line, right after the type and resource ID for the string. If you are using a large number of strings, a string list can lump a number of strings under the same resource ID.

```
Type STR                            ;; A string resource
 ,256
This is a string in a resource      ;; A string

Type STR#                           ;; A string list
 ,256
One string                          ;; A list of strings
Followed by another
Until you have run out
of things to\0Dsay.                 ;; A carriage return: \0D
```

Menus

Menus are a close relation of string resources. Menus contain labels, in English, that correspond to commands. Many of the reasons you would want to change or translate string resources also apply to menus.

A menu specification consists of the type and resource ID followed by a list of menu items. If you want to specify several menus at once, you can omit the "`Type MENU`" line, skip a line between menu specifications and just give the resource ID of the next menu. Special characteristics of menu items, such as whether they are disabled and displayed "dimmed," can be specified in the resource compiler file using special characters. They are the same special characters used in the `AppendMenu` routine:

! Makes the next character the "mark" character for the current item.

< Set character style in combination with the following:
`B` - bold
`U` - underline
`I` - italic
`O` - outline
`S` - shadow

/ Makes the next character a keyboard equivalent. It will be displayed with a "cloverleaf" symbol next to it.

(Disables the menu item

The hyphen, when used in specifying a menu item, creates a horizontal line instead of a hyphen character. The hyphen, when used in combination with the open-parenthesis creates a horizontal line that is disabled, and so it is displayed dimmed. The effect is that a horizontal dotted line that does not respond to the mouse is displayed in place of a menu item. Such a line, which is usually left disabled throughout the running of an application, separates items on the same menu, the way the "undo" item is separated form the rest of the editing commands on MacWrite's edit menu.

```
Type MENU                ;; A menu resource
 ,256
\14                      ;; The menu title: the apple symbol
About that example...    ;; Program information, usually

 ,257
File                     ;; The file menu
Quit                     ;; The label for the "quit" command

 ,258
Edit                     ;; The edit menu
Undo   /Z                ;; The label for the "undo" command
(-                       ;; The "dotted line"
Cut/X                    ;; The label for the "cut" command
Copy/C                   ;; The label for the "copy" command
Paste/V                  ;; The label for the "paste" command
```

Control Resources

Like menus, controls provide an obvious and rapid way for the user to issue commands to an application. Controls, unlike menus, provide visual and tactile feedback to the user. Macintosh controls are like physical controls in this respect. The steering wheel in your car is a control that you use to command the front wheels of your car to turn. When you look at the wheel, or when you feel how far over your hands have moved with the wheel, you can tell how far the front wheels have turned. When a user moves his mouse over a control he can see the control changing, and the act of moving the mouse gives a physical feedback as well.

There are four kinds of predefined controls, each referred to by a different `DefProc`. The `DefProc` is a definition procedure that actually draws the control. The following table shows the constants that refer to the definition procedures and the kinds of controls that each draws:

DefProc	**Control type**
0	Simple button with title in the button
1	Check box, with tile next to it
2	Radio button, with title next to it
16	Scroll bar, same `DefProc` for vertical and horizontal

The most commonly used controls are scroll bars and buttons. Buttons are usually part of a dialog or alert, but scroll bars are frequently used in an applications windows to enable users to move and scroll over a document and need to be defined separately from any dialog. Here is the syntax of the specification of control resources:

```
Type CNTL                ;; A control resource
  ,256                   ;; Resource ID is 256
  vertical scroll bar    ;; The title, invisible for scroll bars
  -1 241 157 257         ;; The bounds rectangle, window relative
  Visible                ;; The scroll bar is initially visible
  16                     ;; The DefProc
  0                      ;; The RefCon
  0 50 0                 ;; initial value, minimum, maximum
```

Finder Resources

Finder resources are the way the Finder finds the icons that represent your application inside your application's resource fork. Three kinds of resources are involved in providing the finder with icons. The first of these is icon lists. Icon lists are used in place of simple icons, because the finder needs two icon resources to make one desktop icon. The first icon in the list describes the appearance of the icon, and the second icon describes the "shadow" of the icon — the filled in shape of the icon. These pairs of icons are grouped in icon lists. The second type of resource used to keep track of finder resources is the file reference. The file reference resource matches icons up with file types. The third kind of resource used is the bundle resource. Bundle resources do two things: they list icon and file reference resources that make up the rest of the set of finder resources for an application, and they are used to assign local IDs to finder resources, so that the finder can change the resource IDs of finder resource to keep them unique. The local IDs are used in the file reference resource to refer to the icon lists because the finder will not change these resource IDs.

Icon lists, which were covered in the part of this chapter that describes icon resources, are to icon resources what string lists are to strings and pattern lists to patterns. Here is the syntax of the file reference and bundle resources:

```
Type FREF    ;; A file reference resource
 ,256        ;; The ID is 256
 APPL 0      ;; Application files get the icon with local ID 0

Type BNDL    ;; A bundle resource
 ,256        ;; The ID is 256
 MYPG 0      ;; The owner is MYPG
 2           ;; There are two items in this bundle
 ICN# 1      ;; There is one icon list in this bundle
 0 256       ;; Its resource ID of 256 is given a local ID of 0
 FREF 1      ;; There is one file refernce in this bundle
```

```
0 256       ;; Its resource ID of 256 is given a local ID of 0
```

The owner of a bundle is identified the same way an application is identified. If the output of this resource compiler file is an application, then the owner of the bundle will be identified with the same four letters that are used in the heading of the resource compiler file to associate the output with a particular application.

Including resources from other files

If you are using the resource compiler to create an application, you will need the output of your compiler — the code resource — included in the resource fork of the resource compiler's output. Fonts are typically imported from other resource files as well because it would be more than tedious to type in a font in hexadecimal for the resource compiler. Fonts are typically created with font editors that deposit a resource file full of the fonts as their output. Somehow you will need to merge these resource files together into a finished application.

The resource specifications for code, driver, and font resources do just that — they bring these resources in from other files. Their syntax consists solely of the resource type line followed by the resource ID line. But in addition to the resource ID, you will find on the same line the name of the file the data is to be found in and the name of the resource. In the case of fonts, a number of files can be specified for inclusion to make up a single font.

Here is the syntax of font, code and driver resource specifications:

```
Type FONT
 !Cambridge,30@0          ;; Name only, no file, size is 0
 Cambridge9,30@9          ;; Cambridge 9 point from file "Cambridge9"
 Cambridge12,30@12        ;; 12 point from "Cambridge12"
 Cambridge18,30@18        ;; 18 point from "Cambridge18"
 Cambridge24,30@24        ;; 24 point from "Cambridge24"

Type CODE                 ;; A code resource
 MyProgram.code,0         ;; The code is in the file "MyProgram.code"

Type DRVR                 ;; A driver resource
 MyDriver!MyDriver,256    ;; The driver is called Mydriver and
                          ;; is in the file "MyDriver"
```

The resource IDs for code resources are ignored, the resource compiler generates resource IDs beginning at 0 for each segment of code included. Font resource IDs have two parts, one is the font number, and it is put in the high byte of a font resource ID, and the other part is the point size, which is put in the low byte of a font resource ID.

Defining new kinds of resources

Resources fill in data structures, and it would be nice to be able to fill in your own data structures with resources as well as the data structures that are predefined by Toolbox software. The resource compiler provides three resource types that have no predefined use. They exist for you to use for your own purposes.

The most general of these free-form resource types is the general resource. The general resource type is formed both the data that makes up the resource and information about the kind of data. Data type information is specified by a period followed by a single letter. The following directives can be used to tell the resource compiler what kinds of data make up a general resource:

Directive	Data type
`.P`	Pascal string(s), one to a line
`.S`	Character string(s) without a length byte, one to a line
`.I`	Integers (C type "int")
`.L`	Long integers (C type "long")
`.H`	Any number of bytes of data entered in hexadecimal
`.B`	Bytes from another file

This is example of the syntax of general resources:

```
Type GNRL                             ;; A general resource
 ,256                                 ;; The ID is 256
 .P                                   ;; Pascal strings follow...
One Pascal style string               ;; The length byte gets added
Another one                           ;;   automatically
 .S                                   ;; Character strings...
A character string                    ;; A character string
One that is null terminated\00        ;; A C style string
 .I                                   ;; 16 bit integers follow...
 17
 256
 77
 .L                                   ;; 32 bit integers follow...
 68000
 6610777
 .H                                   ;; Hex data follows...
 FF00FF00FF00
 AAAA
 AA
 .B                                   ;; Bytes form a file
 ADataFile 128 1024                   ;; The file id called "ADataFile"
                                      ;; The byte count is 128
                                      ;; The length is 1k
```

Two less powerful free-form resources are also provided: The hexadecimal type and the any bytes type. These two types do what two parts of the general resource do. The hexadecimal type has a format identical to the part of a general resource specification following a .H and an any bytes resource is specified that same way the part of a general resource following a .S is specified. Here is the syntax of these two resource type specifications:

```
Type HEXA          ;; A hexadecimal resource
 ,256              ;; The ID is 256
 FF00FF00          ;; Some data in hexadecimal
 AAAAAAAA

Type ANYB          ;; An any bytes resource
 WhereFrom,256     ;; The file is "WhereFrom," The ID is 256
 256 512           ;; 256 bytes extracted at an offset of 512
```

In addition to creating new resource formats and entering free format resources, the resource compiler lets you define your own resource types. Take another look at the general format for resource specifications near the beginning of this chapter. On the first line of any resource specification you can specify a new resource type that inherits the properties of an existing resource type. This is most often used with the free format resource types. Creating new resource formats usually means you have a corresponding data structure to fill with resource data. Creating new resources types serves to associate a particular free-format resource with a particular type of data structure.

Resource Editors

Resource editors are programs that create resources, like fonts and icons, interactively. The most important resource editor is REdit, which can edit a wide variety of resources. Specialized resource editors that edit only fonts and icons also exist.

The most readily available example of resource editing is the desktop pattern editor in the Control Panel desk accessory. If you don't have a real resource editor handy, the Control Panel illustrates the general nature of resource editors: You manipulate a visual representation of a resource, such as an enlarged version of a pattern, by pointing and clicking with the mouse. When you are done, the resource fork of the file that you have applied the resource editor to is modified to reflect the editing you have done.

For some jobs, resource editors are the only reasonable tool to use: It would be painfully laborious to create a font resource with the resource compiler, but with a resource editor, the same task becomes much easier and much less prone to error. Complex dialogs are best composed with a resource editor, so you can see what the user will see without having to compile and run your application (which may not be completely written when you sit down to design the dialogs).

The disadvantage of resource editors is exactly their advantage: you have to interact with them. That is fine when you want instant feedback about the look of a font or icon, but it is an inconvenience if all you want to do is combine the code resources your compiler has created with a few string resources. Even in an application that requires complex resources, you will not be changing them every time you compile, so using the resource editor to create the finished application file is not nearly as convenient as letting the resource compiler create the application without your intervention. The solution to the dilemma of whether to use the powerful resource editors, or the convenient compiler is to use both: A resource editor can be used to modify resources when they need to change, and the resource compiler simply combines the code resources with the dialogs, fonts, patterns, and strings the you have composed interactively with a resource editor.

Benefits

Using resources and the Resource Manager for initializing data structures is convenient both in terms of the number of steps required to program in that initialization and in terms of the time it takes to modify resources. No recompilation of the program is required — only the resource compiler needs to be run. Resources can reduce the cost of producing a foreign language version of a program. Resources let advanced users modify your program without added effort to provide such facilities on your part. Due to the convenience of resources and due to a program-writer's responsibility to provide as much flexibility as possible, the program-writer should use resources liberally.

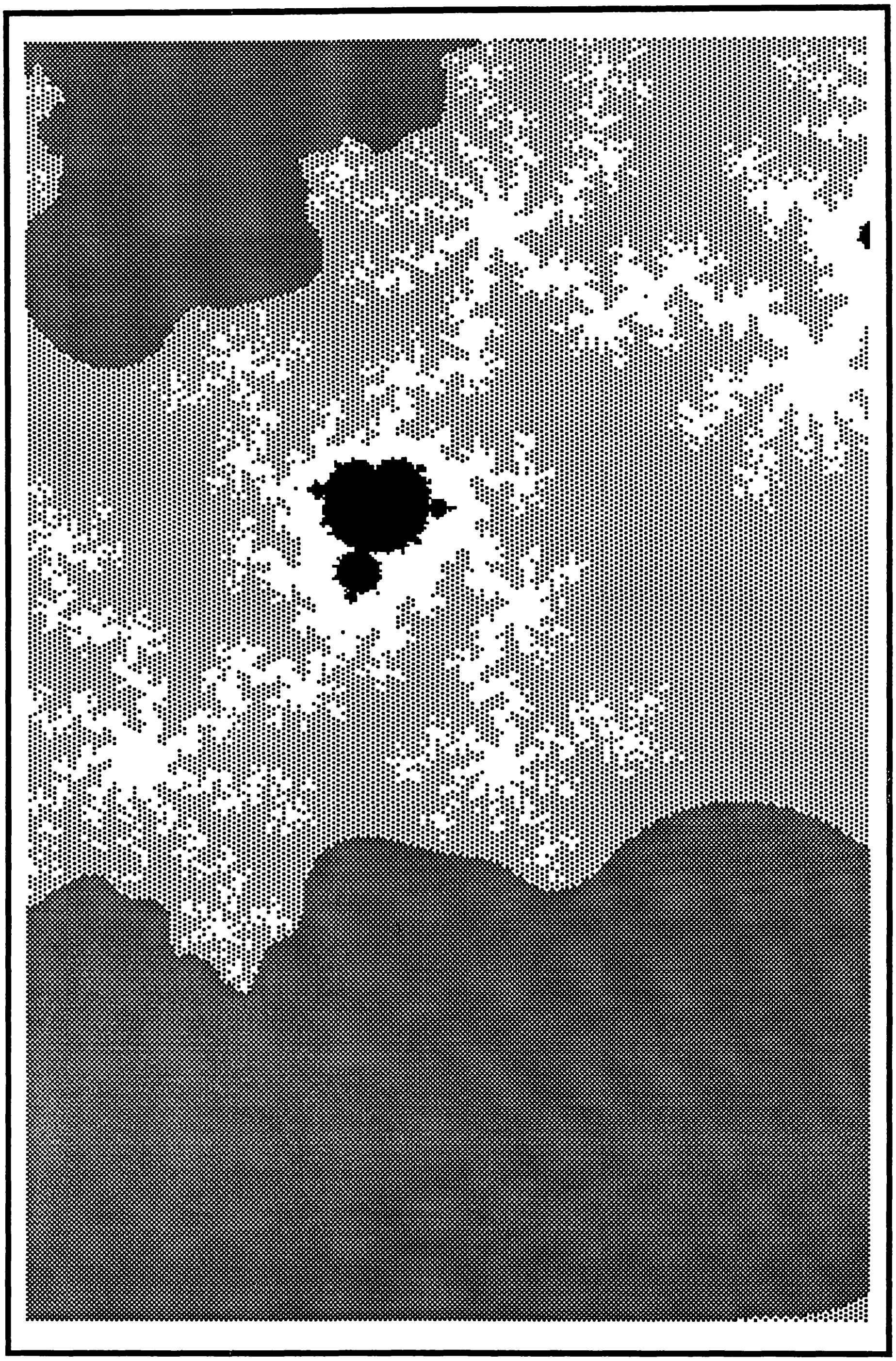
POINTS TO CONSIDER

1. How can resources be used to distribute the work of creating a program between engineering and non-engineering staff?

2. How can resources be used to enable a user of your programs to customize them in a meaningful way?

3. There are two major types of font design tools. What are they, and why are they so different?

4. What kinds of configuration settings can you think of? What would be the best way to present them to the user? What would be the best way to store them for future use? What settings should be stored in an application's resource fork? In a document's resource fork?



7

The Internal Structure of a Macintosh Application

- Place a window on the screen with "Hello World" in the title-bar
- Enable the user to move that window around the screen
- Enable the user to change the size of the window
- Create menus
- Respond to a user's menu selections
- Interacting with scroll bars and other controls

The evolution of an example

This chapter presents an example of a Macintosh application. This application is evolved through four steps. By the end of this chapter, the example program has successfully used the Toolbox to meet the standards of the better commercial Macintosh programs.

Step 1: Getting started

The following program puts a window on the Macintosh's screen, with "Hello World" in the title bar. When you click on the mouse, the program goes away and you are returned to the finder. Like a sumo wrestling match, there are a lot of preliminaries for a short bit of action. In a Unix environment, the program to display "Hello world" on your terminal's screen could be much shorter. It might consist only of the "`main`" procedure, with a call to `printf`, the Unix standard formatted printing routine.

The concepts embodied in the Unix system make it easy to construct simple programs — but difficult to construct visually powerful applications. In the Macintosh environment the opposite is true: Almost every Macintosh applications has a powerful, easy to use, and pleasing to look at visual interface because the Macintosh has all the parts of such an interface built right in. This is great for professional software developer. They can spend their time on the guts of their programs and be sure that the appearance their program will have can be just as polished and professional as those from the biggest software companies. By contrast, Unix lacks all but the most rudimentary tools for creating visually appealing programs.

The richness of the Macintosh user interface toolkit is, at least at first glance, not so good for the person writing software for their own consumption. To get anything at all done, they have to achieve a fairly high degree of polish in their programs. Achieving that level of polish takes about two pages of code just to get things moving. Here are those pages of code:

C code for the hello world program:

```
#include <Quickdraw.h>
#include <WindowMgr.h>
#include <ControlMgr.h>
#include <EventMgr.h>
#include <DeskMgr.h>
#include <MenuMgr.h>

WindowRecord w_record;   /* storage for window info */
WindowPtr hello_window;  /* a pointer to that storage */

main()
{
      init_process();          /* do all the initialization */
      make_window();
      event_loop();
}

/* Do all the random initialization things
 */
init_process()
{
      init_mgrs();
      FlushEvents(everyEvent, 0);
}

/* Do the right thing for most applications: Call the Toolbox
 * initialization routines.
 */
init_mgrs()
{
      InitGraf(&thePort);
```

```
        InitFonts();
        InitWindows();
        InitCursor();
        OpenResFile("\pHelloworld.rsrc");
}

event_loop()
{
        EventRecord event;

        do /* Nothing */ ;
        while (!GetNextEvent(mDownMask,&event));
        ExitToShell();
}

/* Make a window */
make_window()
{
        hello_window = GetNewWindow(256, &w_record,
              (WindowPtr)-1L);
        ShowWindow(hello_window);
}
```

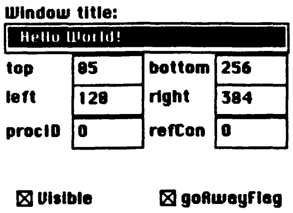
Resources for the hello world program

There is an important and anomalous line in the program:

```
OpenResFile("\pHelloworld.rsrc");
```

This line breaks one of the rules of good Macintosh programming: It incorporates a string directly into the source of your program. It does so in order to make it easier to run this program in the LightspeedC environment. Because of this line you won't have to use the resource editor to paste your program together. Instead, this line causes the resources, such as the description of the window you are creating in the program, to be read in from the file "Helloworld.rsrc."

Let's step through what it takes to create this resource file. Using ResEdit, the most widely used resource editor, we need to do two things. (See the ResEdit documentation for detailed instructions on how to use the program itself.) First, we make a new WIND resource, filling it with the following information:



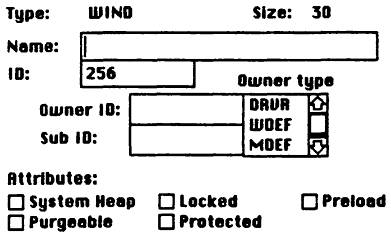
Window title:
Hello World!

top	85	bottom	256
left	128	right	384
procID	0	refCon	0

☒ Visible ☒ goAwayFlag

This fills a window resource with the dimensions of the window, which type of window frame we want to use (determined by the window definition procID), whether the window is visible, and whether the go-away box is drawn in the window's title bar.

Then, using the Get Info command to bring up a window that contains general information about the resource, we change the resource number to 256, the value we use in our program:



Type: WIND Size: 30
Name:
ID: 256
Owner type
Owner ID:
Sub ID:
DRVR
WDEF
MDEF
Attributes:
☐ System Heap ☐ Locked ☐ Preload
☐ Purgeable ☐ Protected

We then save the results as "Helloworld.rsrc," the name of the file we open for searching for resources.

The edit/compile/run cycle

You can use this program to get used to your compiler's development cycle. All compilers come with example programs, and you might find this program, or those examples, useful if you want to jump right in and do some programming. The Macintosh is an immensely satisfying machine when you run a program you have just compiled.

If you have already done that, or if you want to know about the mechanisms behind this program before you experiment, we will pick it apart and explain each piece in detail here. As you read the description of the sample program that follows, go back every now and then and re-read the part of the example that is being described.

Initializing Toolbox managers

First, there is a fairly long list of "include" files. Since we call a number of initialization routines, each from a different part of the Toolbox, we need at least as many include files. We also use defined data types from these include files.

A look at each of these initialization routines yields a rough idea of what parts of the Toolbox are involved in putting a window on the screen:

First there is a call that goes: `InitGraf(&thePort)`. `InitGraf` is in the QuickDraw part of the Toolbox. `InitGraf` initializes QuickDraw, and `thePort` is a Toolbox global symbol that consists of enough storage to hold Quickdraw's global variables. `InitGraf` is called once and only once at the beginning of every Macintosh application. Everything that touches that Macintosh screen, and that is just about everything, relies on QuickDraw to draw on the screen, so before anything else can be accomplished, QuickDraw has to be ready.

Next, there is a call to `InitFonts`, without any parameters. The object of this program is to put the phrase "Hello World!" in the title-bar of a window. Putting any characters on the screen involves the Font Manager part of the toolkit. Initializing the Font Manager by calling `InitFonts` means that the font manager will be ready to go find the systems font for use in the title-bar of our window.

Next, the window manager itself is initialized with a call to `InitWindows`. This principally does two things: The `GrafPort` that the Window Manager works in is created and the desktop is drawn. The `GrafPort` is the data structure that holds information such as the part of memory that is to be drawn in, the current font, information about the "pen," etc. You can see just when in the course of an application this call is made: When you start a program, one of the first things that happens is the replacement of the Finder's desktop which displays disk and file icons with an empty desktop with an empty menu-bar over it. This is the result of calling `InitWindows`.

Lastly `InitCursor` is called. This is a call to the QuickDraw part of the Toolbox. `InitCursor` makes sure that the cursor that appears on your screen is the arrow pointing up and to the left, and that the cursor is visible.

The initialization part of this program is now complete. The number of initialization routines called in this minimal program is one of the effects of the flexibility of the Macintosh toolkit. Since we put text on the screen, but we don't change it once it gets there, we don't need to involve TextEdit — the part of the Toolbox that provides a means of entering and changing text on the screen. We also didn't use sound, memory management, dialog boxes or the printer, and so none of the parts of the system or Toolbox that manage those facilities needed to be initialized. If we didn't have such precise control over the parts of the Toolbox we initialize to prepare to use, every program would have to wait for Toolbox managers to prepare themselves for nothing. That would waste time, and, on the 128k Macintosh, it would be a significant waste of space taken up by memory allocated to data structures that those unused Toolbox managers require.

Creating a window

The first significant thing this sample program does is create a window. This is done by creating a data structure for the information about that window, with the initial information coming from the window resource we have defined. The program then draws the window. Because the Toolbox routines that manage windows are geared toward updating their contents during the course of the interactive use of a program, there is no "draw this window for the first time" routine. Instead we tell the Toolbox to set aside all the information that would cause that window to be drawn, and then we call the routines that update the screen on the basis of this set-aside information. It takes two calls to the Window Manager part of the Toolbox to do this:

First, `GetNewWindow` is called with three parameters: a "window ID," a pointer to memory where the window structure will be stored, and a "behind" parameter that points to the window that we want to put our window behind. The window ID is the ID we gave to the window resource defined in the RMaker file above. The second parameter is a pointer to a window structure (of type `WindowRecord`). It points to the window structure declared at the top of the program source. This is the chunk of memory the window manager will use to store things about our "Hello World" window. The last parameter is also a pointer to a window structure. In this case, the value is -1, which indicates that the window we are creating should be placed in front of all the other windows on the screen.

That -1 is used as an "invalid" pointer value probably rubs some experienced C programmers the wrong way. Using -1 this way relies on the binary representation of -1 being a 32 bit word with all the bits set to 1, and on that memory location lying outside the address space of the 68000 processor. On many machines that Unix runs on -1 is a perfectly good address and it is bad practice to use anything other than 0 as an invalid pointer in the Unix environment. But since the Macintosh environment is an indivisible whole that cannot be separated from the Macintosh hardware, it is permissible to take into account the characteristics of the 68000 processor and the Macintosh architecture in selecting special pointer values that have meanings other than being the addresses of memory locations.

The second call in the set of calls that that draws the "Hello World" window is a call to the `ShowWindow` routine. This Window Manager routine takes as a parameter a pointer to the window that is to be drawn. The result of this call is that the frame of the window — the part the Window Manager itself knows how to draw — is drawn on the screen. An update event is also generated so that if the program itself had anything to draw in the window, an event directing it to do would be in the event queue.

The event loop

At this point in the execution of this program the "Hello World!" window has appeared on the screen. The program then waits for a mouse click and then exits. The loop that waits for the mouse button to be pushed is the heart of the program: it is the event loop.

This program has a simple event loop. All we are looking for is the event of the mouse button being pressed. We use the "event mask" to tell `GetNextEvent` that we are only interested in the mouse button being pressed. The "event mask" is a kind of "bit mask," so called because it is figuratively placed over the bits that represent all of the various kinds of events that could occur, revealing only those that the mask will allow through. The predefined event mask called `mDownMask` reveals only mouse button presses. When `GetNextEvent` returns a value other than 0, an event has occurred. In this program the only event that can can be reported is a mouse button press, so when `GetNextEvent` returns something other than 0, we don't bother checking the data-structure that holds information about the event — we can be sure the mouse button was pressed and it is time to exit.

Your programs will call `GetNextEvent` frequently. To those of you familiar with C programming in the Unix environment all this "polling," waiting for something to happen, may seem like a waste of processor resources. On the Macintosh, polling for events serves an important purpose: before your program is informed of the presence or absence of events it is interested in, the Macintosh system software takes a look at the events, if any, that have occurred. If the system software wants to handle an event it does so before control is returned to your program. Event polling serves to divide the processing resources of the Macintosh between your program and the Macintosh system software (such as desk accessories that need to be updated periodically).

Step 2: Building up

Now we are ready to build on this first program. If you had trouble with your compiler's edit-compile-run cycle you should review your compiler's documentation — we will be adding to this program and you might want to see what happens each step of the way.

The first thing we will add is a proper event loop. The event we will handle will be the mouse-down event. Now, instead of waiting for a mouse button press, the program will exit when the mouse button is pressed and then let go in the "go-away box" of the window.

This version of the program uses a resource file identical to the first version.

C code for the second version of our hello world program:

```
#include <Quickdraw.h>
#include <WindowMgr.h>
#include <ControlMgr.h>
#include <EventMgr.h>
#include <DeskMgr.h>
#include <MenuMgr.h>

WindowRecord w_record;
WindowPtr hello_window;

#define     mk_long(x)    (*((long *)&(x)))

main()
{
     init_process();     /* do all the initialization */
     make_window();
```

```
      event_loop();
}

/* Do all the random initialization things
 */
init_process()
{
      init_mgrs();
      FlushEvents(everyEvent, 0);
}

/* Do the right thing for most applications: Call the Toolbox
 * initialization routines.
 */
init_mgrs()
{
      InitGraf(&thePort);
      InitFonts();
      InitWindows();
      InitCursor();
      OpenResFile("\pHelloworld.rsrc");
}

/* Read window information from the resource branch into a window
 * structure
 */
make_window()
{
      hello_window = GetNewWindow(256, &w_record, -1L);
      ShowWindow(hello_window);
}

/* Get an event, switch on its type, and perform the appropriate
 * action
 */
event_loop()
{
      EventRecord event;

      while (1)
      {     GetNextEvent(everyEvent, &event);
            switch(event.what)
            {     case nullEvent:
                        break;
                  case mouseDown:
                        do_mouse_down(&event);
                  case mouseUp:
                  case keyDown:
                  case keyUp:
                  case autoKey:
                  case updateEvt:
                  case diskEvt:
                  case activateEvt:
                  case networkEvt:
```

```
                case driverEvt:
                case applEvt:
                case app2Evt:
                case app3Evt:
                case app4Evt:
                default:
                     break;
          }
     }
}

/* Find out where a mouse-down event has occurred and do what ought
 * to be done for that location on the desktop
 */
do_mouse_down(eventp)
     EventRecord *eventp;
{
     WindowPtr windowp;

     switch(FindWindow(mk_long(eventp->where), &windowp))
     {    case inDesk:
          case inMenuBar:
          case inSysWindow:
          case inContent:
          case inDrag:
          case inGrow:
               break;
          case inGoAway:
               if (TrackGoAway(windowp,
                    mk_long(eventp->where)))
                         ExitToShell();
               break;
          default:
               break;
     }
}
```

Beefing up the event loop

The most important changes here are the addition of a switch statement in the event loop, and another routine, consisting mostly of a switch statement, that distinguishes between and handles the various kinds of mouse-down events.

The switch statement in the `event_loop` routine has labels for all 15 different kinds of events, even though we are only handling the mouse-down event. The labels were included to elicit a feel for the number of different events that can take place. In the `do_mouse_down` routine, all the different kinds of mouse-down events also all have their labels included in the switch statement. This lets you see that while there are only 15 distinct event types (four of which are reserved for your application to use) there is a rich set of mouse-down events, distinguished by where on the Macintosh screen they occurred. The event mask has also been changed to allow any event through. This is so the event queue does not fill up with events that we have no interest in, instead we let them fall though our switch statement.

It's event driven

If you have compiled this program, you can see how control is passed back and forth between the Macintosh system and your program: When you press the mouse button while the mouse cursor is in the go-away box, your program gets the mouse-down event, and finds out (through the use of a Window Manager routine) that the mouse button was pressed in the go-away box. Control is passed back to the Macintosh Toolbox when the program calls `TrackGoAWay` and is retained by that routine until the mouse button is released. The window's go-away box reflects whether the cursor is still in the box through highlighting. If the cursor remains in the go-away box, the box is highlighted. If the cursor is moved out of the go-away box, the box is unhighlighted. The return value of `TrackGoAway` reflects the final state of the mouse cursor: If it was inside the go-away box when the button was lifted, a non-zero value is returned indicating that the window should be disposed of. If the mouse-button was lifted outside the go-away box, `TrackGoAway` returns 0, indicating that the user had second thoughts about extinguishing the window.

This give-and-take between your application and the Macintosh Toolbox software will be echoed throughout the evolution of this example program.

Step 3: Growth and movement

The next step in the evolution of this example program will bring us two steps closer to presenting a complete set of controls over the size and placement of windows that the user can manipulate. We will allow the user to move the window and change its size.

```
#include <Quickdraw.h>
#include <WindowMgr.h>
#include <ControlMgr.h>
#include <EventMgr.h>
#include <DeskMgr.h>
#include <MenuMgr.h>
#include <ToolboxUtil.h>

GrafPtr w_port;
WindowRecord w_record;
WindowPtr hello_window;
Rect drag_rect, grow_bounds;

#define mk_long(x)    (*((long *)&(x)))

main()
{
    init_process();  /* do all the initialization */
    make_window();
    event_loop();
}

/* Do all the right initialization things
 */
init_process()
{
    init_mgrs();
    set_parameters();
}

/* Do the right thing for most applications: Call the Toolbox
 * initialization routines.
 */
init_mgrs()
{
    InitGraf(&thePort);
    InitFonts();
    FlushEvents(everyEvent, 0);
    InitWindows();
    InitCursor();
    OpenResFile("\pHelloworld.rsrc");
}

/* Set parameters based on screen size, etc. */
set_parameters()
{
    drag_rect = thePort->portRect;
    SetRect(&grow_bounds, 64, 64, thePort->portRect.right,
        thePort->portRect.bottom);
}

/* Read window information from the resource branch into a window
 * structure
 */
make_window()
{
    hello_window = GetNewWindow(256, &w_record, -1L);
}

/* Get an event, switch on its type, and perform the appropriate
 * action
 */
event_loop()
{
    EventRecord my_event;
    Boolean valid;

    while (1)
    {   SystemTask();
        valid = GetNextEvent(everyEvent,&my_event);
        if (!valid) continue;
        switch(my_event.what)
        {   case nullEvent:
                break;
            case mouseDown:
                do_mouse_down(&my_event);
                break;
            case mouseUp:
            case keyDown:
            case keyUp:
            case autoKey:
                break;
            case updateEvt:
                do_update(&my_event);
                break;
            case diskEvt:
                break;
            case activateEvt:
                do_activate(&my_event);
                break;
            case networkEvt:
            case driverEvt:
            case app1Evt:
            case app2Evt:
            case app3Evt:
            case app4Evt:
            default:
                break;
        }
    }
}

/* Find out where a mouse-down event has occurred and do
 * what ought to be done for that location
 */
do_mouse_down(event)
    EventRecord *event;
{
    WindowPtr mouse_window;
    int place_type = FindWindow(mk_long(event->where),
        &mouse_window);

    switch(place_type)
    {   case inDesk:
        case inMenuBar:
        case inSysWindow:
            break;
        case inContent:
            if (mouse_window != FrontWindow())
                SelectWindow(mouse_window);
            break;
        case inDrag:
            DragWindow(mouse_window, mk_long(event->where),
                &drag_rect);
            break;
        case inGrow:
                grow_window(mouse_window, mk_long(event->where));
                break;
            case inGoAway:
                if (TrackGoAway(mouse_window,
                        mk_long(event->where)))
                    ExitToShell();
                break;
            default:
                break;
        }
}

/* Handle and update event - first determine if the event is
 * in one of this application's windows, and if so, update
 * that window.
 */
do_update(event)
    EventRecord *event;
{
    GrafPtr save_graf;
    WindowPtr update_window;

    update_window = (WindowPtr)event->message;
    if (update_window = hello_window)
    {   GetPort(&save_graf);
        SetPort(update_window);
        BeginUpdate(update_window);
        ClipRect(&update_window->portRect);
        EraseRect(&update_window->portRect);
        DrawGrowIcon(update_window);
        draw_content(update_window);
        EndUpdate(update_window);
        SetPort(save_graf);
    }
}

/* Draw the grow icon for the window to indicate whether or
 * not it is active
 */
do_activate(event)
    EventRecord *event;
{
    WindowPtr event_window = (WindowPtr)event->message;

    if(event_window == hello_window)
    {   DrawGrowIcon(event_window);
        if (event->modifiers & 1)
            SetPort(event_window);
    }
}

/* Call the window manager routines that cause a window to
 * grow
 */
```

```
grow_window(window, mouse_point)
    WindowPtr window;
    Point mouse_point;
{
    long new_bounds;

    inval_bars(window);
    new_bounds = GrowWindow(window, mk_long(mouse_point),
        &grow_bounds);
    if (new_bounds == 0)
        return;
    SizeWindow(window, LoWord(new_bounds),
        HiWord(new_bounds), TRUE);
    inval_bars(window);
}

/* Invalidate the scroll bar and grow icon area of a
 * standard window
 */
inval_bars(window)
    WindowPtr window;
{
    Rect temp_rect, port_rect;

    port_rect = window->portRect;
    SetRect(&temp_rect, port_rect.left,
        port_rect.bottom - 16,
        port_rect.right, port_rect.bottom);
    InvalRect(&temp_rect);
    SetRect(&temp_rect, port_rect.right - 16, port_rect.top,
        port_rect.right, port_rect.bottom);
    InvalRect(&temp_rect);
}

draw_content(window)
    WindowPtr window;
{
}
```

Strengthening the framework

Our program has grown considerably. To support the added features of moving and changing the size of our window, we have had to add to our framework. First, we added a routine called `set_parameters`. This new routine performs an important job: it insures that this program will look nice and perform as the user expects even if the next-generation Macintosh has a much larger screen. `Set_parameters` sets this program's parameters according to the values it finds in global variables or through calls to Toolbox routines. So, if the screen of some future Macintosh has a thousand pixels in each direction, this program will allow the window to be dragged all over that huge screen without recompilation or other modification.

This version of our example program does only two things in the `set_parameters` routine: The rectangle in which the window can be dragged is set to be the entire screen, and the limits to which the window can grow or shrink is set to have a fairly arbitrary lower bound, and an upper bound which allows our window to grow to the size of the screen. The second operation is done with the QuickDraw routine `SetRect`, simply because `SetRect` is more convenient than a series of C assignment statements. Using Toolbox routines for even minor jobs like assigning values to a Toolbox data-structure's elements is a good idea because other Macintosh programmers will know immediately that you are assigning, in this case, values to elements of a rectangle, where a series of assignment statements would be much more difficult to read and understand.

The event loop has also "grown-up" a bit. While event polling provides a measure of resource-division, to more completely cooperate with the Macintosh system the program needs to call `SystemTask`, a Desk Manager routine that allows desk accessories, such as the alarm clock, to get processor resources so that they can still operate even though their windows are not active. The next version of this program will further explore the use of the desk manager.

Drawing the grow icon

The following changes, to the event loop and to other parts of our program, are in large measure a consequence of drawing the "grow icon." The grow icon isn't really an icon at all — as far as the routines that support Macintosh icons are concerned. The grow icon is part of the Window Manager. The grow icon is also not really part of window frame — unlike the window frame, the window manager doesn't draw it for you automatically. Fortunately, there *is* a Toolbox routine that will draw the grow icon for a given window. But you have to know when to call this routine.

Knowing when to do this is not obvious, and when you find out, it is still a bit tedious. You can make the best of this situation by learning a bit about the window manager and how windows are *activated*. The active window is the one that interacts with the user. It ought to be obvious to the user which window is active, so visual indications, such as the presence of horizontal lines in the title bar and the presence of the overlapping squares in the grow icon are provided to the user. Our example program has to cooperate with the window manager to produce the right effects in the grow icon. You will also learn a bit about "graphics update," an important part of every Macintosh program.

Updating and activating

In order to deal with activation and updating, our application needs to grab the events that tell it what to do and when. The event loop of the example now includes a call to `do_update` every time an update event occurs, and a call to `do_activate` every time an activate event occurs.

These routines are defined in the example, and contain code that cooperates with the Macintosh system to correctly update the contents of the window — in this case only the grow icon — and to correctly indicate that the window is active.

Responding to the mouse

The switch statement in do_mouse_down has also been modified to include calls to Toolbox routines and routines within the example program to drag the window, to grow the window, and to "select" the window, causing it to be activated.

Support for activating, updating, growing and dragging

Let's take a close look at the routines that support the example program's new abilities: The simplest of these is the call to DragWindow, a Window Manager routine that moves the location of our window on the screen. The interesting thing about DragWindow is the simplicity of the operation of moving the window around: we don't need to know where it is, and we don't need to know where it winds up. This is due to the use of GrafPort environments. All of the drawing we do is within the GrafPort of our window. As long as we remember to set the current GrafPort for drawing to be the GrafPort associated with the window we want to draw in, our program will draw in the right place.

Do_activate is called in response to activate events. There are two kinds of activate events: ones that signify that a window has become inactive, and others that signify that a window has become active. Activate events, therefore, usually happen in pairs, one for the window becoming active, and another for the window becoming inactive. If the activate event has 1 in the zeroth bit of the modifiers field, that is, if the modifiers field is odd, then it signals the activation of a window. Because the Window Manager itself relies on the current GrafPort being the GrafPort of the active window, when our window is activated, SetPort is called with the GrafPort of the newly active window.

The maintenance of the GrafPort is demonstrated in the do_update routine. First, the pointer to the current GrafPort is saved in save_graf, then the current GrafPort is set to be the GrafPort of the window the program is updating. Then the program calls the Window Manager routine BeginUpdate to inform the Window Manager that it is updating this window. The port rectangle of our window is then erased. Actually, only the "invalid" part of the window — the part of the window that has changed on the screen will be erased on the screen, and the other bits remain untouched. Then, the example program has a call to a routine called draw_content. Right now this routine doesn't do anything, but it does mark the place where this example program will draw the contents of its windows.

What causes update events in this version of our example? Growing and shrinking the window. In the example program, the routine grow_window supports changing the size of the window by clicking in the grow icon and then dragging the mouse. Because the grow icon is in the content region of the window, our example program has to take care of making sure that the grow icon disappears from its previous location and is displayed in the new location. It does so through calls to InvalRect. InvalRect is a Window Manager routine that adds the rectangle that it takes as an argument to the "invalid region" associated with the window. Adding the present location of the grow icon to the invalid region will make sure the old grow icon is erased. After the window is resized, the new location of the grow icon is added to the invalid region, so the the new grow icon will be drawn.

The grow_window routine is where our program grows its window. First, as was just explained, the present grow icon is added to the invalid part of the window. Then, a call to the Window Manager routine GrowWindow is made. GrowWindow returns the new width and height as the low and high order words of a 32 bit long-word. All GrowWindow does is show an outline of the window on the screen that tracks the user's mouse movements and, when the user releases the mouse button, informs the program where the window's bounds *ought* to be. The Toolbox Utility routines LoWord and HiWord extract the width and height for use in SizeWindow, which tells the Window Manager that the window has a new width and height. You, of course, have the option to ignore what the user did with the grow icon and size the window to some other dimensions. This might be done to prevent the window from covering up some other part of the screen. In order to use the Toolbox Utility routines, we had to add another include file at the top of the program: toolutil.h.

What to do about invalid areas

What actually happens to "invalid" parts of our window? Take a look at do_update: Invalid regions are erased as a result of a call to EraseRect. Even if the program were to draw something in the invalid parts of the window, those parts should be erased first. Otherwise the program might be scribbling over leftover pieces of grow icon and other detritus.

An invitation to tinker

Now that our program has grown to a substantial size, it can be tinkered with to see why all the Toolbox calls are where they are. For example, you could take out one or the other — or both — of the calls to InvalRect in the grow_window routine and see how bits of the grow icon are left in their old position, or how new grow icons sometimes fail to appear. Growing the window will still work, but if the invalid region is not kept up the user will not have a proper visual indication of the state of the window. The next version of the example program, and the last one presented in this chapter, will be much more complex, since it will unleash the desk accessories. So if you want to tinker around and willfully break this program, do so at this stage. And if you have the slightest inclination to tinker — do so! Playing with an example — commenting out Toolbox calls and seeing what effect that has — is the fastest way to connect, in your mind, parts of a program and their effect on interaction with the user.

Step 4: Menus and scroll bars

The following version of our example program is the last version for this chapter. While this framework will be used in the following two chapters, this will be the last version that maintains a pristine emptiness — doing nothing, but it does it with all the refinement a Macintosh application could ask for. If you need a break from all that nothing, start up a desk accessory. If you want to see some different nothing, use the scroll bars.

In this version of the example, the menu bar will have menus in it, and the scroll bars will be placed in the presently empty spaces above and to the left of the grow icon. This adds quite a bit of code, and the discussion of this version will be divided into a discussion of menus and a discussion of scroll bars and other controls.

Running this version of the program will provide the first example of the "Hello World" window being deactivated. By starting up some desk accessories you can see how the window manager brings windows to the foreground when they become active, and how the example program behaves in the background when another window is active.

Here is the final version of the "Hello World!" program:

```
#include <Quickdraw.h>
#include <WindowMgr.h>
#include <ControlMgr.h>
#include <EventMgr.h>
#include <DeskMgr.h>
#include <MenuMgr.h>
#include <ToolboxUtil.h>

GrafPtr w_port;
WindowRecord w_record;
WindowPtr hello_window;
Rect drag_rect, grow_bounds;

struct long_halves
{   int high;
    int low;
};

pascal void up_action(), down_action();

#define V_SCROLL 256 /* Resource ID of the vertical scroll bar */
#define H_SCROLL 257 /* Resource ID of the horizontal scroll bar */

#define UP 1
```

```
#define DOWN 2

#define APPLE_MENU 1
#define FILE_MENU 256
#define EDIT_MENU 257
#define DRVR 0x44525652L /* The string "DRVR" as a long */

#define mk_long(x)   (*((long *)&(x)))

main()
{
    init_process();  /* do all the initialization */
    make_window();
    event_loop();
}

/* Do all the right initialization things
 */
init_process()
{
    init_mgrs();
    set_parameters();
    fill_menus();
}


/* Do the right thing for most applications: Call the toolbox
 * initialization routines.
 */
init_mgrs()
{
    InitGraf(&thePort);
    InitFonts();
    FlushEvents(everyEvent, 0);
    InitWindows();
    InitCursor();
    InitMenus();
    TEInit();
    OpenResFile("\pHelloworld.rsrc");
}

/* Set parameters based on screen size, etc. */
set_parameters()
{
    drag_rect = thePort->portRect;
    SetRect(&grow_bounds, 64, 64, thePort->portRect.right,
        thePort->portRect.bottom);
}

fill_menus()
{
    MenuHandle menu;

    menu = GetMenu(APPLE_MENU);
    AddResMenu(menu, DRVR);
    InsertMenu(menu, 0);
    InsertMenu(GetMenu(FILE_MENU), 0);
    InsertMenu(GetMenu(EDIT_MENU), 0);
    DrawMenuBar();
}

/* Read window information from the resource branch into a window
 * structure. Get the scroll bars for this window and mark them to
 * distinguish them from any other controls that might be in this
 * window
 */
make_window()
{
    ControlHandle scroll_bar;

    hello_window = GetNewWindow(256, &w_record, -1L);
    scroll_bar = GetNewControl(V_SCROLL, hello_window);
    SetCRefCon(scroll_bar, (long)V_SCROLL);
    scroll_bar = GetNewControl(H_SCROLL, hello_window);
    SetCRefCon(scroll_bar, (long)H_SCROLL);
}

/* Get an event, switch on its type, and perform the appropriate
 * action
 */
event_loop()
{
    EventRecord my_event;
    Boolean valid;

    while (1)
    {   SystemTask();
        valid = GetNextEvent(everyEvent,&my_event);
        if (!valid) continue;
        switch(my_event.what)
        {   case nullEvent:
                break;
            case mouseDown:
                do_mouse_down(&my_event);
                break;
            case mouseUp:
            case keyDown:
            case keyUp:
            case autoKey:
                break;
            case updateEvt:
                do_update(&my_event);
                break;
            case diskEvt:
                break;
            case activateEvt:
                do_activate(&my_event);
                break;
            case networkEvt:
            case driverEvt:
            case app1Evt:
            case app2Evt:
            case app3Evt:
            case app4Evt:
            default:
                break;
        }
    }
}

/* Find out where a mouse-down event has occured and do what ought to
 * be done for that location
 */

do_mouse_down(event)
    EventRecord *event;
{
    WindowPtr mouse_window;
    int place_type = FindWindow(mk_long(event->where), &mouse_window);

    switch(place_type)
    {   case inDesk:
            break;
        case inMenuBar:
            do_menu(MenuSelect(mk_long(event->where)));
            break;
        case inSysWindow:
            SystemClick(event, mouse_window);
            break;
        case inContent:
            if (mouse_window != FrontWindow())
                SelectWindow(mouse_window);
            else
                do_controls(mouse_window, mk_long(event->where));
            break;
        case inDrag:
            DragWindow(mouse_window, mk_long(event->where), &drag_rect);
            break;
        case inGrow:
            grow_window(mouse_window, mk_long(event->where));
            break;
        case inGoAway:
            if (TrackGoAway(mouse_window, mk_long(event->where)))
                ExitToShell();
            break;
        default:
            break;
    }
}

/* Find which part of which control was used. Then find out how the
 * value of that control has changed. Then call one of this
 * applications routines that performs the action that reflects the
 * change in the control. In the case of the up and down buttons,
 * TrackControl calls an action routine that should show some
 * intermediate result, like srolling the screen
 * one line in an editor.
 */
do_controls(window, where)
    WindowPtr window;
    long where;
{
    int part_code, old_value, new_value;
    ControlHandle control;

    GlobalToLocal(&where);
    part_code = FindControl(where, window, &control);
    if (!part_code) return;
    switch(part_code)
    {   case inUpButton:
            TrackControl(control, where, up_action);
            break;
        case inDownButton:
            TrackControl(control, where, down_action);
            break;
        case inPageUp:
        case inPageDown:
            page_movement(window, control, part_code);
            break;
        case inThumb:
            old_value = GetCtlValue(control);
            TrackControl(control, where, 0L);
            new_value = GetCtlValue(control);
            thumb_movement(window, control, old_value, new_value);
        default:
            break;
    }
}

 pascal void
up_action(control, part_code)
    ControlHandle control;
{
    WindowPtr window = (*control)->contrlOwner;
    int old_value = GetCtlValue(control);

    SetCtlValue(control, old_value - 1);
    scroll_window(window, control, UP, 1);
}

 pascal void
down_action(control, part_code)
    ControlHandle control;
{
    WindowPtr window = (*control)->contrlOwner;
    int old_value = GetCtlValue(control);
```

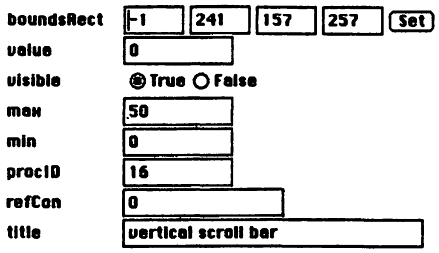
```
        SetCtlValue(control, old_value + 1);
        scroll_window(window, control, DOWN, 1);
    }

page_movement(window, control, part_code)
    WindowPtr window;
    ControlHandle control;
{
    int units = get_page_units(window, control);
    int direction = part_code == inPageUp ? UP : DOWN;
    int old_value = GetCtlValue(control);

    if (direction == DOWN)
        SetCtlValue(control, old_value + units);
    else
        SetCtlValue(control, old_value - units);
    scroll_window(window, control, direction, units);
}

thumb_movement(window, control, old_value, new_value)
    WindowPtr window;
    ControlHandle control;
{
    int units = old_value - new_value;
    int direction = units < 0 ? DOWN : UP;

    if (units)
    {   units = units < 0 ? - units : units;
        scroll_window(window, control, direction, units);
    }
}

get_page_units(window, control)
    WindowPtr window;
    ControlHandle control;
{
    return 5;
}

scroll_window(window, control, direction, units)
    WindowPtr window;
    ControlHandle control;
{
}

/* Handle and update event - first determine if the event is in one of
 * this application's windows, and if so, update that window.
 */
do_update(event)
    EventRecord *event;
{
    GrafPtr save_graf;
    WindowPtr update_window;
    update_window = (WindowPtr)event->message;
    if (update_window = hello_window)
    {   GetPort(&save_graf);
        SetPort(update_window);
        BeginUpdate(update_window);
        EraseRect(&update_window->portRect);
        DrawGrowIcon(update_window);
        DrawControls(update_window);
        draw_content(update_window);
        EndUpdate(update_window);
        SetPort(save_graf);
    }
}

/* If the modifiers are odd, then this is an activate event for the
 * window pointed to in the message field of the event. If that is
 * the case then the graf port is set to that window's graf port
 */
do_activate(event)
    EventRecord *event;
{
    WindowPtr event_window = (WindowPtr)event->message;
    WindowPeek peek = (WindowPeek)event_window;
    ControlHandle control = (ControlHandle)peek->controlList;
    long label;

    if(event_window == hello_window)
    {   if (event->modifiers & 1)
        {   SetPort(event_window);
            DisableItem(GetMHandle(EDIT_MENU), 0);
            while (control)
            {   label = GetCRefCon(control);
                if (label == V_SCROLL || label == H_SCROLL)
                    ShowControl(control);
                control = (*control)->nextControl;
            }
        }
        else
        {   EnableItem(GetMHandle(EDIT_MENU), 0);
            while (control)
            {   label = GetCRefCon(control);
                if (label == V_SCROLL || label == H_SCROLL)
                    HideControl(control);
                control = (*control)->nextControl;
            }
        }
        DrawGrowIcon(event_window);
    }
}

/* Call the window manager routines that cause a window to grow */
grow_window(window, mouse_point)
    WindowPtr window;
    Point mouse_point;
{
    long new_bounds;

    inval_grow(window);
    new_bounds = GrowWindow(window, mk_long(mouse_point),
                        &grow_bounds);
    if (new_bounds == 0)
        return;
    SizeWindow(window, LoWord(new_bounds), HiWord(new_bounds), TRUE);
    move_bars(window);
    inval_grow(window);
}

/* Invalidate the grow icon area of a standard window */
inval_grow(window)
    WindowPtr window;
{
    Rect temp_rect, port_rect;

    port_rect = window->portRect;
    SetRect(&temp_rect, port_rect.right - 16, port_rect.bottom - 16,
        port_rect.right, port_rect.bottom);
    InvalRect(&temp_rect);
}

/* Go through the list of controls for this window, identify the
 * scroll bars, and change their position and size to conform to the
 * window's new size
 */
move_bars(window)
    WindowPtr window;
{
    WindowPeek peek = (WindowPeek)window;
    ControlHandle control = peek->controlList;
    int new_top = window->portRect.top;
    int new_left = window->portRect.left;
    int new_bottom = window->portRect.bottom;
    int new_right = window->portRect.right;
    long label;

    while (control)
    {   label = GetCRefCon(control);
        if (label == V_SCROLL)
        {   HideControl(control);
            MoveControl(control, new_right - 15, new_top - 1);
            SizeControl(control, 16, new_bottom - new_top - 13);
            ShowControl(control);
        }
        else if (label == H_SCROLL)
        {   HideControl(control);
            MoveControl(control, new_left - 1, new_bottom - 15);
            SizeControl(control, new_right - new_left - 13, 16);
            ShowControl(control);
        }
        control = (*control)->nextControl;
    }
}

do_menu(command)
    long command;
{
    int menu_id = HiWord(command);
    int item = LoWord(command);
    char item_name[32];

    switch(menu_id)
    {   case APPLE_MENU:
            GetItem(GetMHandle(menu_id), item, item_name);
            OpenDeskAcc(item_name);
            break;
        case FILE_MENU:
            ExitToShell();
            break;
        case EDIT_MENU:
            SystemEdit(item - 1);
            break;
    }
    HiliteMenu(0);
}

draw_content(window)
    WindowPtr window;
{
}
```

Setting up menus and scroll bars

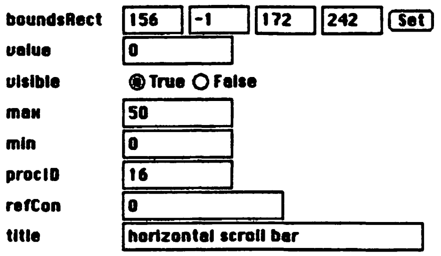
In the first three versions of this example program, the framework of this program was built. Here that framework is used to support more of the same sort of meshing with Toolbox routines.

To inplement further meshing with Toolbox managers, we need to define more resources: the resource file "Helloworld.rsrc" now includes descriptions of three menus and two controls.

The boundaries of the scroll bars are carefully chosen to conform to the areas above and to the left of the grow icon that were blank in the previous version of the example. The range of values (0 - 50) that the scroll bars display is arbitrarily chosen, and since our window doesn't display anything, manipulating the scroll bars has no effect other than to move the "thumb" in the scroll bar being used. Here is the way the definition of the scroll bars are entered through ResEdit:



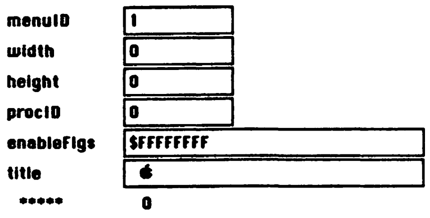
boundsRect	-1 | 241 | 157 | 257 | Set
value	0
visible	[✓ True] False
max	50
min	0
procID	16
refCon	0
title	vertical scroll bar



boundsRect	156 | -1 | 172 | 242 | Set
value	0
visible	[✓ True] False
max	50
min	0
procID	16
refCon	0
title	horizontal scroll bar

The scroll bars are initialized when the "Hello World" window is created. Controls have a close relationship with windows: Windows have a list of controls that are associated with that window and controls each have a pointer that points to the window that owns that control. The scroll bar controls are created — and initialized with the data in the resource fork — by a call to GetNewControl. Because controls cannot be easily identified by looking at their control records, the scroll bars in the example program have their resource IDs stashed away in the RefCon field of their control records.

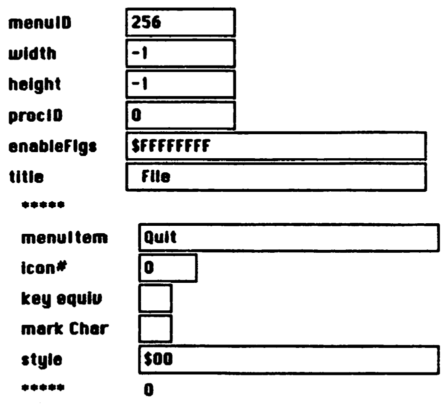
In order to initialize the menus, the routine fill_menus has been added to the program and is called from init_process. fill_menus gets menus that have been filled with the templates from the resource fork by calling GetMenu and inserts the menus into the menu bar by calling InsertMenu. Here is the way the menus are entered through ResEdit:



menuID	1
width	0
height	0
procID	0
enableFlgs	$FFFFFFFF
title	
*****	0

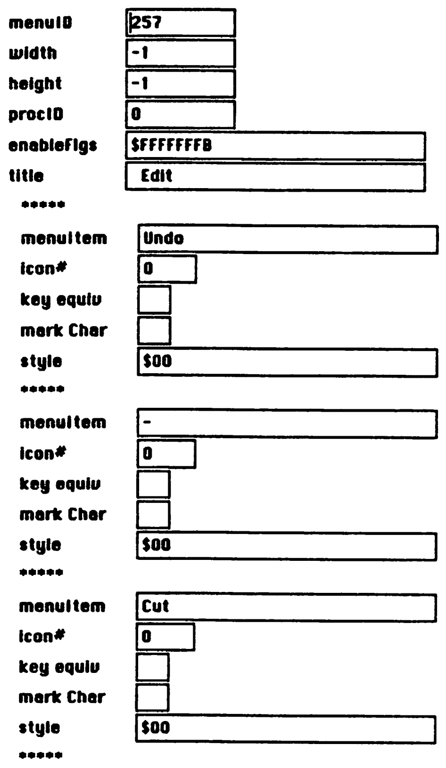
The "Apple menu" is treated specially: Instead of consisting of names of commands, the Apple menu consists of the names of desk accessories. These are loaded into the menu by calling AddResMenu, a Menu Manager routine that hunts down all the resources of a given type — in this case the DRVR type — and adds them to the specified menu.

The File menu contains just one command here, "Quit:"

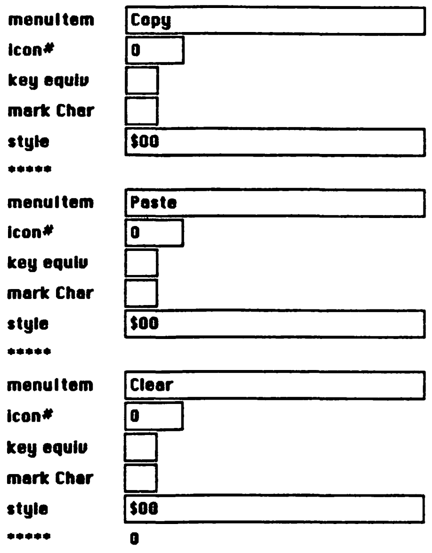


```
menuID        256
width         -1
height        -1
procID        0
enableFlgs    $FFFFFFFF
title          File
  *****
  menuItem    Quit
  icon#       0
  key equiv
  mark Char
  style       $00
  *****       0
```

The Edit menu contains the standard commands for editing, and it will be used to pass those commands through to desk accessories that use them:



```
menuID        257
width         -1
height        -1
procID        0
enableFlgs    $FFFFFFFB
title          Edit
  *****
  menuItem    Undo
  icon#       0
  key equiv
  mark Char
  style       $00
  *****
  menuItem    -
  icon#       0
  key equiv
  mark Char
  style       $00
  *****
  menuItem    Cut
  icon#       0
  key equiv
  mark Char
  style       $00
  *****
```



menuItem	Copy
icon#	0
key equiv	
mark Char	
style	$00
*****	
menuItem	Paste
icon#	0
key equiv	
mark Char	
style	$00
*****	
menuItem	Clear
icon#	0
key equiv	
mark Char	
style	$00
*****	0

Interacting with menus

The use of menus introduces yet another major category of interaction between Macintosh applications and the Toolbox. Like the switch statement in the event loop and in `do_mouse_down`, `do_menu` has a switch statement that switches on the result of a call to a Toolbox routine.

In the case of menus, the Toolbox routine `MenuSelect` is used to track the user's mouse after a mouse-down event has occurred in the menu bar. If a menu item was selected by the user having released the mouse button over that menu item, then `MenuSelect` returns a menu id and item number encoded in a longword. This result is passed to our example's routine `do_menu` where a switch statement is used to dispatch according to the menu where the selection occurred. If no menu item was selected, or if an item from a desk accessory's menu was selected, `do_menu` will do nothing.

The action associated with the Apple menu is launching desk accessories. This takes two steps: In the first step the name of the desk accessory is found through a calls to the Menu Manager routines `GetMHandle` and `GetItem`. The return value of `GetMHandle` is passed to `GetItem`, which deposits the name of the menu item — in this case the name of the desk accessory we want to start — in a buffer. The second step is the actual launch of the desk accessory through a call to `OpenDeskAcc`.

The file menu consists of only one item: "Quit." So the program does no checking to see which item from the file menu was picked — it knows right away that it is time to quit.

Our program does no editing, so the items on the "Edit" menu are all disabled if the "Hello World" window is the active window. When our window in inactive — when a desk accessory's window is the active window — the edit menu is enabled. This is done in `do_activate`.

Interacting with controls

Controls are the most direct way to translate the user's desires in actions. In combination with the mouse, the scroll bars solve one of the thorniest problems facing user interface designers: How will the user scroll and move the cursor? On the Macintosh the design issues are clear cut, but your programs still have to interface to the scroll bars to benefit from them. Using scroll bars is fairly complex because scroll bars have three major components: The arrows at the end that are used for scrolling up on "line" — whatever a line may mean to your program; The areas above and below the "thumb" which are used for "paging" up and down in screen-sized units; The "thumb" itself, which is used to move the window over large expanses of the document being viewed.

Each of these components interacts with the application in a somewhat different way. Because the up and down buttons (the arrows) need to show intermediate results, the application passes a function pointer to `TrackControl`, the Control Manager routine that is called when a mouse down is detected in the up or down buttons. The page up and down areas are easier: all we need to show are the results, which in the case of our example is only the new location of the thumb. The thumb is moved by the control manager, and the new value of the control is set for us, so to interact with the thumb the program needs to store the value of the control before the the thumb is moved so that the difference between its old and new location can be reflected in the contents of the window.

Because our sample program has no content to display in the window, the range of values that the scroll bar controls display and the number of units in a "page" are chosen arbitrarily to demonstrate the use of these controls.

When there is something to display, a program will have to set the range of control values, and calculate the "page" size based on the size of the window and the size of the document being viewed. In the example program, we have put in a dummy scrolling routine to show what information is available for determining how much to scroll and in which direction and a dummy `get_page_units` routine that returns a value

Controls and activation

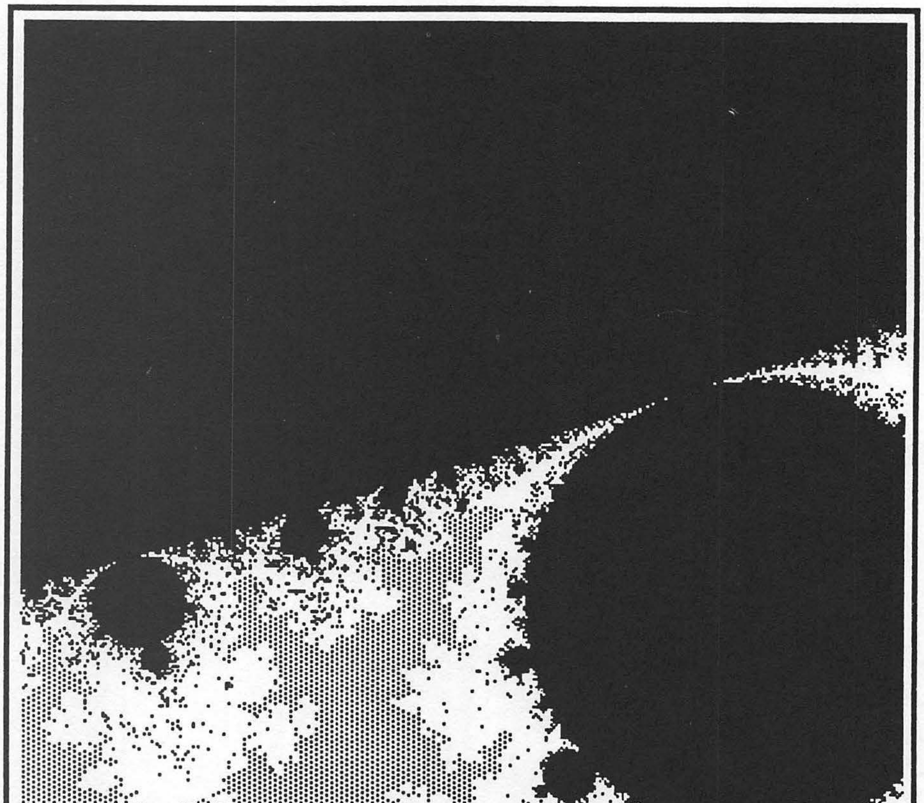
When a window is inactive, its title bar is plain white, its grow icon is gone, and its scroll bars are hidden. To achieve this effect, the program has to call `HideControl` when the window is deactivated and `ShowControl` when it is activated. Because you may want to treat some controls differently than others, the example program uses the `RefCon` field of the control to label the scroll bars as such, and only the scroll bars are hidden on deactivation.

Use them!

Although controls are complex, and require a fair bit of cooperation from your application to make them work, you should use them liberally. They are the most intuitive form of user interface available. Nobody needs a manual to operate a stereo — if the volume is set to 11, it is obviously louder than 10. So it is with controls.

POINTS TO CONSIDER

1. What, if anything, does Macintosh programming remind you of?
2. What problems did you run into in running your first Macintosh program? Why do you think those problems occurred?
3. What, thus far, has proved to be the most valuable tool in helping you create Macintosh software?

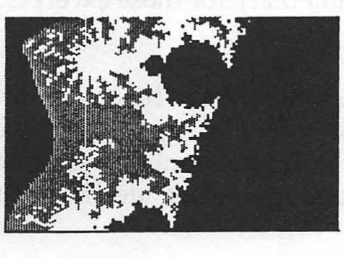


8

Exploring the Mandelbrot Set

- What is the Mandelbrot Set
- Finding the complex numbers that form the set
- The design of a Macintosh application that explores the Mandelbrot Set
- The implementation of such an application in C, using the framework created in the previous chapter
- Using menus and controls to enable the user to manipulate an application
- What "graphics update" is and how to do it
- Scrolling a graphical document

Pictured below is a portion of the border of the Mandelbrot Set. The



border of the Mandelbrot Set is a fractal. No matter how closely you look at the border of a fractal, there is still more detail to be seen. The border of the Mandelbrot Set, and any fractal, is infinitely long. So if you think fractals are interesting and beautiful, there is an infinite amount of interest and beauty to be found along the edge of the Mandelbrot Set.

The example application presented in this chapter, built on the foundation laid in the previous chapter, is a tool for exploring the neighborhood of the Mandelbrot Set.

Calculating and plotting the Mandelbrot Set is an attractive target for an example Macintosh application. The math behind the Mandelbrot Set is fairly easy and the code that does the calculations will not overshadow the purpose of the example program. The huge number of calculations involved in computing the boundaries of the Mandelbrot Set ensure that this example will not be a "toy" program that tackles a problem too small to be worth automating in the first place. Instead, a simple repetitive task is being performed by the Macintosh to yield a visually interesting result. It would not be practical to explore the Mandelbrot Set without a computer.

The scale of the problem affects the implementation: On a minicomputer, you might let a long calculation run its course, even if it takes days to complete. But the Macintosh is an interactive personal computer. You don't want it to sit there, silent and unresponsive while it is grinding through a lengthy calculation. At least, the desk accessories ought to remain available. This means that long calculations, like spreadsheet updates, document repagination in word processors, and long scientific or engineering calculations should be done piecemeal. In this chapter we will examine this issue and the other issues involved in designing a worthwhile, easy to use, and powerful Macintosh application.

A shift in presentation

In the previous chapter the example program was presented in stages. In this chapter, and in the next chapter, the example program will be presented as a *fait accompli* because it would be too large to include program listings and commentary for each stage in the development of our Mandelbrot Set exploration program. Instead, the program listing is presented at the end of the chapter and it shows only the complete example program. The stages of development that went into this example, and that would go into programs you write, are discussed in each of the sections of this chapter.

Each section will present excerpts from the code. These excerpts will be discussed in detail, but will be presented only once — in their final form. The stages of development each part of the program went through will be part of the subject of the commentary for those excerpts.

Stating the problem

The Mandelbrot Set is a set of *complex* numbers. Since complex numbers have two components, a natural way to plot a set of complex numbers is a two-dimensional map. In this case, the numbers inside the Mandelbrot Set will be mapped in black, and those outside the set in white or some other pattern.

Numbers that lie inside the Mandelbrot Set can be found by dropping them into the following equation in place of "c:"

$$z = z^2 + c$$

The variable "z" starts at zero. Evaluating the right side of the equation yields a new value for "z." By repeating the process of determining the value of the equation, and using the value as the value of "z" for the next calculation, two classes of numbers emerge: Numbers that cause the calculation to run off to infinity, or "diverge," and those that cause the result of the calculation to perpetually have a magnitude less than two. In practice it takes about 700 iterations of this calculation to decide that the calculation will not run away to infinity and that the initial value of "c" is therefore in the Mandelbrot Set.

In the case of the Mandelbrot Set, more information than the in-the-set-or-out, black-or-white information about complex numbers can be presented. Numbers that lie outside the Mandelbrot Set can be assigned a distance from the set. "Distance," in this case, is determined by the number of calculations required to decide that a number is outside the Mandelbrot Set. If it takes a large number of calculations to make this determination, a number is near the set, if it takes one or a only a few calculations, the number is far away.

Goals and desired results

Simply stated, the results we want are interesting pictures. Exploring the Mandelbrot Set is like looking through a telescope at the stars or though a microscope at things that are normally invisible. Because there is little value in the naked data about which complex numbers are in or out of the Mandelbrot Set, the way the data is presented is important. In addition to providing a solution to the stated problem, *the goal of this program is to turn the Macintosh into an instrument for exploring the Mandelbrot Set.*

One notion behind this goal is that people do not use many general purpose devices in day-to-day life. They use scissors to cut paper and cloth, knives to cut food, and saws to cut wood. They use telescopes to look at stars and microscopes to look at bugs. They do not expect to turn their telescopes around and use them as microscopes. They do not even expect their dishwashers to be their clothes-washers even though both machines slosh hot water around in a big white box.

The universal problem faced by software designers is the problem of transforming, temporarily, a general purpose computer into an instrument specific to an application. How can the Macintosh, which sloshes code around in a small beige box be transformed into a sketch-pad, a printed page, a drafting board, a ledger, or, in this case, a tool for looking at a mathematical object?

Visual Goals: Presentation

A broad hint at the solution is in the picture at the beginning of this chapter. In that picture, numbers in the Mandelbrot Set are plotted as little black squares, numbers just outside the set are plotted as little white squares, and numbers that are increasingly distant from the set are plotted in increasingly *darker* patterns. By juxtaposing white and black, the border of the Mandelbrot Set is highlighted. The black regions that form the body of the set itself are surrounded by a halo of white, which then fades to a dark gray as points grow more distant from the set. Our choice of visual representation was made in a way that combines accuracy — the border of the set is sharply defined — with esthetics.

By creating a program that maps parts of the Mandelbrot Set in an accurate and pleasing format, and that allows the user to steer around the map in an intuitive manner we are temporarily transforming the Macintosh into an instrument for inspecting the neighborhood of the Mandelbrot Set. The example program presented in this chapter is an example of an implementation of a software instrument. Software instruments like this one have an advantage over physical instruments in that they can be used to look at things like the Mandelbrot Set that don't exist in the physical world.

Enumerating the parameters

Exploring the Mandelbrot Set means changing parameters: The point in the upper left hand corner of the map could be moved to a new location; The distance between points could be changed; The size of the map could be changed; The portion of the map being viewed could be changed.

The following parameters are used in the example program:

- The starting point. This is the point in the complex plane mapped in the upper right-hand corner of the screen.

- The granularity. This is the distance, in both the real and imaginary axes, between points being mapped.

- The scale factor for calculating the data. If we do not want to calculate a result for every pixel, the scale factor specifies how many pixels to skip in each direction.

- The scale factor for viewing the data. This allows map plotting to occur at a larger (coarser) scale factor than the calculations.

- The X dimension. The number of columns in the map.

- The Y dimension. The number of slots for results in each column of the map.

- The offset we begin drawing at. In case the user has shrunk a map window, and then used the scroll bars to move around the map, the point at which drawing begins is specified by an X and Y offset.

It is impossible to know all of the parameters of a problem when you sit down to devise a solution. For example, our first Mandelbrot Set exploration program started out with only one scale factor, used in both viewing and in calculating. It was split in two because changing the scale factor for calculations means changing the size of the vectors holding the results of the calculations, which makes it hard to go back to a larger scale factor for viewing without throwing away hard won results.

Designing the data structures

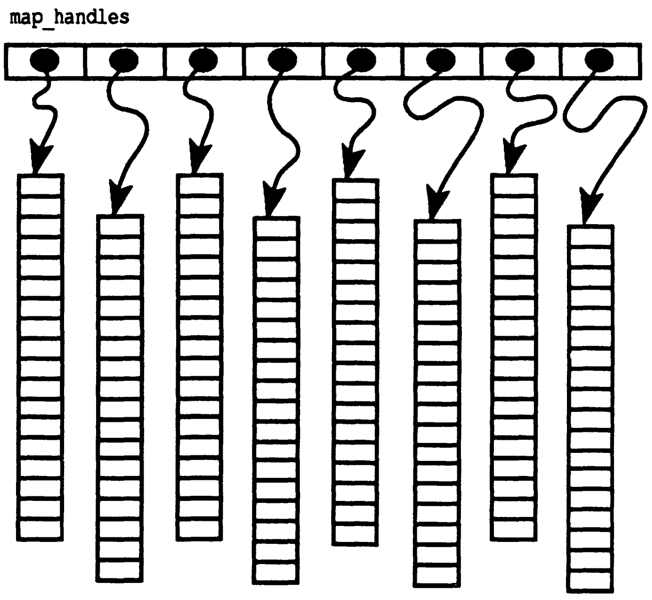
On the screen, the Mandelbrot Set is represented by squares filled with patterns. Because the window containing the plot of the Mandelbrot Set will have to be redrawn after, for instance, a desk accessory is closed, a representation of the plot must kept in memory so that the plot can be recreated.

The on-screen map reflects the parameters the user has selected and the results of the calculations that have been performed. The data structure used to represent a map in the sample application has a "header" portion used to hold the parameters of the map, and a "data" portion used to hold the results of calculations. The size of the header is fixed, and the size of the data can be inferred from the parameters in the header.

Here is the map data structure from the example program:

```
struct map                      /* A map structure */
{   struct cx_num start_at;     /* Complex number at top left corner */
    double step;                /* The granularity from point to point */
    int scale;                  /* Scale at which we calculate the map */
    int view_scale;             /* Scale at which we draw the map */
    int x_offset, y_offset;     /* The offset we begin drawing at */
    int x_dim, y_dim;           /* The dimensions of the map */
    int last_x, last_y;         /* Where we left off */
    Handle map_values[1];       /* An array  of column handles, allocated
                                 * to the correct size
                                 */
};
```

The data portion of the structure is not laid out in the structure definition. The structure member `map_values` just holds the first pointer in the data section of a map. The storage needed to hold all the data for a map is allocated when the dimensions of the map are changed and when the map is first created. The data portion of a map is a vector of pointers, `x_dim` long, that points to vectors `y_dim` long that store the results of the computations.



Solving the problem — computing the results

The guts of the Mandelbrot Set exploration program are the routines that fill in the map. The primary goal of these routines is efficiency (though utmost efficiency has been sacrificed for clarity in the example sources and flexibility in the program).

The example program spends more than 90% of its time in the loop that determines whether a point lies in the Mandelbrot Set. This loop evaluates the expression z^2+c up to several hundred times. z and c are both complex numbers with real and imaginary parts. The result of the expression is the new value of z, so the result has two parts as well.

There at least two alternative strategies for coding this computation in C:

1. Write subroutines that do complex-number multiplication, addition, and magnitude comparison. The structure of the computation is then clean and easy to read:

```
struct cx_num z, c;
struct cx_num *cx_add(), *cx_square();
int cx_magnitude();

...
do
{   z = *cx_add(cx_square(&z), c);
}   while (cx_magnitude(z) < 2);
```

2. Code the complex number arithmetic "in-line" — right in the loop.

This approach has two advantages: First, there is no procedure call overhead. Instead of three procedure calls per pass through the loop, there are none. Second, intermediate results can be used. Finding the magnitude of a complex number involves a square-root operation that need not be performed for this application (since the formaula calls for the square of the number). The intermediate result before the square-root operation can be used in the comparison in the while statement.

This is the approach taken in the example, and here is the routine that determines whether a point lies inside or outside the Mandelbrot Set:

```
/* Check if a point is inside the Mandelbrot Set. If the magnitude
 * of the complex number has not exceeded 2 in 700 iterations, it is
 * most likely IN the mandelbrot set. Otherwise it lies outside and
 * the number of iterations it took to determine this is used to
 * select a pattern for that point. We check for pending events every
 * 128 iterations.
 */
 char
calc_value(where)
    register struct cx_num *where;
{
    register double val_real, val_imag, sq_real, sq_imag;
    register int count;
    EventRecord dummy;

    val_real = val_imag = 0.0;
    for (count = 0; count < 700; count++)
    {   sq_real = val_real * val_real;
        sq_imag = val_imag * val_imag;
        if ((sq_real + sq_imag) > 4.0) break;
        if (!(count & 0x7F) && EventAvail(everyEvent, &dummy))
            return NO_VALUE;
        val_imag = (val_real * val_imag * 2.0) + where->imag;
        val_real = sq_real - sq_imag + where->real;
    }
    return which_pattern(count);
}
```

The solution used in our example program is really a compromise between efficiency, readability, and flexibility. Including the complex number calculations in-line makes the program acceptably efficient, but greater efficiency could have been attained. Instead of using C's built-in floating point numbers, we could have used fixed-point numbers and done our own fixed-point multiplication in-line (as well as the complex-number arithmetic).

Graphic display and graphics update

"Visual" applications all have to update the screen. On a character-only display, like a terminal, screen update means figuring out which character positions need to be changed after the user has done something like deleting a word in a paragraph. On the Macintosh, information in the windows on the screen is not locked in to a grid of character positions as it is on a terminal. Therefore, on the Macintosh, the pixels, not characters, that need to be changed have to be kept track of. Keeping track of pixels as opposed to character positions is called "graphics update" — something that every Macintosh application must do.

The Window Manager keeps track of the parts of the screen that need to be updated. Dragging and changing the size of windows can cause parts of windows to require redrawing. The Window Manager draws what it knows how to draw — window frames and the desktop. The rest of the changed windows have to be updated by the application. To make this easier for the application writer, the Window Manager has collected all of the "dirty" areas of the screen into the "invalid region." Window Manager routines allow the application to use the invalid region to draw only the parts of its windows that need updating. Calling these routines causes a "clip region" to be set up. Clipping is like masking off the parts of a car that don't need painting. In this case, the parts of the screen that don't need updating are masked off and the application can "paint" the entire window without causing any unnecessary drawing on the screen.

Our example program contains two sets of routines for plotting the map of the Mandelbrot Set. One that plots the map in response to update events and one that displays the results of the calculations for a point immediately after they are completed:

The following routines from the example program update a window in response to update events:

```
draw_content(window)
    WindowPtr window;
{
    Rect clip_rect;
    RgnHandle old_clip = NewRgn();

    clip_rect = window->portRect;
    clip_rect.right -= BAR_WIDTH;
    clip_rect.bottom -= BAR_WIDTH;
    GetClip(old_clip);
    ClipRect(&clip_rect);
    plot_map(window);
    SetClip(old_clip);
    DisposeRgn(old_clip);
}

plot_map(window)
    WindowPtr window;
{
    register map_handle map = (map_handle)((WindowPeek)window)->refCon;
    register int scale_ratio = (*map)->view_scale / (*map)->scale;
    register int x, y;

    for (x = 0; x < (*map)->x_dim; x += scale_ratio)
    {   for (y = 0; y < (*map)->y_dim; y += scale_ratio)
            plot_one(map, x, y);
    }
}

/* Plot one point in the map.
 */
plot_one(map, x, y)
    map_handle map;
    register int x, y;
{
    register int fill_with = VALUE(map, x, y);
    register int scale = (*map)->scale;
    register int view_scale = (*map)->view_scale;
    Rect to_fill;

    x -= (*map)->x_offset; y -= (*map)->y_offset;
    x *= scale; y *= scale;
    SetRect(&to_fill, x, y, x + view_scale, y + view_scale);
    switch(fill_with)
    {   case BLACK: FillRect(&to_fill, &black); break;
        case WHITE: FillRect(&to_fill, &white); break;
        case LIGHT_GRAY: FillRect(&to_fill, &ltGray); break;
        case GRAY: FillRect(&to_fill, &gray); break;
        case DARK_GRAY: FillRect(&to_fill, &dkGray); break;
        case NO_VALUE:
            break;
    }
}
```

Draw_content is called by do_update while handling an update event. Prior to calling draw_content, BeginUpdate is called to set up the "vis-region" of the GrafPort to contain the intersection of the update region and the exposed part of the window. Draw_content further restricts the part of the screen to be drawn on by setting the "clip region."

The vis-region and the clip region are parts of the GrafPort. The Window Manager uses the vis-region to make sure that drawing is confined to the visible parts of a window that need updating, preventing applications from overwriting other windows and the borders of their own windows. Applications use the clip region to make sure that their own drawing is confined to the intersection of the vis-region and the clip region. In the case of our example program, the clip region is used to prevent plot_map from overwriting the scroll bars.

The Window Manager provides a way for applications to manipulate the update region. InvalRgn and ValidRgn add and remove regions from the update region of a window.The following routine interacts with the Window Manager and QuickDraw to display the results of a calculation immediately after it is completed:

```
paint_point(window, x, y)
    WindowPtr window;
{
    GrafPtr save_graf;
    register map_handle map = (map_handle)GetWRefCon(window);
    register int scale = (*map)->view_scale;
    register int scale_ratio = scale / (*map)->scale;
    register int inval_x = (x - (*map)->x_offset) / scale_ratio,
        inval_y = (y - (*map)->y_offset) / scale_ratio;
    Rect rect, content;

    content = window->portRect;
    content.bottom -= BAR_WIDTH; content.right -= BAR_WIDTH;
    inval_x *= scale; inval_y *= scale;
    SetRect(&rect, inval_x, inval_y, inval_x + scale, inval_y + scale);
    if (SectRect(&rect, &content, &rect))
    {   GetPort(&save_graf);
        SetPort(window);
        InvalRect(&rect);
        plot_one(map, x, y);
        ValidRect(&rect);
        SetPort(save_graf);
    }
}
```

Paint_point is called right after the pattern for a point has been determined. Paint_point calls the Window Manager routine InvalRect to put the rectangle that it wants to fill in in the update region. Then the point is plotted. Then the call to ValidRect cancels the update event caused by the call to InvalRect, so the plotting done by paint_point does not cause the whole window to be replotted.

Creating a user interface

Now that we have designed the data structures, coded the calculations that fill in those structures, and mapped the results, we need to provide a set of controls to enable the user to operate the Mandelbrot Set mapping instrument we have created.

Macintosh user interfaces are usually made up of menus and dialogs. Simple operations are accessible from menus and take effect right away: the "quit" menu item usually returns the user to the finder without further prompting (unless a file may need to be saved). Other commands require a dialog with the new to get information or at least confirm that previously obtained information is still current.

Designing with dialogs

In our example program we provide the user with the ability to move around the complex plane, and change the granularity of the map. Position on the complex plane and granularity are changed through "modal" dialogs. Modal dialogs are the most common form of dialog. Modal dialogs are called modal dialogs because program is in a mode in which the user can do nothing but interact with the dialog.

The Macintosh user interface is for the most part modeless — the user can do anything at any time. This contrasts with "menu driven" software that insists on leading the user through a hierarchy of choices that can become tiresome. Because modes are undesirable when overused, modal dialogs should be used carefully. They should not, in general, be nested as menus are in menu driven programs. The user should not need to use modal dialogs often, because even selecting the menu item that causes the dialog to appear can become tedious if that operation needs to be performed often. In the case of the example program, the modal dialog that changes position would be used only infrequently — after enough of a map has been calculated and displayed for the user to decide if the current place being mapped is interesting.

Modal dialogs are particularly easy on the implementor. One routine, `ModalDialog`, conducts the dialog with the user and returns when a potentially interesting result has been obtained. Modal dialogs "know" how to operate buttons and editable text boxes, so no interaction with the application is required while the dialog is under way. `ModalDialog` is called repeatedly until the dialog is either canceled or completed.

The following routine gets a new granularity for the map from the user through a modal dialog box that looks something like the control panel of a coffee grinder, with buttons for the various granularities:

```
/* Ask the user for a new scale for the map */
get_new_resolution(map)
    map_handle map;
{
    DialogPtr dialog;
    int scale = (*map)->view_scale;
    int item;

    dialog = GetNewDialog(RES_DIALOG, 0L, -1L);
    dialog_radio(dialog, scale_to_button(scale));
    while (1)
    {   ModalDialog(0L, &item);
        switch (item)
        {   case RES_D_CANCEL:
                scale = (*map)->view_scale;   /* Fall through... */
            case RES_D_OK:
                DisposDialog(dialog);
                return scale;
            case RES_D_COARSE:
                scale = COARSE;
                dialog_radio(dialog, item);
                continue;
            case RES_D_MEDIUM:
                scale = MEDIUM;
                dialog_radio(dialog, item);
                continue;
            case RES_D_FINE:
                scale = FINE;
                dialog_radio(dialog, item);
                continue;
            case RES_D_EXTRA_FINE:
                scale = EXTRA_FINE;
                dialog_radio(dialog, item);
                continue;
            default:
                continue;
        }
    }
    return (*map)->view_scale;
}
```

The default action (the one that is taken when the user presses "return" on the keyboard) is to cancel the dialog. In some cases the default action might be to complete the dialog. Typically, if the dialog changes a parameter or performs some action that is difficult or inconvenient to undo, the default action should be to cancel the dialog. In this case, changing the granularity of the map can cause much more memory to be used up, so we make sure the user wants to do this.

Dialogs are described in resource compiler format. The description of dialogs is similar to that of windows. The resource compiler source for all of the dialogs in our example is at the end of this chapter.

Source listing

Here is the complete source listing for our example program, the Mandelbrot Set mapper:

```
#include <Quickdraw.h>
#include <WindowMgr.h>
#include <ControlMgr.h>
#include <EventMgr.h>
#include <DeskMgr.h>
#include <MenuMgr.h>
#include <ToolboxUtil.h>
#include <MemoryMgr.h>
#include <DialogMgr.h>

GrafPtr w_port;
WindowRecord w_record;
WindowPtr hello_window;
Rect drag_rect, grow_bounds;

struct cx_num          /* A complex number */
{   double real;       /* The real part */
    double imag;       /* The imaginary part */
};
```

```
struct map                          /* A map structure */
{   struct cx_num start_at;         /* Complex number at top left corner */
    double step;                    /* The granularity from point to point */
    int scale;                      /* Scale at which we calculate the map */
    int view_scale;                 /* Scale at which we draw the map */
    int x_offset, y_offset;         /* The offset we begin drawing at */
    int x_dim, y_dim;               /* The dimensions of the map */
    int last_x, last_y;             /* Where we left off */
    Handle map_values[1];           /* An array  of column handles, allocated
                                     * to the correct size
                                     */
};

/* Find the X'th handle, and the Y'th byte in the array refered to by
 * that handle
 */
#define VALUE(MAP, X, Y) (*(*MAP)->map_values[X])[Y]

typedef struct map **map_handle;

pascal void SysBeep() = 0xA9C8;

pascal void up_action(), down_action();
char calc_value(), which_pattern();
Size calc_map_size();
map_handle make_map();
Handle new_column();
WindowPtr make_window();
ControlHandle lookup_control();

#define V_SCROLL 256        /* Resource ID of the vertical scroll bar */
#define H_SCROLL 257        /* Resource ID of the horizontal scroll bar */

#define BAR_WIDTH 15        /* The width of a scroll bar */

#define NO_VALUE 0          /* Haven't calculated the value */
#define BLACK 1             /* Corresponds to the pattern black */
#define WHITE 2             /* Corresponds to the pattern white */
#define LIGHT_GRAY 3        /* Corresponds to the pattern ltGray */
#define GRAY 4              /* Corresponds to the pattern gray */
#define DARK_GRAY 5         /* Corresponds to the pattern dkGray */

#define UP 1                /* Scrolling up? */
#define DOWN 2              /* Or down? */

#define APPLE_MENU 1        /* The menu marked by the Apple symbol */
#define FILE_MENU 256       /* The "File" menu */
#define EDIT_MENU 257       /* the "Edit" menu */
#define MAP_MENU 258        /* Controls map paramters */

/* Items on the map menu */
#define RESOLUTION 1
#define MAGNIFICATION 2
```

```
#define POSITIONING 3

#define RES_DIALOG 256   /* Get a new resolution for the map */

/* Buttons in the new-resolution dialog */
#define RES_D_CANCEL 1
#define RES_D_OK 2

#define RES_D_COARSE 3
#define RES_D_MEDIUM 4
#define RES_D_FINE 5
#define RES_D_EXTRA_FINE 6

#define POS_DIALOG 257   /* Start a map at a new position */

/* Items in the positioning dialog */
#define POS_D_CANCEL 1
#define POS_D_OK 2
#define POS_D_BOX 3

/* Scale values stored in maps */
#define EXTRA_FINE 1
#define FINE 2
#define MEDIUM 4
#define COARSE 8

/* Initial values */
#define INIT_REAL -0.745         /* The initial starting point */
#define INIT_IMAG 0.260          /* The initial starting point */
#define INIT_STEP 0.00025        /* The initial step value */
#define INIT_SCALE MEDIUM        /* The initial scale factor */

/* Operations the count routine supports */
#define SET 1
#define GET 2
#define ADD 3

#define DRVR 0x44525652L         /* The string "DRVR" as a long */

#define mk_long(x)   (*((long *)&(x)))

main()
{
    init_process(); /* do all initialization */
    make_window(hello_window = (WindowPtr)&w_record);
    event_loop();
}

/* Do all the right initialization things
 */
init_process()
{
    init_mgrs();
    set_parameters();
    fill_menus();
}

/* Do the right thing for most applications: Call the toolbox
 * initialization routines.
 */
init_mgrs()
{
    InitGraf(&thePort);
    InitFonts();
    InitWindows();
    FlushEvents(everyEvent, 0);
    InitCursor();
    InitMenus();
    TEInit();
    InitDialogs(0L);
    MaxApplZone();
    OpenResFile("\pMandelbrot.rsrc");
}

/* Set parameters based on screen size, etc. */
set_parameters()
{
    drag_rect = thePort->portRect;
    SetRect(&grow_bounds, 64, 64, thePort->portRect.right,
        thePort->portRect.bottom);
}

fill_menus()
{
    MenuHandle menu;

    menu = GetMenu(APPLE_MENU);
    AddResMenu(menu, DRVR);
    InsertMenu(menu, 0);
    InsertMenu(GetMenu(FILE_MENU), 0);
    InsertMenu(GetMenu(EDIT_MENU), 0);
    InsertMenu(GetMenu(MAP_MENU), 0);
    DrawMenuBar();
}

/* Read window information from the resource branch into a window
 * structure. Get the scroll bars for this window and mark them to
 * distinguish them from any other controls that might be in this window.
 * The parameter points to an uninitialized window record
 */
 WindowPtr
make_window(new_window)
    WindowPtr new_window;
{
    ControlHandle scroll_bar;
    struct cx_num start_at;
    map_handle new_map;
    new_window = GetNewWindow(256, new_window, -1L);
    scroll_bar = GetNewControl(V_SCROLL, new_window);
    SetCRefCon(scroll_bar, (long)V_SCROLL);
    scroll_bar = GetNewControl(H_SCROLL, new_window);
    SetCRefCon(scroll_bar, (long)H_SCROLL);
    move_bars(new_window);
    start_at.real = INIT_REAL; start_at.imag = INIT_IMAG;
    new_map = make_map(new_window, &start_at, INIT_STEP, INIT_SCALE);
    SetWRefCon(new_window, (long)new_map);
    init_bar(new_window, H_SCROLL, 0, 0);
    init_bar(new_window, V_SCROLL, 0, 0);
    fill_in_map(new_window);
}

/* Get an event, switch on its type, and perform the appropriate
 * action
 */
event_loop()
{
    EventRecord my_event;
    Boolean valid;

    while (1)
    {   SystemTask();
        valid = GetNextEvent(everyEvent,&my_event);
        if (!valid)
        {   fill_in_map(hello_window);
            continue;
        }
        switch(my_event.what)
        {   case nullEvent:
                break;
            case mouseDown:
                do_mouse_down(&my_event);
                break;
            case mouseUp:
            case keyDown:
            case keyUp:
            case autoKey:
                break;
            case updateEvt:
                do_update(&my_event);
                break;
            case diskEvt:
                break;
            case activateEvt:
                do_activate(&my_event);
                break;
            case networkEvt:
            case driverEvt:
            case app1Evt:
            case app2Evt:
            case app3Evt:
            case app4Evt:
                break;
            default:
                break;
        }
    }
}

/* Find out where a mouse-down event has occured and do what ought to
 * be done for that location
 */
do_mouse_down(event)
    EventRecord *event;
{
    WindowPtr mouse_window;
    int place_type = FindWindow(mk_long(event->where), &mouse_window);

    switch(place_type)
    {   case inDesk:
            break;
        case inMenuBar:
            do_menu(MenuSelect(mk_long(event->where)));
            break;
        case inSysWindow:
            SystemClick(event, mouse_window);
            break;
        case inContent:
            if (mouse_window != FrontWindow())
                SelectWindow(mouse_window);
            else
                do_controls(mouse_window, mk_long(event->where));
            break;
        case inDrag:
            DragWindow(mouse_window, mk_long(event->where), &drag_rect);
            break;
        case inGrow:
            grow_window(mouse_window, mk_long(event->where));
            break;
        case inGoAway:
            if (TrackGoAway(mouse_window, mk_long(event->where)))
                finish();
            break;
        default:
            break;
    }
}

/* Find which part of which control was used. Then find out how the value
 * of that control has changed. Then call one of this applications routines
 * that performs the action that reflects the change in the control. In the
 * case of the up and down buttons, TrackControl calls an action routine
 * that should show some intermediate result, like srolling the screen
 * one line in an editor.
 */
do_controls(window, where)
```

```
    WindowPtr window;
    long where;
{
    int part_code, old_value, new_value;
    ControlHandle control;

    GlobalToLocal(&where);
    part_code = FindControl(where, window, &control);
    if (!part_code) return;
    check_update();
    (void)count(SET, 0);
    switch(part_code)
    {   case inUpButton:
            TrackControl(control, where, up_action);
            break;
        case inDownButton:
            TrackControl(control, where, down_action);
            break;
        case inPageUp:
        case inPageDown:
            page_movement(window, control, part_code);
            break;
        case inThumb:
            old_value = GetCtlValue(control);
            TrackControl(control, where, 0L);
            new_value = GetCtlValue(control);
            thumb_movement(window, control, old_value, new_value);
        default:
            break;
    }
}

check_update()
{
    EventRecord dummy;

    if (EventAvail(updateMask, &dummy))
        do_update(&dummy);
}

 pascal void
up_action(control, part_code)
    ControlHandle control;
{
    WindowPtr window = (*control)->contrlOwner;
    int old_value = GetCtlValue(control);

    SetCtlValue(control, old_value - 1);
    scroll_window(window, control, UP, 1);
    (void)count(ADD, 1);
}

 pascal void
down_action(control, part_code)
```

```
    ControlHandle control;
{
    WindowPtr window = (*control)->contrlOwner;
    int old_value = GetCtlValue(control);

    SetCtlValue(control, old_value + 1);
    scroll_window(window, control, DOWN, 1);
    (void)count(ADD, 1);
}

page_movement(window, control, part_code)
    WindowPtr window;
    ControlHandle control;
{
    int units = get_page_units(window, control);
    int direction = part_code == inPageUp ? UP : DOWN;
    int old_value = GetCtlValue(control);

    if (direction == DOWN)
        SetCtlValue(control, old_value + units);
    else
        SetCtlValue(control, old_value - units);
    scroll_window(window, control, direction, units);
}

thumb_movement(window, control, old_value, new_value)
    WindowPtr window;
    ControlHandle control;
{
    int units = old_value - new_value;
    int direction = units < 0 ? DOWN : UP;

    if (units)
    {   units = units < 0 ? -units : units;
        scroll_window(window, control, direction, units);
    }
}

get_page_units(window, control)
    WindowPtr window;
    ControlHandle control;
{
    return 5;
}

/* Set up the port rectangle and clipping for the window */
scroll_window(window, control, direction, units)
    WindowPtr window;
    ControlHandle control;
{
    Rect content;
    static RgnHandle save_clip = (RgnHandle)0;

    content = window->portRect;
    if (!save_clip) save_clip = NewRgn();
    else SetEmptyRgn(save_clip);
    content = window->portRect;
    content.right -= BAR_WIDTH;
    content.bottom -= BAR_WIDTH;
    GetClip(save_clip);
    ClipRect(&content);
    scroll_map(window, control, direction, units, &content);
    SetClip(save_clip);
}

/* Scroll the contents of the window and keep track of the offset in
 * the map structure
 */
scroll_map(window, control, direction, units, content)
    WindowPtr window;
    ControlHandle control;
    Rect *content;
{
    map_handle map = (map_handle)GetWRefCon(window);
    int max = GetCtlMax(control);
    long bar_id = GetCRefCon(control);
    int sign = direction == UP ? 1 : -1;
    int current, n_to_scroll;
    int scale = (*map)->view_scale;
    static RgnHandle to_update = (RgnHandle)0;

    if (!to_update) to_update = NewRgn();
    else SetEmptyRgn(to_update);
    current = bar_id == V_SCROLL ? (*map)->y_offset : (*map)->x_offset;
    units *= sign;
    units = (current - units) < 0 ? -current : units;
    units = (current - units) > max ? max - current : units;
    n_to_scroll = units * scale;
    if (bar_id == V_SCROLL)
    {   ScrollRect(content, 0, n_to_scroll, to_update);
        OffsetRgn(to_update, 0, scale * count(GET, 0) * sign);
        (*map)->y_offset -= units;
    }
    else
    {   ScrollRect(content, n_to_scroll, 0, to_update);
        OffsetRgn(to_update, scale * count(GET, 0) * sign, 0);
        (*map)->x_offset -= units;
    }
    InvalRgn(to_update);
}

count(op, arg)
{
    static int counter;

    switch (op)
    {   case SET: counter = arg; break;
        case ADD: counter += arg; break;
        case GET: break;
    }
    return counter;
}

/* Handle and update event - first determine if the event is in one of
 * this application's windows, and if so, update that window.
 */
do_update(event)
    EventRecord *event;
{
    GrafPtr save_graf;
    WindowPtr update_window = (WindowPtr)event->message;

    if (update_window == hello_window)
    {   GetPort(&save_graf);
        SetPort(update_window);
        BeginUpdate(update_window);
        EraseRect(&update_window->portRect);
        DrawGrowIcon(update_window);
        DrawControls(update_window);
        draw_content(update_window);
        EndUpdate(update_window);
        SetPort(save_graf);
    }
}

/* If the modifiers are odd, then this is an activate event for the
 * window pointed to in the message field of the event. If that is the case
 * then the graf port is set to that window's graf port
 */
do_activate(event)
    EventRecord *event;
{
    WindowPtr event_window = (WindowPtr)event->message;
    WindowPeek peek = (WindowPeek)event_window;
    ControlHandle control = (ControlHandle)peek->controlList;
    long label;

    if(event_window == hello_window)
    {   if (event->modifiers & 1)
        {   SetPort(event_window);
            DisableItem(GetMHandle(EDIT_MENU), 0);
            while (control)
            {   label = GetCRefCon(control);
                if (label == V_SCROLL || label == H_SCROLL)
                    ShowControl(control);
                control = (*control)->nextControl;
            }
        }
        else
        {   EnableItem(GetMHandle(EDIT_MENU), 0);
            while (control)
            {   label = GetCRefCon(control);
```

```
                if (label == V_SCROLL || label == H_SCROLL)
                    HideControl(control);
                control = (*control)->nextControl;
            }
        }
        DrawGrowIcon(event_window);
    }
}

/* Call the window manager routines that cause a window to grow */
grow_window(window, mouse_point)
    WindowPtr window;
    Point mouse_point;
{
    long new_bounds;

    inval_grow(window);
    new_bounds = GrowWindow(window, mk_long(mouse_point), &grow_bounds);
    if (new_bounds == 0)
        return;
    SizeWindow(window, LoWord(new_bounds), HiWord(new_bounds), TRUE);
    move_bars(window);
    inval_grow(window);
    size_map(window);
}

/* Invalidate the grow icon area of a standard window */
inval_grow(window)
    WindowPtr window;
{
    Rect temp_rect, port_rect;

    port_rect = window->portRect;
    SetRect(&temp_rect, port_rect.right - 16, port_rect.bottom - 16,
        port_rect.right, port_rect.bottom);
    InvalRect(&temp_rect);
}

/* Go through the list of controls for this window, identify the
 * scroll bars, and change their position and size to conform to the
 * window's new size
 */
move_bars(window)
    WindowPtr window;
{
    WindowPeek peek = (WindowPeek)window;

    ControlHandle control = peek->controlList;
    int new_top = window->portRect.top;
    int new_left = window->portRect.left;
    int new_bottom = window->portRect.bottom;
    int new_right = window->portRect.right;
    long label;
    while (control)
    {   label = GetCRefCon(control);
        if (label == V_SCROLL)
        {   HideControl(control);
            MoveControl(control, new_right - BAR_WIDTH, new_top - 1);
            SizeControl(control, 16, new_bottom - new_top - 13);
            ShowControl(control);
        }
        else if (label == H_SCROLL)
        {   HideControl(control);
            MoveControl(control, new_left - 1, new_bottom - BAR_WIDTH);
            SizeControl(control, new_right - new_left - 13, 16);
            ShowControl(control);
        }
        control = (*control)->nextControl;
    }
}

do_menu(command)
    long command;
{
    int menu_id = HiWord(command);
    int item = LoWord(command);
    char item_name[32];

    switch(menu_id)
    {   case APPLE_MENU:
            GetItem(GetMHandle(menu_id), item, item_name);
            OpenDeskAcc(item_name);
            break;
        case FILE_MENU:
            finish();
            break;
        case EDIT_MENU:
            SystemEdit(item - 1);
            break;
        case MAP_MENU:
            switch(item)
            {   case RESOLUTION: do_resolution(); break;
                case MAGNIFICATION:  do_magnification(); break;
                case POSITIONING:    do_positioning(); break;
            }
    }
    HiliteMenu(0);
}

/* Is this window one of my windows? */
my_window(window)
    WindowPtr window;
{
    if (window == hello_window)
        return TRUE;
    else
        return FALSE;
```

```
}

/* Find my front-most window */
 WindowPtr
foremost_window()
{
    WindowPeek window = (WindowPeek)FrontWindow();

    while (window)
    {   if (my_window(window)) return (WindowPtr)window;
        else window = window->nextWindow;
    }
    finish();
}

draw_content(window)
    WindowPtr window;
{
    Rect clip_rect;
    RgnHandle old_clip = NewRgn();

    clip_rect = window->portRect;
    clip_rect.right -= BAR_WIDTH;
    clip_rect.bottom -= BAR_WIDTH;
    GetClip(old_clip);
    ClipRect(&clip_rect);
    plot_map(window);
    SetClip(old_clip);
    DisposeRgn(old_clip);
}

/* Make a map and return a handle to it. It is sized to fit the values for
 * enought points in the complex plane to fill the specified window at the
 * specified scale
 */
 map_handle
make_map(window, start_at, step, scale)
    WindowPtr window;
    struct cx_num *start_at;
    double step;
{
    Size size = calc_map_size(window, scale);
    map_handle new_map = (map_handle)NewHandle(size);

    (*new_map)->start_at = *start_at;
    (*new_map)->step = step;
    (*new_map)->scale = (*new_map)->view_scale = scale;
    (*new_map)->last_x = (*new_map)->last_y = 0;
    (*new_map)->x_offset = (*new_map)->y_offset = 0;
    set_dimensions(window, new_map);
    make_columns(new_map);
    return new_map;
}
```

```
 Size
calc_map_size(window, scale)
    WindowPtr window;
{
    Size size = sizeof(struct map);
    long x_size = window->portRect.right - window->portRect.left;

    size += (((x_size - BAR_WIDTH) / scale) + 1) * sizeof(Handle);
    return size;
}

/* Set the dimensions of an existing map. The scale of the map must be set
 * before calling set_dimensions.
 */
set_dimensions(window, map)
    WindowPtr window;
    map_handle map;
{
    int x_size = window->portRect.right - window->portRect.left;
    int y_size = window->portRect.bottom - window->portRect.top;

    (*map)->x_dim = ((x_size - BAR_WIDTH) / (*map)->scale) + 1;
    (*map)->y_dim = ((y_size - BAR_WIDTH) / (*map)->scale) + 1;
}

make_columns(map)
    register map_handle map;
{
    register Size column_size = (*map)->y_dim;
    register int i;

    for (i = 0; i < (*map)->x_dim; i++)
        (*map)->map_values[i] = new_column(column_size);
}

 Handle
do_new_column(column_size, tries)
    register Size column_size;
{
    register Handle new = NewHandle(column_size);
    register int i;

    if (!new)
    {   if (tries > 5) finish();
        MoreMasters();
        return new_column(column_size, tries + 1);
    }
    for (i = 0; i < column_size; i++)
        (*new)[i] = NO_VALUE;
    return new;
}

 Handle
new_column(column_size)
```

```
    register Size column_size;
{
    return do_new_column(column_size, 0);
}

size_map(window)
    WindowPtr window;
{
    map_handle map = (map_handle)GetWRefCon(window);
    int x_size = window->portRect.right - window->portRect.left;
    int y_size = window->portRect.bottom - window->portRect.top;
    int new_x_dim, new_y_dim;

    new_x_dim = ((x_size - BAR_WIDTH) / (*map)->scale) + 1 +
                    (*map)->x_offset;
    new_y_dim = ((y_size - BAR_WIDTH) / (*map)->scale) + 1 +
                    (*map)->y_offset;
    if (new_x_dim > (*map)->x_dim || new_y_dim > (*map)->y_dim)
    {   grow_map(map, new_x_dim, new_y_dim);
        (*map)->last_x = (*map)->last_y = 0;
    }
    adjust_bars(window);
}

/* Grow the map, if needed */
grow_map(map, new_x_dim, new_y_dim)
    register map_handle map;
    register int new_x_dim, new_y_dim;
{
    int x_diff = new_x_dim - (*map)->x_dim;
    int y_diff = new_y_dim - (*map)->y_dim;
    register Size old_size, new_size;
    register int x, y, new_dim;

    /* Add new columns, if needed */
    if (x_diff > 0)
    {   old_size = GetHandleSize((Handle)map);
        new_size = old_size + (x_diff * sizeof(Handle));
        SetHandleSize((Handle)map, new_size);
        new_size = y_diff > 0 ? new_y_dim : (*map)->y_dim;
        for (x = (*map)->x_dim; x < new_x_dim; x++)
        {   (*map)->map_values[x] = new_column(new_size);
            if (MemError()) finish();
        }
    }
    /* Extend existing columns, if needed */
    if (y_diff > 0)
    {   new_size = new_y_dim;
        for (x = 0; x < (*map)->x_dim; x++)
        {   SetHandleSize((*map)->map_values[x], new_size);
            if (MemError()) finish();
            for (y = (*map)->y_dim; y < new_y_dim; y++)
                VALUE(map, x, y) = NO_VALUE;
        }
    }
    /* Store the new dimensions in the map */
    if (x_diff > 0) (*map)->x_dim = new_x_dim;
    if (y_diff > 0) (*map)->y_dim = new_y_dim;
}

/* After a window has been re-sized, some parts of the map may no longer
 * be visible. If so, the scroll bars should be enabled and set to the
 * correct range and starting value for the new window size.
 */
adjust_bars(window)
    WindowPtr window;
{
    map_handle map = (map_handle)GetWRefCon(window);
    int scale = (*map)->scale;
    int x_max = (*map)->x_dim - 1;
    int y_max = (*map)->y_dim - 1;
    int x_max_in_view = (window->portRect.right - BAR_WIDTH) / scale;
    int y_max_in_view = (window->portRect.bottom - BAR_WIDTH) / scale;
    int diff;

    if (!(*map)->x_offset && (diff = x_max - x_max_in_view) <= 0)
        turn_off_control(window, V_SCROLL);
    else init_bar(window, V_SCROLL, (*map)->x_offset, diff);
    if (!(*map)->y_offset && (diff = y_max - y_max_in_view) <= 0)
        turn_off_control(window, H_SCROLL);
    else init_bar(window, H_SCROLL, (*map)->y_offset, diff);
}

/* Initialize the range and value of a scroll bar */
init_bar(window, id, value, range)
    WindowPtr window;
{
    ControlHandle control = lookup_control(window, id);
    map_handle map  = (map_handle)GetWRefCon(window);

    if (!range) switch_control(window, id, 255);
    else
    {   SetCtlMin(control, 0);
        SetCtlMax(control, range);
        SetCtlValue(control, value);
        switch_control(window, id, 0);
        InvalRect(&(*control)->contrlRect);
    }
}

/* Hilite a control in such a way as to show that it is inactive. Here
 * we use "255" hiliting assuming we do not want to know about mouse
 * clicks in the control.
 */
turn_off_control(window, id)
    WindowPtr window;
{
    switch_control(window, id, 255);
```

```
}

/* Find a control and hilite it - if 254 or 255 are used as values
 * of hiliting, the control is turned off.
 */
switch_control(window, id, hilite)
    WindowPtr window;
{
    ControlHandle control = lookup_control(window, id);

    HiliteControl(control, hilite);
}

 ControlHandle
lookup_control(window, id)
    WindowPtr window;
{
    ControlHandle control = ((WindowPeek)window)->controlList;
    long label;

    while (control)
    {   label = GetCRefCon(control);
        if (LoWord(label) == id) break;
        control = (*control)->nextControl;
    }
    return control;
}

/* make the assumption that resolution changes by multiples of two */
do_resolution()
{
    WindowPtr window = foremost_window();
    map_handle map = (map_handle)GetWRefCon(window);
    int new_scale = get_new_resolution(map);
    int old_scale = (*map)->scale;
    int scale_factor = old_scale / new_scale;
    int new_x_dim, new_y_dim;

    if (new_scale < old_scale)
    {   new_x_dim = (*map)->x_dim * scale_factor;
        new_y_dim = (*map)->y_dim * scale_factor;
        grow_map(map, new_x_dim, new_y_dim);
        (*map)->scale = new_scale;
        spread_data(map, scale_factor);
    }
    if (((*map)->view_scale = new_scale) != old_scale);
    {   InvalRect(&window->portRect);
        (*map)->last_x = (*map)->last_y = 0;
        (*map)->x_offset *= scale_factor;
        (*map)->y_offset *= scale_factor;
        adjust_bars(window);
    }
}
```

```
/* Ask the user for a new scale for the map */
get_new_resolution(map)
    map_handle map;
{
    DialogPtr dialog;
    int scale = (*map)->view_scale;
    int item;

    dialog = GetNewDialog(RES_DIALOG, 0L, -1L);
    dialog_radio(dialog, scale_to_button(scale));
    while (1)
    {   ModalDialog(0L, &item);
        switch (item)
        {   case RES_D_CANCEL:
                scale = (*map)->view_scale;   /* Fall through... */
            case RES_D_OK:
                DisposDialog(dialog);
                return scale;
            case RES_D_COARSE:
                scale = COARSE;
                dialog_radio(dialog, item);
                continue;
            case RES_D_MEDIUM:
                scale = MEDIUM;
                dialog_radio(dialog, item);
                continue;
            case RES_D_FINE:
                scale = FINE;
                dialog_radio(dialog, item);
                continue;
            case RES_D_EXTRA_FINE:
                scale = EXTRA_FINE;
                dialog_radio(dialog, item);
                continue;
            default:
                continue;
        }
    }
    return (*map)->view_scale;
}

scale_to_button(scale)
{
    switch(scale)
    {   case COARSE: return RES_D_COARSE;
        case MEDIUM: return RES_D_MEDIUM;
        case FINE: return RES_D_FINE;
        case EXTRA_FINE: return RES_D_EXTRA_FINE;
    }
}

/* Given an item number for a radio button, turn that button on
 * and the other buttons off. This assumes that all the radio buttons
 * in the dialog are related.
 */
dialog_radio(dialog, item)
    DialogPtr dialog;
{
    int type, i;
    ControlHandle button;
    Rect box;
    int n_items = **(int **)((DialogPeek)dialog)->items + 2;

    for(i = 1; i < n_items; i++)
    {   GetDItem(dialog, i, &type, (Handle *)&button, &box);
        if (type == (ctrlItem | radCtrl))
            SetCtlValue(button, i == item ? 1 : 0);
    }
}

/* Take a map that has been increased in size by the specified scale
 * factor and spread the existing data out over the map
 */
spread_data(map, scale_factor)
    register map_handle map;
    register int scale_factor;
{
    register int x, y, x1, y1;
    register Handle swap_temp;
    int old_x_dim = (*map)->x_dim / scale_factor;
    int old_y_dim = (*map)->y_dim / scale_factor;

    /* First spread the data in the columns */
    for (x = 0; x < old_x_dim; x++)
    {   for (y = old_y_dim - 1, y1 = (*map)->y_dim - scale_factor; y > 0;
                y--, y1 -= scale_factor)
        {   VALUE(map, x, y1) = VALUE(map, x, y);
            VALUE(map, x, y) = NO_VALUE;
        }
    }
    /* Then spread the columns by switching them with the new columns */
    for (x = old_x_dim - 1, x1 = (*map)->x_dim - scale_factor; x > 0;
            x--, x1 -= scale_factor)
    {   swap_temp = (*map)->map_values[x];
        (*map)->map_values[x] = (*map)->map_values[x1];
        (*map)->map_values[x1] = swap_temp;
    }

}

do_magnification()
{
}

do_positioning()
{
    DialogPtr pos_dialog;
    int item, type, got_mouse = 0;
    Rect box;
    GrafPtr save_graf;
    Point mouse_point, new_mouse_point;

    pos_dialog = GetNewDialog(POS_DIALOG, 0L, -1L);
    if (!pos_dialog) return;
    GetDItem(pos_dialog, POS_D_BOX, &type, &item, &box);
    GetPort(&save_graf);
    SetPort(pos_dialog);
    draw_pos_box(&box);
    while (1)
    {   ModalDialog((ProcPtr)0L, &item);
        switch (item)
        {   case POS_D_BOX:
                GetMouse(&mouse_point);
                new_position(mk_long(mouse_point), 0);
                while(StillDown())
                {   GetMouse(&new_mouse_point);
                    if (mk_long(mouse_point) != mk_long(new_mouse_point))
                    {   mouse_point = new_mouse_point;
                        new_position(mk_long(mouse_point), 0);
                    }
                }
                got_mouse = 1;
                continue;
            case POS_D_OK:
                if (got_mouse)
                {   new_position(0L, 1);
                    break;
                }
                else continue;
            case POS_D_CANCEL:
                SetPort(save_graf);
                DisposDialog(pos_dialog);
                return;
            default:
                continue;
        }
        break;
    }
    SetPort(save_graf);
    DisposDialog(pos_dialog);
    move_map(&box, mk_long(mouse_point));
}

/* Calculate the new origin of the map from the position of a point
 * withing the box, and initialize the map.
 */
move_map(box, place)
    Rect *box;
    long place;
{
    Point point;
    int side = box->right - box->left;          /* Assume it is square */
    WindowPtr map_window = hello_window;  /* For now only one window */
    register map_handle map = (map_handle)GetWRefCon(map_window);
    struct cx_num new_origin;
    register int x, y;
    Rect content;

    point = *(Point *)&place;
    point.h = (point.h - box->left) - side / 2;
    point.v = side / 2 - (point.v - box->top);
    new_origin.real = (double)point.h / (double)50;
    new_origin.imag = (double)point.v / (double)50;
    (*map)->start_at = new_origin;
    (*map)->last_x = (*map)->last_y = 0;
    for (x = 0; x < (*map)->x_dim; x++)
    {   for (y = 0; y < (*map)->y_dim; y++)
            VALUE(map, x, y) = NO_VALUE;
    }
    content = map_window->portRect;
    content.bottom -= BAR_WIDTH;
    content.right -= BAR_WIDTH;
    InvalRect(&content);
    EraseRect(&content);
    ValidRect(&content);
}

draw_pos_box(box)
    Rect *box;
{
    int side = box->right - box->left;     /* Assume it is square */

    FrameRect(box);
    MoveTo(box->left + side / 2, box->top);
    Line(0, side - 1);
    MoveTo(box->left, box->top + side / 2);
    Line(side - 1, 0);
    MoveTo(box->left + side / 2 + 3, box->top + side / 2 + 12);
    DrawText("(0,0)", 0, 5);
    draw_map_rects(box);
}

draw_map_rects(box)
    Rect *box;
{
    Rect rect;
    double x, y;
    int side = box->right - box->left;     /* Assume it is square */
    WindowPtr window = FrontWindow();
    map_handle map;

    for(; window; window = (WindowPtr)((WindowPeek)window)->nextWindow)
    {   if (my_window(window))
        {   map = (map_handle)GetWRefCon(window);
            x = (*map)->start_at.real;
            y = (*map)->start_at.imag;
            rect.top = (side / 2) - (int)(y * 50) + box->top;
            rect.left = (side / 2) + (int)(x * 50) + box->left;
            rect.bottom = rect.top +
                (int)((*map)->step * (*map)->scale * (*map)->y_dim * 50);
            rect.right = rect.left +
                (int)((*map)->step * (*map)->scale * (*map)->x_dim * 50);
            FillRect(&rect, &gray);
            FrameRect(&rect);
        }
    }
}

/* Mark the new position. The pen mode is patCopy after this routine
 * is called. If "final" is non-zero, cur_position is used as a new
 * origin for the map.
 */
new_position(where, final)
    long where;
{
    static int position_valid = 0;
    static long cur_position;

    PenMode(patXor);
    if (position_valid)
        x_marks_new_spot(cur_position);
    x_marks_new_spot(where);
    cur_position = where;
    position_valid = 1;
    PenMode(patCopy);
    if (final)
        position_valid = 0;
}

/* Draws an "+" at the specified spot in the current pen mode. So if the
 * mode is patXor, this routine can be used to erase old spots.
 */
x_marks_new_spot(spot)
    long spot;
{
    Point point;

    point = *(Point *)&spot;
    MoveTo(point.h - 2, point.v);
    Line(4, 0);
    MoveTo(point.h, point.v - 2);
    Line(0, 4);
}

/* Fill in the map. Real numbers go left to right, increasing.
 * Imaginary numbers go top to bottom, decreasing. We calculate a value
 * for a point if: 1) It has no value; 2) It would be visible at the
 * current resolution OR we have already finished calculating all the
 * visible points.
 */
```

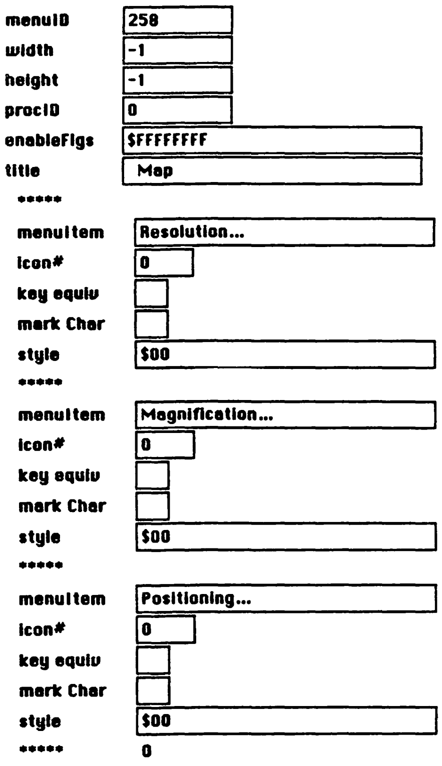
```
fill_in_map(window)
    WindowPtr window;
{
    register map_handle map = (map_handle)GetWRefCon(window);
    register double step = (*map)->step;
    register int x = (*map)->last_x;
    register int y = (*map)->last_y;
    register int scale = (*map)->scale;
    register int scale_ratio = (*map)->view_scale / scale;
    PicHandle pict;
    struct cx_num where;

    for (; x < (*map)->x_dim; x++)
    {   for (; y < (*map)->y_dim; y++)
        {   if (VALUE(map, x, y) == NO_VALUE &&
                    (scale_ratio == 1 ||
                        !(x % scale_ratio || y % scale_ratio)))
            {   where.real = (*map)->start_at.real + (x * step * scale);
                where.imag = (*map)->start_at.imag - (y * step * scale);
                ((VALUE(map, x, y) = calc_value(&where)) != NO_VALUE);
                    paint_point(window, x, y);
                (*map)->last_x = x; (*map)->last_y = y;
                return;
            }
        }
        y = 0;  /* Start another column */
    }
}

/* Check if a point is inside the Mandelbrot Set. If the magnitude
 * of the complex number has not exceeded 2 in 700 iterations, it is
 * most likely IN the mandelbrot set. Otherwise it lies outside and
 * the the number of iterations it took to determine this is used to
 * select a pattern for that point. We check for pending events every
 * 128 iterations.
 */
 char
calc_value(where)
    register struct cx_num *where;
{
    register double val_real, val_imag, sq_real, sq_imag;
    register int count;
    EventRecord dummy;

    val_real = val_imag = 0.0;
    for (count = 0; count < 700; count++)
    {   sq_real = val_real * val_real;
        sq_imag = val_imag * val_imag;
        if ((sq_real + sq_imag) > 4.0) break;
        if (!(count & 0x7F) && EventAvail(everyEvent, &dummy))
            return NO_VALUE;
        val_imag = (val_real * val_imag * 2.0) + where->imag;
        val_real = sq_real - sq_imag + where->real;
    }
    return which_pattern(count);
}

/* Select a pattern based on whether a point is in the Mandlebrot Set, or
 * if it lies outside, how soon was it determined to lie outside.
 */
 char
which_pattern(count)
{
    if (count >= 700) return BLACK;
    else if (count > 60) return WHITE;
    else if (count > 24) return LIGHT_GRAY;
    else if (count > 15) return GRAY;
    else return DARK_GRAY;
}

paint_point(window, x, y)
    WindowPtr window;
{
    GrafPtr save_graf;
    register map_handle map = (map_handle)GetWRefCon(window);
    register int scale = (*map)->view_scale;
    register int scale_ratio = scale / (*map)->scale;
    register int inval_x = (x - (*map)->x_offset) / scale_ratio,
        inval_y = (y - (*map)->y_offset) / scale_ratio;
    Rect rect, content;

    content = window->portRect;
    content.bottom -= BAR_WIDTH; content.right -= BAR_WIDTH;
    inval_x *= scale; inval_y *= scale;
    SetRect(&rect, inval_x, inval_y, inval_x + scale, inval_y + scale);
    if (SectRect(&rect, &content, &rect))
    {   GetPort(&save_graf);
        SetPort(window);
        InvalRect(&rect);
        plot_one(map, x, y);
        ValidRect(&rect);
        SetPort(save_graf);
    }
}

plot_map(window)
    WindowPtr window;
{
    register map_handle map = (map_handle)((WindowPeek)window)->refCon;
    register int scale_ratio = (*map)->view_scale / (*map)->scale;
    register int x, y;

    for (x = 0; x < (*map)->x_dim; x += scale_ratio)
    {   for (y = 0; y < (*map)->y_dim; y += scale_ratio)
            plot_one(map, x, y);
    }
}
```

```
/* Plot one point in the map.
 */
plot_one(map, x, y)
    map_handle map;
    register int x, y;
{
    register int fill_with = VALUE(map, x, y);
    register int scale = (*map)->scale;
    register int view_scale = (*map)->view_scale;
    Rect to_fill;

    x -= (*map)->x_offset; y -= (*map)->y_offset;
    x *= scale; y *= scale;
    SetRect(&to_fill, x, y, x + view_scale, y + view_scale);
    switch(fill_with)
    {   case BLACK: FillRect(&to_fill, &black); break;
        case WHITE: FillRect(&to_fill, &white); break;
        case LIGHT_GRAY: FillRect(&to_fill, &ltGray); break;
        case GRAY: FillRect(&to_fill, &gray); break;
        case DARK_GRAY: FillRect(&to_fill, &dkGray); break;
        case NO_VALUE:
            break;
    }
}

/* Exit the program cleanly */
finish()
{
    ExitToShell();
}
```

The resources for the example program

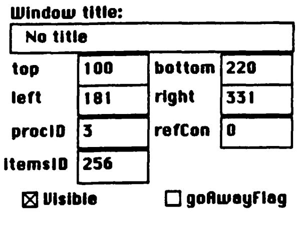
In addition to the resources used in the example program of the previous chapter, a menu and two dialog boxes have been added to support operations that affect the map of the Mandelbrot set (e.g. map resolution).

The additional menu is described in the following screen-shots of ResEdit dialogs:



menuID	258
width	-1
height	-1
procID	0
enableFlgs	$FFFFFFFF
title	Map
*****	
menuItem	Resolution...
icon#	0
key equiv	
mark Char	
style	$00
*****	
menuItem	Magnification...
icon#	0
key equiv	
mark Char	
style	$00
*****	
menuItem	Positioning...
icon#	0
key equiv	
mark Char	
style	$00
*****	0

The dialogs added to the skeletons application are described below. First, the dialog itslef is described. It has an ID of 256, corresponding to the constant defined in the file mandelbrot.h.

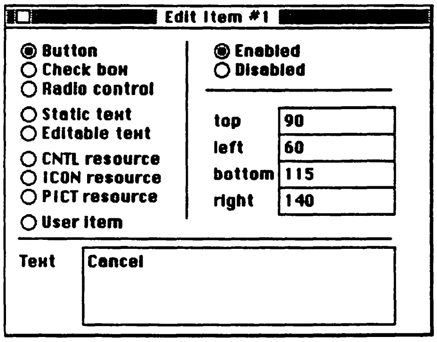


Window title:
No title

top	100	bottom	220
left	181	right	331
procID	3	refCon	0
itemsID	256		

☒ Visible ☐ goAwayFlag

The parts of this dialog are numbered from one to six, starting with the default button which, in this case, is the "Cancel" button:

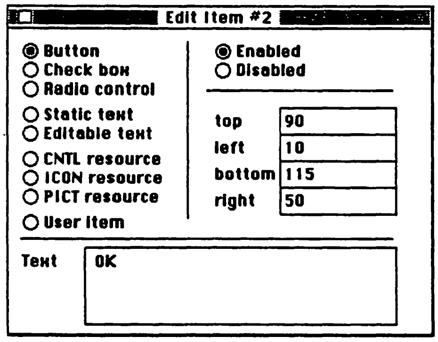

Edit Item #1

[✓ Button] Check box Radio control Static text Editable text CNTL resource ICON resource PICT resource User item

[✓ Enabled] Disabled

top	90
left	60
bottom	115
right	140

Text: Cancel

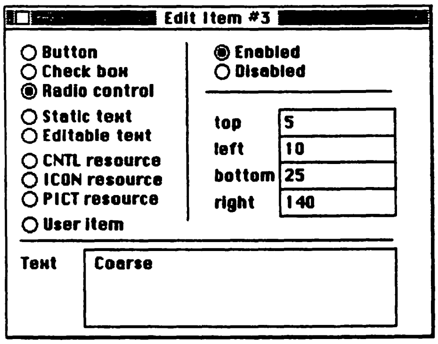

Edit Item #2

[✓ Button] Check box Radio control Static text Editable text CNTL resource ICON resource PICT resource User item

[✓ Enabled] Disabled

top	90
left	10
bottom	115
right	50

Text: OK

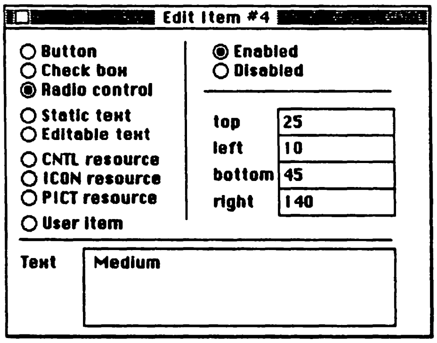

Edit Item #3

Button Check box [✓ Radio control] Static text Editable text CNTL resource ICON resource PICT resource User item

[✓ Enabled] Disabled

top	5
left	10
bottom	25
right	140

Text: Coarse

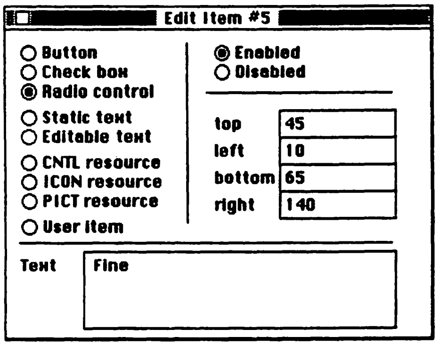

Edit Item #4

Button Check box [✓ Radio control] Static text Editable text CNTL resource ICON resource PICT resource User item

[✓ Enabled] Disabled

top	25
left	10
bottom	45
right	140

Text: Medium

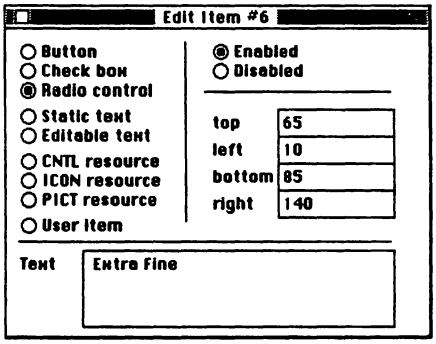

Edit Item #5

Button Check box [✓ Radio control] Static text Editable text CNTL resource ICON resource PICT resource User item

[✓ Enabled] Disabled

top	45
left	10
bottom	65
right	140

Text: Fine


Edit Item #6

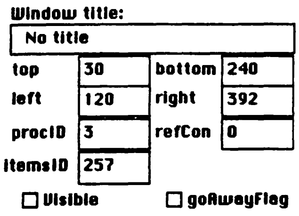
Button Check box [✓ Radio control] Static text Editable text CNTL resource ICON resource PICT resource User item

[✓ Enabled] Disabled

top	65
left	10
bottom	85
right	140

Text: Extra Fine

The position of the map on the page is also determined by a dialog box, this one with the ID of 257:

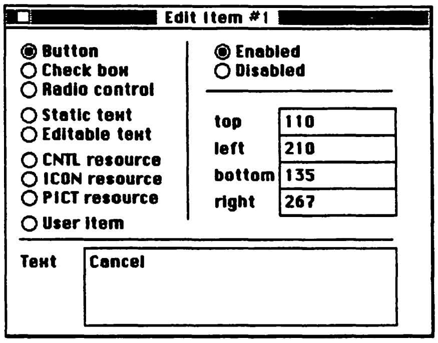

Window title:

No title

top	30	bottom	240
left	120	right	392
procID	3	refCon	0
itemsID	257		

☐ Visible ☐ goAwayFlag

This dialog has two buttons and auser item. The user item is used to contain a diagram of the coordinates of the map:



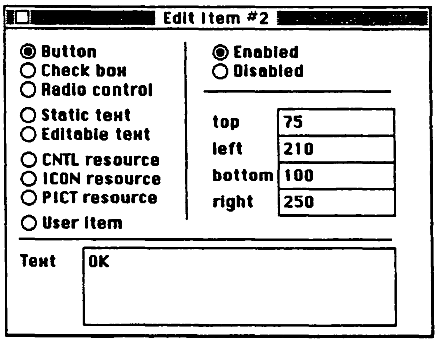
Edit Item #1

[✓ Button]
Check box
Radio control
Static text
Editable text
CNTL resource
ICON resource
PICT resource
User item

[✓ Enabled]
Disabled

top	110
left	210
bottom	135
right	267

Text: Cancel



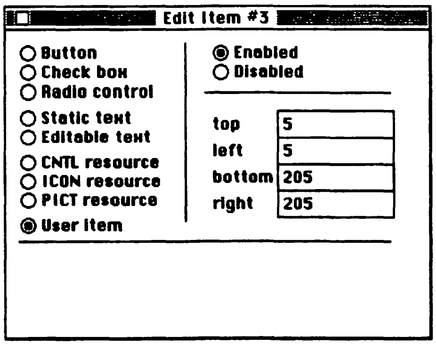
Edit Item #2

[✓ Button]
Check box
Radio control
Static text
Editable text
CNTL resource
ICON resource
PICT resource
User item

[✓ Enabled]
Disabled

top	75
left	210
bottom	100
right	250

Text: OK



Edit Item #3

Button
Check box
Radio control
Static text
Editable text
CNTL resource
ICON resource
PICT resource
[✓ User item]

[✓ Enabled]
Disabled

top	5
left	5
bottom	205
right	205

Extracting information from this listing

The example program above is hundreds of lines long. It would be impractical to try to comprehend every corner of it without a machine-readable copy and the time to modify and play with it. The information you can extract from this listing, and the one in the next chapter that lists the final form of the example program, is code that is *analogous* to code that you are trying to write. Not every type of graphics update situation is covered here, but a representative one is. Similarly, you may find solutions to other problems in the example program's code that handles scroll bars, mouse tracking, user items in dialogs, etc. While examples cannot be comprehensive, you will need to refer to examples to give substance to reference information, and to fill in the spaces between available reference information.

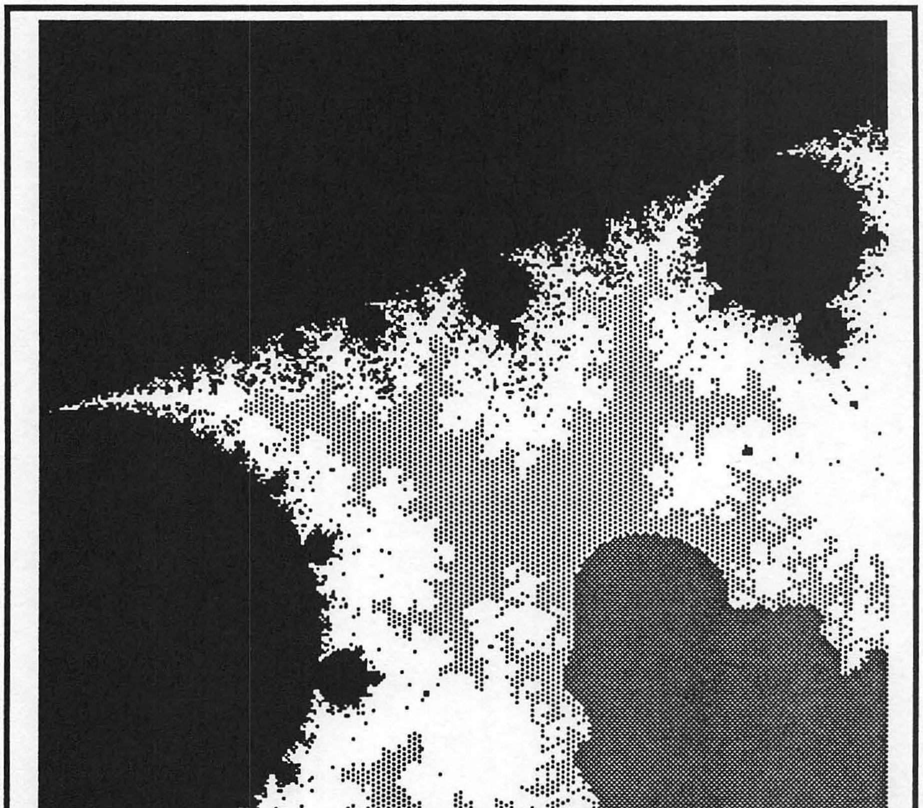
Example code is, in general, the fastest way to learn how to work within the framework of an unfamiliar system. But in order to keep from picking up other people's bad habits, you should accompany you study of examples with a good familiarity with the reference material available to Macintosh programmers.

POINTS TO CONSIDER

1. What would you do to extend the usefulness of this program in exploring the Mandelbrot set?

2. What would you do to make the user interface better?

3. What would you do to optimize redisplay? Where could you trade space for time?



9

Extending Our Grasp

- Creating files; writing into them and reading from them
- Why the Macintosh has two file systems
- How to print out plots on any printer attached to the Macintosh

Completing the application

With the ability to file, cut-and-paste, and print, the Mandelbrot mapping program becomes a complete Macintosh application. By using the framework of this example program, you can conveniently create your own applications.

The source code of our Mandelbrot Set explorer has become large compared to most example programs presented in books that describe programming techniques. Often it is not possible to describe programming for a machine or system with a monolithic example. Unix programs have a much more varied structure than Macintosh programs: Graphics programs have fundamentally different structure than interactive editors, which are in turn different from simple "filter" programs. MS-DOS applications are even more widely varied. User interface standards and programming techniques are diverse, and this diversity is reflected in the lack of user interface standards among Unix and MS-DOS programs.

We have already discussed the impact of the lack of a standard application structure on the user, but there is an effect on programmers as well: On systems unlike the Macintosh, there is no comprehensive framework in which to present programming techniques. The example program presented here can be the foundation of almost any Macintosh application. The structure is equally applicable to business applications, games, and scientific programming.

Choices for filing

The Macintosh has two file systems: the Macintosh File System (MFS) and the Hierarchical File System (HFS). This is deplorable, but not a disaster. If your application is written correctly, it does not need to know which kind of file system it is dealing with and it can use both at the same time.

Another source of confusion in dealing with the Macintosh file system is the two sets of file system traps. There is one set of higher level traps that perform simple file system operations like read, write, and seek. Another set of lower-level functions replicates capabilities of the higher level functions but with a different interface. The lower level functions accept their arguments in parameter blocks, which are data structures that contain all of the items that are used as parameters and also contain return values in all of the file system and device manager calls. The advantage to using parameter block calls is that one parameter block can be used in many calls and that the parameter block interface is more efficient than the high-level interface because the high level interface is translated into the parameter block interface.

In extending our application to save and restore Mandelbrot Set plots in disk files, we keep the filing operations as simple as possible. We use only the higher level file-system interactions supplied by Toolbox routines, and we do not implement any filing operations that have to be aware of directories.

Why two file systems?

The newer Hierarchical File System is an improvement on the original Macintosh File System in several ways. in MFS, each volume could hold only a small number of files, and the organization of the volume into folders was maintained and displayed by the Finder. So although folders could be inside folders, and the Finder diplayed a desktop organized hierarchically, the hierarchy was visible only to the Finder. From an application's point of view, there was no hierarchy at all.

When a user opens a file on an MFS volume, he is presented with all the files (or a selection of up to four file-types) on that volume. Now that hard disks are a common Macintosh accessory, the number of files displayed in a standard file dialog could become unwieldy. Even on disk systems like the Hyperdrive that can divide a physical disk into several volumes, the number of files in a volume could become unmanageable.

Filing in the example program

Sticking to the high-level file system calls may seem to be a simple prescription for file system independence, but many existing programs do not work correctly on HFS volumes. They may fail to find their documents, or they may fail to find system resources. It is easy to get distracted by issues surrounding ancillary files and documents.

Choices for cut-and-paste

The scrap manager is a way of keeping track of two kinds of standard information, and application-specific information as well. An example of application specific scrap information is the information that MacWrite deposits in the desk scrap when a passage is cut out of a MacWrite document. This scrap information consists of the passage as a standard "text" scrap and as a "mwrt" scrap usable only by MacWrite.

For the example program, we use the standard "pict" type of scrap.

Choices for printing

There are three primary choices for printing in Macintosh applications:

1. Draft printing. Draft printing uses a "native" printing style available on the printer being used. In MacWrite, draft printing provides a quick way to print out drafts of a document without much regard for the final appearance.

2. "Spool" printing. This kind of printing is not to be confused with the usual meaning of spooling. Spool printing is not deferred, and your application can not, in general, do anything else but print while spool printing. This kind of printing called spool printing because information may be buffered on disk in the course of printing a document.

   Spool printing is the most complicated form of printing. It involves creating bit-images in grafPorts that reflect the native resolution of the printer being used. It may take several passes to fill a page.

3. Bit map printing. Bit map printing is a simplified version of spool printing. Bit map printing lets an application copy a bit map onto a printer. This kind of printing is well suited to printing Mandelbrot Set plots.

Printing in our application

In our application we will implement bit map printing. Bit map printing is the quickest and easiest printing method for graphics oriented applications. Bit map printing would have been a bad choice for an application that uses text heavily because many printer drivers handle text specially. Spool printing would be the best choice for text.

The last listing

This is the example program in its final form. It is now a complete Macintosh application capable of all of the operations any commercial application can perform.

```
#include <Quickdraw.h>
#include <WindowMgr.h>
#include <ControlMgr.h>
#include <EventMgr.h>
#include <DeskMgr.h>
#include <MenuMgr.h>
#include <ToolboxUtil.h>
#include <MemoryMgr.h>
#include <DialogMgr.h>
#include <FileMgr.h>
#include <StdFilePkg.h>
#include <PrintMgr.h>

struct cx_num           /* A complex number */
{   double real;        /* The real part */
    double imag;        /* The imaginary part */
};

struct map                          /* A map structure */
{   int modified;                   /* Is this map modified */
    char save_file[32];             /* The file to save this map in */
    int save_volume;                /* The volume refnum of the save file */
    struct cx_num start_at;         /* Complex number at top left corner */
    double step;                    /* The granularity from point to point */
    int scale;                      /* Scale at which we calculate the map */
    int view_scale;                 /* Scale at which we draw the map */
    int x_offset, y_offset;         /* The offset we begin drawing at */
    int x_dim, y_dim;               /* The dimensions of the map */
    int last_x, last_y;             /* Where we left off */
    Handle map_values[1];           /* An array  of column handles, allocated
                                       to the correct size */
};

/* Find the X'th handle, and the Y'th byte in the array refered to by
 * that handle
 */
#define VALUE(MAP, X, Y) (*(*MAP)->map_values[X])[Y]

typedef struct map **map_handle;

pascal void SysBeep() = 0xA9C8;   /* The beep trap */

pascal void up_action(), down_action();
char calc_value(), which_pattern();
Size calc_map_size();
map_handle make_map(), read_in_map();
Handle new_column();
WindowPtr make_window(), foremost_window();
ControlHandle lookup_control();

#define V_SCROLL 256      /* Resource ID of the vertical scroll bar */
#define H_SCROLL 257      /* Resource ID of the horizontal scroll bar */

#define BAR_WIDTH 15      /* The width of a scroll bar */
```

```
#define NO_VALUE 0       /* Haven't calculated the value */
#define BLACK 1          /* Corresponds to the pattern black */
#define WHITE 2          /* Corresponds to the pattern white */
#define LIGHT_GRAY 3     /* Corresponds to the pattern ltGray */
#define GRAY 4           /* Corresponds to the pattern gray */
#define DARK_GRAY 5      /* Corresponds to the pattern dkGray */

#define UP 1             /* Scrolling up? */
#define DOWN 2           /* Or down? */

#define APPLE_MENU 1     /* The menu marked by the Apple symbol */
#define FILE_MENU 256    /* The "File" menu */
#define EDIT_MENU 257    /* the "Edit" menu */
#define MAP_MENU 258     /* Controls map paramters */

/* Items on the file menu */
#define NEW 1
#define OPEN 2
#define CLOSE 3
#define SAVE 4
#define SAVE_AS 5
#define REVERT 6
#define FILE_LINE_1 7
#define PRINT 8
#define FILE_LINE_2 9
#define QUIT 10

/* Items on the map menu */
#define RESOLUTION 1
#define MAGNIFICATION 2
#define POSITIONING 3

#define RES_DIALOG 256   /* Get a new resolution for the map */

/* Buttons in the new-resolution dialog */
#define RES_D_CANCEL 1
#define RES_D_OK 2

#define RES_D_COARSE 3
#define RES_D_MEDIUM 4
#define RES_D_FINE 5
#define RES_D_EXTRA_FINE 6

#define POS_DIALOG 257   /* Start a map at a new position */

/* Items in the positioning dialog */
#define POS_D_CANCEL 1
#define POS_D_OK 2
#define POS_D_BOX 3

/* Scale values stored in maps */
#define EXTRA_FINE 1
#define FINE 2
```

```
#define MEDIUM 4
#define COARSE 8

/* Initial values */
#define INIT_REAL -0.775      /* The initial starting point */
#define INIT_IMAG 0.260       /* The initial starting point */
#define INIT_STEP 0.001       /* The initial step value */
#define INIT_SCALE MEDIUM     /* The initial scale factor */

/* Operations the count routine supports */
#define SET 1
#define GET 2
#define ADD 3

#define DRVR 0x44525652L      /* The string "DRVR" as a long */
#define STR_ 0x53545220L      /* The string "STR " as a long */
#define MNAP 0x4d4e4150L
#define MANM 0x4d4e4150L

#define SAVE_AS_PROMPT    256 /* String resource for the prompt in the
                               * SFPutFile dialog
                               */

#define SAVE_CANCEL        -1 /* Returned if save operation is cancelled */

#define SC_CANCEL    1
#define SC_YES       2
#define SC_NO        3

#define mk_long(x)   (*((long *)&(x)))
```

The file "mandelbrot.c"

```
#include "mandelbrot.h"

GrafPtr w_port;
WindowRecord w_record;
WindowPtr hello_window;
Rect drag_rect, grow_bounds;
Point get_put = { 100, 100 };

int white_max = 700;      /* Above this value, assign black */
int lt_gray_max = 60;     /* Above this value, assign white */
int gray_max = 24;        /* Above this value, assign light gray */
int dk_gray_max = 15;     /* Above this value, assign gray */
                          /* Below dk_gray_max, assign dark gray */

main()
{
    init_process();  /* do all the initialization */
    make_window(hello_window = (WindowPtr)&w_record);
    event_loop();
}
```

```
/* Do all the right initialization things
 */
init_process()
{
    init_mgrs();
    set_parameters();
    fill_menus();
}

/* Do the right thing for most applications: Call the toolbox
 * initialization routines.
 */
init_mgrs()
{
    InitGraf(&thePort);
    InitFonts();
    InitWindows();
    FlushEvents(everyEvent, 0);
    InitCursor();
    InitMenus();
    TEInit();
    InitDialogs(0L);
    MaxApplZone();
}

/* Set parameters based on screen size, etc. */
set_parameters()
{
    drag_rect = thePort->portRect;
    SetRect(&grow_bounds, 64, 64, thePort->portRect.right,
        thePort->portRect.bottom);
}

fill_menus()
{
    MenuHandle menu;

    menu = GetMenu(APPLE_MENU);
    AddResMenu(menu, DRVR);
    InsertMenu(menu, 0);
    InsertMenu(GetMenu(FILE_MENU), 0);
    InsertMenu(GetMenu(EDIT_MENU), 0);
    InsertMenu(GetMenu(MAP_MENU), 0);
    DrawMenuBar();
}

/* Read window information from the resource branch into a window
 * structure. Get the scroll bars for this window and mark them to
 * distinguish them from any other controls that might be in this window.
 * The parameter points to an uninitialized window record
 */
 WindowPtr
make_window(new_window)
    WindowPtr new_window;
```

```
{
    ControlHandle scroll_bar;
    struct cx_num start_at;
    map_handle new_map;

    new_window = GetNewWindow(256, new_window, -1L);
    scroll_bar = GetNewControl(V_SCROLL, new_window);
    SetCRefCon(scroll_bar, (long)V_SCROLL);
    scroll_bar = GetNewControl(H_SCROLL, new_window);
    SetCRefCon(scroll_bar, (long)H_SCROLL);
    move_bars(new_window);
    start_at.real = INIT_REAL; start_at.imag = INIT_IMAG;
    new_map = make_map(new_window, &start_at, INIT_STEP, INIT_SCALE);
    SetWRefCon(new_window, (long)new_map);
    init_bar(new_window, H_SCROLL, 0, 0);
    init_bar(new_window, V_SCROLL, 0, 0);
    fill_in_map(new_window);
}

/* Get an event, switch on its type, and perform the appropriate
 * action
 */
event_loop()
{
    EventRecord my_event;
    Boolean valid;

    while (1)
    {   SystemTask();
        valid = GetNextEvent(everyEvent,&my_event);
        if (!valid)
        {   fill_in_map(hello_window);
            continue;
        }
        switch(my_event.what)
        {   case nullEvent:
                break;
            case mouseDown:
                do_mouse_down(&my_event);
                break;
            case mouseUp:
            case keyDown:
            case keyUp:
            case autoKey:
                break;
            case updateEvt:
                do_update(&my_event);
                break;
            case diskEvt:
                break;
            case activateEvt:
                do_activate(&my_event);
                break;
            case networkEvt:
```

```
            case driverEvt:
            case app1Evt:
            case app2Evt:
            case app3Evt:
            case app4Evt:
                break;
            default:
                break;
        }
    }
}

/* Find out where a mouse-down event has occured and do what ought to
 * be done for that location
 */
do_mouse_down(event)
    EventRecord *event;
{
    WindowPtr mouse_window;
    int place_type = FindWindow(mk_long(event->where), &mouse_window);

    switch(place_type)
    {   case inDesk:
            break;
        case inMenuBar:
            do_menu(MenuSelect(mk_long(event->where)));
            break;
        case inSysWindow:
            SystemClick(event, mouse_window);
            break;
        case inContent:
            if (mouse_window != FrontWindow())
                SelectWindow(mouse_window);
            else
                do_controls(mouse_window, mk_long(event->where));
            break;
        case inDrag:
            DragWindow(mouse_window, mk_long(event->where), &drag_rect);
            break;
        case inGrow:
            grow_window(mouse_window, mk_long(event->where));
            break;
        case inGoAway:
            if (TrackGoAway(mouse_window, mk_long(event->where)))
                do_close();
            break;
        default:
            break;
    }
}

/* Find which part of which control was used. Then find out how the value
 * of that control has changed. Then call one of this applications routines
 * that performs the action that reflects the change in the control. In the
 * case of the up and down buttons, TrackControl calls an action routine
 * that should show some intermediate result, like srolling the screen
 * one line in an editor.
 */
do_controls(window, where)
    WindowPtr window;
    long where;
{
    int part_code, old_value, new_value;
    ControlHandle control;

    GlobalToLocal(&where);
    part_code = FindControl(where, window, &control);
    if (!part_code) return;
    (void)count(SET, 0);
    switch(part_code)
    {   case inUpButton:
            TrackControl(control, where, up_action);
            break;
        case inDownButton:
            TrackControl(control, where, down_action);
            break;
        case inPageUp:
        case inPageDown:
            page_movement(window, control, part_code);
            break;
        case inThumb:
            old_value = GetCtlValue(control);
            TrackControl(control, where, 0L);
            new_value = GetCtlValue(control);
            thumb_movement(window, control, old_value, new_value);
        default:
            break;
    }
}

 pascal void
up_action(control, part_code)
    ControlHandle control;
{
    WindowPtr window = (*control)->contrlOwner;
    int old_value = GetCtlValue(control);

    SetCtlValue(control, old_value - 1);
    if (GetCtlValue(control) == old_value) return;
    scroll_window(window, control, UP, 1);
    (void)count(ADD, 1);
}

 pascal void
down_action(control, part_code)
    ControlHandle control;
{
    WindowPtr window = (*control)->contrlOwner;
    int old_value = GetCtlValue(control);

    SetCtlValue(control, old_value + 1);
    if (GetCtlValue(control) == old_value) return;
    scroll_window(window, control, DOWN, 1);
    (void)count(ADD, 1);
}

page_movement(window, control, part_code)
    WindowPtr window;
    ControlHandle control;
{
    int units = get_page_units(window, control);
    int direction = part_code == inPageUp ? UP : DOWN;
    int old_value = GetCtlValue(control);

    if (direction == DOWN)
    {   SetCtlValue(control, old_value + units);
        units = GetCtlValue(control) - old_value;
    }
    else
    {   SetCtlValue(control, old_value - units);
        units = old_value - GetCtlValue(control);
    }
    if (units) scroll_window(window, control, direction, units);
}

thumb_movement(window, control, old_value, new_value)
    WindowPtr window;
    ControlHandle control;
{
    int units = old_value - new_value;
    int direction = units < 0 ? DOWN : UP;

    if (units)
    {   units = units < 0 ? -units : units;
        scroll_window(window, control, direction, units);
    }
}

get_page_units(window, control)
    WindowPtr window;
    ControlHandle control;
{
    return 5;
}

/* Set up the port rectangle and clipping for the window */
scroll_window(window, control, direction, units)
    WindowPtr window;
    ControlHandle control;
{
    Rect content;
    static RgnHandle save_clip = (RgnHandle)0;
    content = window->portRect;
    if (!save_clip) save_clip = NewRgn();
    else SetEmptyRgn(save_clip);
    content = window->portRect;
    content.right -= BAR_WIDTH;
    content.bottom -= BAR_WIDTH;
    GetClip(save_clip);
    ClipRect(&content);
    scroll_map(window, control, direction, units, &content);
    SetClip(save_clip);
}

/* Scroll the contents of the window and keep track of the offset in
 * the map structure. Units are visual units.
 */
scroll_map(window, control, direction, units, content)
    WindowPtr window;
    ControlHandle control;
    Rect *content;
{
    map_handle map = (map_handle)GetWRefCon(window);
    int max = GetCtlMax(control);
    long bar_id = GetCRefCon(control);
    int sign = direction == UP ? 1 : -1;
    int current, n_to_scroll;
    int scale = (*map)->view_scale;
    int scale_ratio = (*map)->view_scale / (*map)->scale;
    static RgnHandle to_update = (RgnHandle)0;

    if (!to_update) to_update = NewRgn();
    else SetEmptyRgn(to_update);
    current = bar_id == V_SCROLL ? (*map)->y_offset : (*map)->x_offset;
    units *= sign;
    n_to_scroll = units * scale * scale_ratio;
    if (bar_id == V_SCROLL)
    {   ScrollRect(content, 0, n_to_scroll, to_update);
        OffsetRgn(to_update, 0, scale * scale_ratio * count(GET, 0) * sign);
        (*map)->y_offset -= units * scale_ratio;
    }
    else
    {   ScrollRect(content, n_to_scroll, 0, to_update);
        OffsetRgn(to_update, scale * scale_ratio * count(GET, 0) * sign, 0);
        (*map)->x_offset -= units * scale_ratio;
    }
    InvalRgn(to_update);
}

count(op, arg)
{
    static int counter;

    switch (op)
    {   case SET: counter = arg; break;
```

```
        case ADD: counter += arg; break;
        case GET: break;
    }
    return counter;
}

/* Handle and update event - first determine if the event is in one of
 * this application's windows, and if so, update that window.
 */
do_update(event)
    EventRecord *event;
{
    GrafPtr save_graf;
    WindowPtr update_window;

    update_window = (WindowPtr)event->message;
    {   if (update_window == hello_window)
        {   GetPort(&save_graf);
            SetPort(update_window);
            BeginUpdate(update_window);
            EraseRect(&update_window->portRect);
            DrawGrowIcon(update_window);
            DrawControls(update_window);
            draw_content(update_window);
            EndUpdate(update_window);
            SetPort(save_graf);
        }
    }
}

/* If the modifiers are odd, then this is an activate event for the
 * window pointed to in the message field of the event. If that is the case
 * then the graf port is set to that window's graf port
 */
do_activate(event)
    EventRecord *event;
{
    WindowPtr event_window = (WindowPtr)event->message;
    WindowPeek peek = (WindowPeek)event_window;
    ControlHandle control = (ControlHandle)peek->controlList;
    long label;

    if(event_window == hello_window)
    {   if (event->modifiers & 1)
        {   SetPort(event_window);
            DisableItem(GetMHandle(EDIT_MENU), 0);
            while (control)
            {   label = GetCRefCon(control);
                if (label == V_SCROLL || label == H_SCROLL)
                    ShowControl(control);
                control = (*control)->nextControl;
            }
        }
        else
        {   EnableItem(GetMHandle(EDIT_MENU), 0);
            while (control)
            {   label = GetCRefCon(control);
                if (label == V_SCROLL || label == H_SCROLL)
                    HideControl(control);
                control = (*control)->nextControl;
            }
        }
        DrawGrowIcon(event_window);
    }
}

/* Call the window manager routines that cause a window to grow */
grow_window(window, mouse_point)
    WindowPtr window;
    Point mouse_point;
{
    long new_bounds;

    inval_grow(window);
    new_bounds = GrowWindow(window, mk_long(mouse_point), &grow_bounds);
    if (new_bounds == 0)
        return;
    SizeWindow(window, LoWord(new_bounds), HiWord(new_bounds), TRUE);
    move_bars(window);
    inval_grow(window);
    size_map(window);
}

/* Invalidate the grow icon area of a standard window */
inval_grow(window)
    WindowPtr window;
{
    Rect temp_rect, port_rect;

    port_rect = window->portRect;
    SetRect(&temp_rect, port_rect.right - 16, port_rect.bottom - 16,
        port_rect.right, port_rect.bottom);
    InvalRect(&temp_rect);
}

/* Go through the list of controls for this window, identify the
 * scroll bars, and change their position and size to conform to the
 * window's new size
 */
move_bars(window)
    WindowPtr window;
{
    WindowPeek peek = (WindowPeek)window;

    ControlHandle control = peek->controlList;
    int new_top = window->portRect.top;
    int new_left = window->portRect.left;
    int new_bottom = window->portRect.bottom;
    int new_right = window->portRect.right;
    long label;

    while (control)
    {   label = GetCRefCon(control);
        if (label == V_SCROLL)
        {   HideControl(control);
            MoveControl(control, new_right - BAR_WIDTH, new_top - 1);
            SizeControl(control, 16, new_bottom - new_top - 13);
            ShowControl(control);
        }
        else if (label == H_SCROLL)
        {   HideControl(control);
            MoveControl(control, new_left - 1, new_bottom - BAR_WIDTH);
            SizeControl(control, new_right - new_left - 13, 16);
            ShowControl(control);
        }
        control = (*control)->nextControl;
    }
}

do_menu(command)
    long command;
{
    int menu_id = HiWord(command);
    int item = LoWord(command);
    char item_name[32];

    switch (menu_id)
    {   case APPLE_MENU:
            GetItem(GetMHandle(menu_id), item, item_name);
            OpenDeskAcc(item_name);
            break;
        case FILE_MENU:
            switch (item)
            {   case NEW:         do_new(); break;
                case OPEN:        do_open(); break;
                case CLOSE:       do_close(); break;
                case SAVE:        (void)do_save(SAVE); break;
                case SAVE_AS:     (void)do_save(SAVE_AS); break;
                case REVERT: do_revert(); break;
                case PRINT:       do_print(); break;
                case QUIT:        do_quit(); break;
            }
            break;
        case EDIT_MENU:
            SystemEdit(item - 1);
            break;
        case MAP_MENU:
            switch (item)
            {   case RESOLUTION: do_resolution(); break;
                case MAGNIFICATION:  do_magnification(); break;
                case POSITIONING:    do_positioning(); break;
            }
    }
    HiliteMenu(0);
}

/* Is this window one of my windows? */
my_window(window)
    WindowPtr window;
{
    if (window == hello_window)
        return TRUE;
    else
        return FALSE;
}

/* Find my front-most window */
 WindowPtr
foremost_window()
{
    WindowPeek window = (WindowPeek)FrontWindow();

    while (window)
    {   if (my_window(window)) return (WindowPtr)window;
        else window = window->nextWindow;
    }
    return (WindowPtr)window;
}

draw_content(window)
    WindowPtr window;
{
    Rect clip_rect;
    RgnHandle old_clip = NewRgn();

    clip_rect = window->portRect;
    clip_rect.right -= BAR_WIDTH;
    clip_rect.bottom -= BAR_WIDTH;
    GetClip(old_clip);
    ClipRect(&clip_rect);
    plot_map(window);
    SetClip(old_clip);
    DisposeRgn(old_clip);
}

/* Make a map and return a handle to it. It is sized to fit the values for
 * enought points in the complex plane to fill the specified window at the
 * specified scale
 */
 map_handle
make_map(window, start_at, step, scale)
    WindowPtr window;
    struct cx_num *start_at;
    double step;
{
    Size size = calc_map_size(window, scale);
    map_handle new_map = (map_handle)NewHandle(size);

    (*new_map)->start_at = *start_at;
    (*new_map)->step = step;
    (*new_map)->scale = (*new_map)->view_scale = scale;
    (*new_map)->last_x = (*new_map)->last_y = 0;
    (*new_map)->x_offset = (*new_map)->y_offset = 0;
    (*new_map)->save_file[0] = 0;
    set_dimensions(window, new_map);
    make_columns(new_map);
    return new_map;
}

 Size
calc_map_size(window, scale)
    WindowPtr window;
{
    Size size = sizeof(struct map);
    long x_size = window->portRect.right - window->portRect.left;

    size += (((x_size - BAR_WIDTH) / scale) + 1) * sizeof(Handle);
    return size;
}

/* Set the dimensions of an existing map. The scale of the map must be set
 * before calling set_dimensions.
 */
set_dimensions(window, map)
    WindowPtr window;
    map_handle map;
{
    int x_size = window->portRect.right - window->portRect.left;
    int y_size = window->portRect.bottom - window->portRect.top;

    (*map)->x_dim = ((x_size - BAR_WIDTH) / (*map)->scale) + 1;
    (*map)->y_dim = ((y_size - BAR_WIDTH) / (*map)->scale) + 1;
}

make_columns(map)
    register map_handle map;
{
    register Size column_size = (*map)->y_dim;
    register int i;

    for (i = 0; i < (*map)->x_dim; i++)
        (*map)->map_values[i] = new_column(column_size);
}

 Handle
do_new_column(column_size, tries)
    register Size column_size;
{
    register Handle new = NewHandle(column_size);
    register int i;
    if (!new)
    {   if (tries > 5) finish();
        MoreMasters();
        return new_column(column_size, tries + 1);
    }
    for (i = 0; i < column_size; i++)
        (*new)[i] = NO_VALUE;
    return new;
}

 Handle
new_column(column_size)
    register Size column_size;
{
    return do_new_column(column_size, 0);
}

size_map(window)
    WindowPtr window;
{
    map_handle map = (map_handle)GetWRefCon(window);
    int x_size = window->portRect.right - window->portRect.left;
    int y_size = window->portRect.bottom - window->portRect.top;
    int new_x_dim, new_y_dim;

    new_x_dim = ((x_size - BAR_WIDTH) / (*map)->scale) + 1 +
                    (*map)->x_offset;
    new_y_dim = ((y_size - BAR_WIDTH) / (*map)->scale) + 1 +
                    (*map)->y_offset;
    if (new_x_dim > (*map)->x_dim || new_y_dim > (*map)->y_dim)
    {   grow_map(map, new_x_dim, new_y_dim);
        (*map)->last_x = (*map)->last_y = 0;
    }
    adjust_bars(window);
}

/* Grow the map, if needed */
grow_map(map, new_x_dim, new_y_dim)
    register map_handle map;
    register int new_x_dim, new_y_dim;
{
    int x_diff = new_x_dim - (*map)->x_dim;
    int y_diff = new_y_dim - (*map)->y_dim;
    register Size old_size, new_size;
    register int x, y, new_dim;

    /* Add new columns, if needed */
    if (x_diff > 0)
    {   old_size = GetHandleSize((Handle)map);
        new_size = old_size + (x_diff * sizeof(Handle));
        SetHandleSize((Handle)map, new_size);
        new_size = y_diff > 0 ? new_y_dim : (*map)->y_dim;
        for (x = (*map)->x_dim; x < new_x_dim; x++)
```

```
            {   (*map)->map_values[x] = new_column(new_size);
                if (MemError()) finish();
            }
        }
        /* Extend existing columns, if needed */
        if (y_diff > 0)
        {   new_size = new_y_dim;
            for (x = 0; x < (*map)->x_dim; x++)
            {   SetHandleSize((*map)->map_values[x], new_size);
                if (MemError()) finish();
                for (y = (*map)->y_dim; y < new_y_dim; y++)
                    VALUE(map, x, y) = NO_VALUE;
            }
        }
        /* Store the new dimensions in the map */
        if (x_diff > 0) (*map)->x_dim = new_x_dim;
        if (y_diff > 0) (*map)->y_dim = new_y_dim;
}

/* After a window has been re-sized, some parts of the map may no longer
 * be visible. If so, the scroll bars should be enabled and set to the
 * correct range and starting value for the new window size.
 */
adjust_bars(window)
    WindowPtr window;
{
    map_handle map = (map_handle)GetWRefCon(window);
    int scale_ratio = (*map)->view_scale / (*map)->scale;
    int x_max = (*map)->x_dim - 1, y_max = (*map)->y_dim - 1;
    int x_max_in_view = (window->portRect.right - BAR_WIDTH) /
        (*map)->scale;
    int y_max_in_view = (window->portRect.bottom - BAR_WIDTH) /
        (*map)->scale;
    int diff;

    /* If the scale has changed, the offset is bumped down to the next
     * lower multiple of the new scale ratio.
     */
    (*map)->x_offset -= (*map)->x_offset % scale_ratio;
    (*map)->y_offset -= (*map)->y_offset % scale_ratio;
    if (!(*map)->x_offset &&
            (diff = ((*map)->x_dim - x_max_in_view) / scale_ratio) - 1
                <= 0)
        turn_off_control(window, H_SCROLL);
    else init_bar(window, H_SCROLL, (*map)->x_offset / scale_ratio, diff);
    if (!(*map)->y_offset &&
            (diff = ((*map)->y_dim - y_max_in_view) / scale_ratio) - 1
                <= 0)
        turn_off_control(window, V_SCROLL);
    else init_bar(window, V_SCROLL, (*map)->y_offset / scale_ratio, diff);
}

/* Initialize the range and value of a scroll bar */
init_bar(window, id, value, range)
```

```
    WindowPtr window;
{
    ControlHandle control = lookup_control(window, id);
    map_handle map  = (map_handle)GetWRefCon(window);

    if (!range) switch_control(window, id, 255);
    else
    {   SetCtlMin(control, 0);
        SetCtlMax(control, range);
        SetCtlValue(control, value);
        switch_control(window, id, 0);
        InvalRect(&(*control)->contrlRect);
    }
}

/* Hilite a control in such a way as to show that it is inactive. Here
 * we use "255" hiliting assuming we do not want to know about mouse
 * clicks in the control.
 */
turn_off_control(window, id)
    WindowPtr window;
{
    switch_control(window, id, 255);
}

/* Find a control and hilite it - if 254 or 255 are used as values
 * of hiliting, the control is turned off.
 */
switch_control(window, id, hilite)
    WindowPtr window;
{
    ControlHandle control = lookup_control(window, id);

    HiliteControl(control, hilite);
}

 ControlHandle
lookup_control(window, id)
    WindowPtr window;
{
    ControlHandle control = ((WindowPeek)window)->controlList;
    long label;

    while (control)
    {   label = GetCRefCon(control);
        if (LoWord(label) == id) break;
        control = (*control)->nextControl;
    }
    return control;
}

/* make the assumption that resolution changes by multiples of two */
do_resolution()
{
    WindowPtr window = foremost_window();
    map_handle map = (map_handle)GetWRefCon(window);
    int new_scale = get_new_resolution(map);
    int old_scale = (*map)->scale;
    int scale_factor = old_scale / new_scale;
    int new_x_dim, new_y_dim;

    if (new_scale < old_scale)
    {   new_x_dim = (*map)->x_dim * scale_factor;
        new_y_dim = (*map)->y_dim * scale_factor;
        grow_map(map, new_x_dim, new_y_dim);
        (*map)->scale = new_scale;
        spread_data(map, scale_factor);
    }
    if (((*map)->view_scale = new_scale) != old_scale);
    {   InvalRect(&window->portRect);
        (*map)->last_x = (*map)->last_y = 0;
        (*map)->x_offset *= scale_factor;
        (*map)->y_offset *= scale_factor;
        adjust_bars(window);
    }
}

/* Ask the user for a new scale for the map */
get_new_resolution(map)
    map_handle map;
{
    DialogPtr dialog;
    int scale = (*map)->view_scale;
    int item;

    dialog = GetNewDialog(RES_DIALOG, 0L, -1L);
    dialog_radio(dialog, scale_to_button(scale));
    while (1)
    {   ModalDialog(0L, &item);
        switch (item)
        {   case RES_D_CANCEL:
                scale = (*map)->view_scale;   /* Fall through... */
            case RES_D_OK:
                DisposDialog(dialog);
                return scale;
            case RES_D_COARSE:
                scale = COARSE;
                dialog_radio(dialog, item);
                continue;
            case RES_D_MEDIUM:
                scale = MEDIUM;
                dialog_radio(dialog, item);
                continue;
            case RES_D_FINE:
                scale = FINE;
                dialog_radio(dialog, item);
                continue;
            case RES_D_EXTRA_FINE:
                scale = EXTRA_FINE;
                dialog_radio(dialog, item);
                continue;
            default:
                continue;
        }
    }
    (*map)->modified = 1;
    return (*map)->view_scale;
}

scale_to_button(scale)
{
    switch(scale)
    {   case COARSE: return RES_D_COARSE;
        case MEDIUM: return RES_D_MEDIUM;
        case FINE: return RES_D_FINE;
        case EXTRA_FINE: return RES_D_EXTRA_FINE;
    }
}

/* Given an item number for a radio button, turn that button on
 * and the other buttons off. This assumes that all the radio buttons
 * in the dialog are related.
 */
dialog_radio(dialog, item)
    DialogPtr dialog;
{
    int type, i;
    ControlHandle button;
    Rect box;
    int n_items = **(int **)((DialogPeek)dialog)->items + 2;

    for(i = 1; i < n_items; i++)
    {   GetDItem(dialog, i, &type, (Handle *)&button, &box);
        if (type == (ctrlItem | radCtrl))
            SetCtlValue(button, i == item ? 1 : 0);
    }
}

/* Take a map that has been increased in size by the specified scale
 * factor and spread the existing data out over the map
 */
spread_data(map, scale_factor)
    register map_handle map;
    register int scale_factor;
{
    register int x, y, x1, y1;
    register Handle swap_temp;
    int old_x_dim = (*map)->x_dim / scale_factor;
    int old_y_dim = (*map)->y_dim / scale_factor;

    /* First spread the data in the columns */
    for (x = 0; x < old_x_dim; x++)
    {   for (y = old_y_dim - 1, y1 = (*map)->y_dim - scale_factor; y > 0;
                y--, y1 -= scale_factor)
        {   VALUE(map, x, y1) = VALUE(map, x, y);
            VALUE(map, x, y) = NO_VALUE;
        }
    }
    /* Then spread the columns by switching them with the new columns */
    for (x = old_x_dim - 1, x1 = (*map)->x_dim - scale_factor; x > 0;
            x--, x1 -= scale_factor)
    {   swap_temp = (*map)->map_values[x];
        (*map)->map_values[x] = (*map)->map_values[x1];
        (*map)->map_values[x1] = swap_temp;
    }

}

/* How do you think magnification should be controlled?
 * Put you code here:
 */
do_magnification()
{
    return;
}

/* This routine get a new starting position for the map. */
do_positioning()
{
    DialogPtr pos_dialog;
    int item, type, got_mouse = 0;
    Handle box_item;
    Rect box;
    GrafPtr save_graf;
    Point mouse_point, new_mouse_point;

    pos_dialog = GetNewDialog(POS_DIALOG, 0L, -1L);
    if (!pos_dialog) return;
    GetDItem(pos_dialog, POS_D_BOX, &type, &box_item, &box);
    GetPort(&save_graf);
    SetPort(pos_dialog);
    draw_pos_box(&box);
    while (1)
    {   ModalDialog((ProcPtr)0L, &item);
        switch (item)
        {   case POS_D_BOX:
                GetMouse(&mouse_point);
                new_position(mk_long(mouse_point), 0);
                while(StillDown())
                {   GetMouse(&new_mouse_point);
                    if (mk_long(mouse_point) != mk_long(new_mouse_point))
                    {   mouse_point = new_mouse_point;
                        new_position(mk_long(mouse_point), 0);
                    }
                }
                got_mouse = 1;
```

```
                    continue;
                case POS_D_OK:
                    if (got_mouse)
                    {   new_position(0L, 1);
                        break;
                    }
                    else continue;
                case POS_D_CANCEL:
                    SetPort(save_graf);
                    DisposDialog(pos_dialog);
                    return;
                default:
                    continue;
            }
            break;
        }
        SetPort(save_graf);
        DisposDialog(pos_dialog);
        move_map(&box, mk_long(mouse_point));
}

/* Calculate the new origin of the map from the position of a point
 * withing the box, and initialize the map.
 */
move_map(box, place)
    Rect *box;
    long place;
{
    Point point;
    int side = box->right - box->left;        /* Assume it is square */
    WindowPtr window = hello_window;      /* For now only one window */
    register map_handle map = (map_handle)GetWRefCon(window);
    struct cx_num new_origin;
    register int x, y;
    Rect content;

    point = *(Point *)&place;
    point.h = (point.h - box->left) - side / 2;
    point.v = side / 2 - (point.v - box->top);
    new_origin.real = (double)point.h / (double)50;
    new_origin.imag = (double)point.v / (double)50;
    (*map)->start_at = new_origin;
    (*map)->last_x = (*map)->last_y = 0;
    (*map)->x_offset = (*map)->y_offset = 0;
    for (x = 0; x < (*map)->x_dim; x++)
    {   for (y = 0; y < (*map)->y_dim; y++)
            VALUE(map, x, y) = NO_VALUE;
    }
    content = window->portRect;
    content.bottom -= BAR_WIDTH;
    content.right -= BAR_WIDTH;
    InvalRect(&content);
    EraseRect(&content);
    ValidRect(&content);
    adjust_bars(window);
}

/* A support routine for the positioning dialog. Here we draw our current
 * position.
 */
draw_pos_box(box)
    Rect *box;
{
    int side = box->right - box->left;    /* Assume it is square */

    FrameRect(box);
    MoveTo(box->left + side / 2, box->top);
    Line(0, side - 1);
    MoveTo(box->left, box->top + side / 2);
    Line(side - 1, 0);
    MoveTo(box->left + side / 2 + 3, box->top + side / 2 + 12);
    DrawText("(0,0)", 0, 5);
    draw_map_rects(box);
}

/* Draw a scaled-down box showing our current map's position in the larger
 * scheme of things
 */
draw_map_rects(box)
    Rect *box;
{
    Rect rect;
    double x, y;
    int side = box->right - box->left;    /* Assume it is square */
    WindowPtr window = FrontWindow();
    map_handle map;

    for(; window; window = (WindowPtr)((WindowPeek)window)->nextWindow)
    {   if (my_window(window))
        {   map = (map_handle)GetWRefCon(window);
            x = (*map)->start_at.real;
            y = (*map)->start_at.imag;
            rect.top = (side / 2) - (int)(y * 50) + box->top;
            rect.left = (side / 2) + (int)(x * 50) + box->left;
            rect.bottom = rect.top +
                (int)((*map)->step * (*map)->scale * (*map)->y_dim * 50);
            rect.right = rect.left +
                (int)((*map)->step * (*map)->scale * (*map)->x_dim * 50);
            FillRect(&rect, gray);
            FrameRect(&rect);
        }
    }
}

/* Mark the new position. The pen mode is patCopy after this routine
 * is called. If "final" is non-zero, cur_position is used as a new
 * origin for the map.
 */
```

```
new_position(where, final)
    long where;
{
    static int position_valid = 0;
    static long cur_position;

    PenMode(patXor);
    if (position_valid)
        x_marks_new_spot(cur_position);
    x_marks_new_spot(where);
    cur_position = where;
    position_valid = 1;
    PenMode(patCopy);
    if (final)
        position_valid = 0;
}

/* Draws an "+" at the specified spot in the current pen mode. So if the
 * mode is patXor, this routine can be used to erase old spots.
 */
x_marks_new_spot(spot)
    long spot;
{
    Point point;

    point = *(Point *)&spot;
    MoveTo(point.h - 2, point.v);
    Line(4, 0);
    MoveTo(point.h, point.v - 2);
    Line(0, 4);
}

/* Fill in the map. Real numbers go left to right, increasing.
 * Imaginary numbers go top to bottom, decreasing. We calculate a value
 * for a point if: 1) It has no value; 2) It would be visible at the
 * current resolution OR we have already finished calculating all the
 * visible points.
 */
fill_in_map(window)
    WindowPtr window;
{
    register map_handle map;
    register double step;
    register int x, y, scale, scale_ratio;
    PicHandle pict;
    struct cx_num where;

    if (!window) return;
    map = (map_handle)GetWRefCon(window);
    step = (*map)->step;
    x = (*map)->last_x; y = (*map)->last_y;
    scale = (*map)->scale;
    scale_ratio = (*map)->view_scale / scale;
    for (; x < (*map)->x_dim; x++)
    {   for (; y < (*map)->y_dim; y++)
        {   if (VALUE(map, x, y) == NO_VALUE &&
                    (scale_ratio == 1 ||
                        !(x % scale_ratio || y % scale_ratio)))
            {   where.real = (*map)->start_at.real + (x * step * scale);
                where.imag = (*map)->start_at.imag - (y * step * scale);
                if ((VALUE(map, x, y) = calc_value(&where)) != NO_VALUE)
                {   paint_point(window, x, y);
                    (*map)->last_x = x; (*map)->last_y = y;
                    (*map)->modified;
                }
                else return;
            }
        }
        y = 0;  /* Start another column */
    }
}

/* Check if a point is inside the Mandelbrot Set. If the magnitude
 * of the complex number has not exceeded 2 in "white_max" iterations,
 * it is likely IN the mandelbrot set. Otherwise it lies outside and
 * the the number of iterations it took to determine this is used to
 * select a pattern for that point. We check for pending events every
 * 128 iterations.
 */
 char
calc_value(where)
    register struct cx_num *where;
{
    register double val_real, val_imag, sq_real, sq_imag;
    register int count;
    EventRecord dummy;

    val_real = val_imag = 0.0;
    for (count = 0; count <= white_max; count++)
    {   sq_real = val_real * val_real;
        sq_imag = val_imag * val_imag;
        if ((sq_real + sq_imag) > 4.0) break;
        if (!(count & 0x7F) && EventAvail(everyEvent, &dummy))
            return NO_VALUE;
        val_imag = (val_real * val_imag * 2.0) + where->imag;
        val_real = sq_real - sq_imag + where->real;
    }
    return which_pattern(count);
}

/* Select a pattern based on whether a point is in the Mandlebrot Set, or
 * if it lies outside, how soon was it determined to lie outside.
 */
 char
which_pattern(count)
{
    if (count > white_max) return BLACK;
    else if (count > lt_gray_max) return WHITE;
    else if (count > gray_max) return LIGHT_GRAY;
    else if (count > dk_gray_max) return GRAY;
    else return DARK_GRAY;
}

paint_point(window, x, y)
    WindowPtr window;
{
    GrafPtr save_graf;
    register map_handle map = (map_handle)GetWRefCon(window);
    register int scale = (*map)->view_scale;
    register int scale_ratio = scale / (*map)->scale;
    register int inval_x = (x - (*map)->x_offset) / scale_ratio,
        inval_y = (y - (*map)->y_offset) / scale_ratio;
    Rect rect, content;

    content = window->portRect;
    content.bottom -= BAR_WIDTH; content.right -= BAR_WIDTH;
    inval_x *= scale; inval_y *= scale;
    SetRect(&rect, inval_x, inval_y, inval_x + scale, inval_y + scale);
    if (SectRect(&rect, &content, &rect))
    {   GetPort(&save_graf);
        SetPort(window);
        InvalRect(&rect);
        BeginUpdate(window);
        plot_one(map, x, y);
        EndUpdate(window);
        SetPort(save_graf);
    }
}

plot_map(window)
    WindowPtr window;
{
    register map_handle map = (map_handle)((WindowPeek)window)->refCon;
    register int scale_ratio = (*map)->view_scale / (*map)->scale;
    register int x, y;
    for (x = 0; x < (*map)->x_dim; x += scale_ratio)
    {   for (y = 0; y < (*map)->y_dim; y += scale_ratio)
            plot_one(map, x, y);
    }
}

/* Plot one point in the map. If clipping has not be set up for the
 * map window, a rectangle may be provided to clip an individual point
 * to.
 */
plot_one(map, x, y)
    map_handle map;
    register int x, y;
{
    register int fill_with = VALUE(map, x, y);
    register int scale = (*map)->scale;
    register int view_scale = (*map)->view_scale;
    Rect to_fill;

    x -= (*map)->x_offset; y -= (*map)->y_offset;
    x *= scale; y *= scale;
    SetRect(&to_fill, x, y, x + view_scale, y + view_scale);
    switch(fill_with)
    {   case BLACK: FillRect(&to_fill, black); break;
        case WHITE: FillRect(&to_fill, white); break;
        case LIGHT_GRAY: FillRect(&to_fill, ltGray); break;
        case GRAY: FillRect(&to_fill, gray); break;
        case DARK_GRAY: FillRect(&to_fill, dkGray); break;
        case NO_VALUE:
            break;
    }
}

/* Exit the program cleanly */
finish()
{
    ExitToShell();
}
```

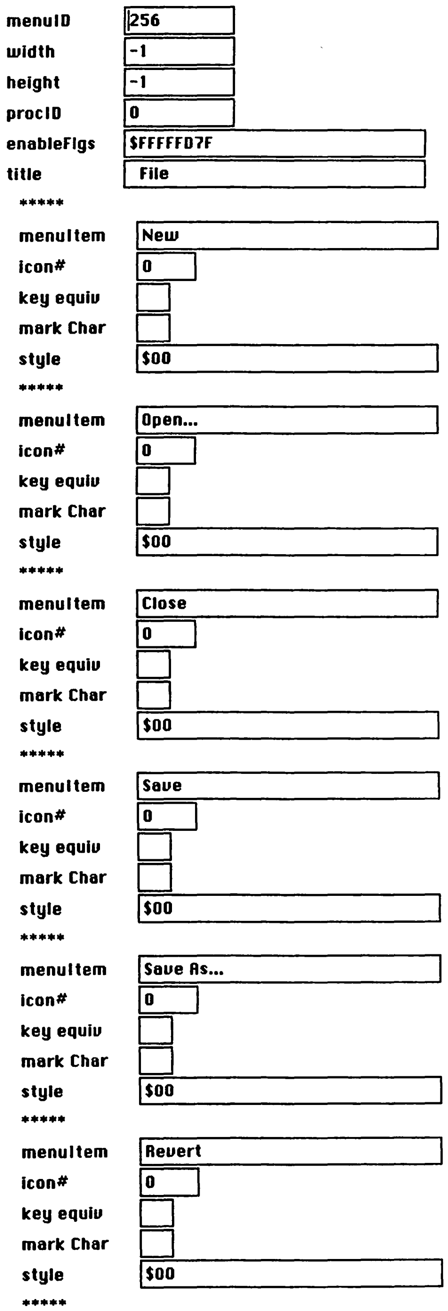
The file "file_menu.c"

```
#include "mandelbrot.h"

extern WindowPtr hello_window;
extern WindowRecord w_record;
extern Point get_put;

do_new()
{
    if (hello_window) return;
    make_window(hello_window = (WindowPtr)&w_record);
}

do_open()
{
    register WindowPtr window = (WindowPtr)&w_record;
    register map_handle map;
    register OSErr error = noErr;
    register ControlHandle scroll_bar;
    int file_refnum;
    SFReply reply;
    SFTypeList types;

    if (hello_window) return;
    types[0] = MANM;
    SFGetFile(mk_long(get_put), 0L, 0L, 1, types, 0L, &reply);
    if (!reply.good) return;
    if (error = FSOpen(reply.fName, reply.vRefNum, &file_refnum))
        return;
    if (!(map = read_in_map(file_refnum))) return;
    if (error = FSClose(file_refnum)) return;
    (*map)->save_volume = reply.vRefNum;
    SetWRefCon(window, (long)map);
    ShowWindow(window);
    move_bars(window);
    adjust_bars(window);
    InvalRect(&window->portRect);
    hello_window = window;
}

/* Read in the map header structure first to determine how many columns
 * of map data there are and how long those columns are.
 */
 map_handle
read_in_map(file_refnum)
{
    map_handle map = (map_handle)NewHandle((Size)sizeof(struct map));
    Size size = sizeof(struct map);
    register Handle column;
    register int x;
    OSErr error = noErr;

    if (!map) return (map_handle)0L;
    HLock(map);
    error = FSRead(file_refnum, &size, *map);
    HUnlock(map);
    if (error) return (map_handle)0L;
    SetHandleSize(map,
        sizeof(struct map) + ((*map)->x_dim * sizeof(Handle)));
    size = (*map)->y_dim;
    for (x = 0; x < (*map)->x_dim; x++)
    {   column = NewHandle((Size)(*map)->y_dim);
        if (!column) return (map_handle)0L;
        HLock(column);
        error = FSRead(file_refnum, &size, *column);
        HUnlock(column);
        (*map)->map_values[x] = column;
    }
    (*map)->last_x = (*map)->last_y = 0;
    (*map)->x_offset = (*map)->y_offset = 0;
    return map;
}

/* Close windows: If the window is a DA's, close the DA, otherwise
 * check if the map has been saved, and close the map window.
 */
do_close()
{
    WindowPeek front_window = (WindowPeek)FrontWindow();
    map_handle map;

    if (!front_window) return;
    if (!my_window(front_window))
    {   CloseDeskAcc(front_window->windowKind);
        return;
    }
    map = (map_handle)GetWRefCon(front_window);
    if ((*map)->modified)
    {   switch (save_check())
        {   case SC_CANCEL:  return;
            case SC_YES: if (do_save(SAVE) == SAVE_CANCEL) return;
            case SC_NO:      break;
        }
    }
    HideWindow(front_window);
    hello_window = 0L;
    free_map(map);
}

/* Loops through the columns of the map, disposing of the handles to the
 * columns, then dispose of the map structure's handle.
 */
free_map(map)
    register map_handle map;
{
    register int x;

    for (x = 0; x < (*map)->x_dim; x++)
        DisposHandle((*map)->map_values[x]);
    DisposHandle(map);
}

save_check()
{
    return CautionAlert(256, 0L);
}

do_save(save_type)
{
    WindowPtr window = foremost_window();
    SFReply reply;
    OSErr error;
    map_handle map;
    int file_refnum;
    static char **prompt = 0L;

    if (!window) return SAVE_CANCEL;
    map = (map_handle)GetWRefCon(window);
    if (!(*map)->save_file[0] || save_type == SAVE_AS)
    {   if (!prompt) prompt = GetResource(STR_, SAVE_AS_PROMPT);
        SFPutFile(mk_long(get_put), *prompt, (*map)->save_file, 0L,
            &reply);
        if (!reply.good) return SAVE_CANCEL;
        error = FSOpen(reply.fName, reply.vRefNum, &file_refnum);
        if (error == fnfErr)
        {   error = Create(reply.fName, reply.vRefNum, MNAP, MANM);
            if (error) goto save_error;
            error = FSOpen(reply.fName, reply.vRefNum, &file_refnum);
            if (error) goto save_error;
        }
        else if (error) goto save_error;
        pstring_assign((*map)->save_file, reply.fName);
        store_map(map, file_refnum);
        if (error = FSClose(file_refnum)) goto save_error;
    }
    else
    {   error = FSOpen((*map)->save_file, (*map)->save_volume,
            &file_refnum);
        if (error == fnfErr)
        {   error = Create((*map)->save_file, (*map)->save_volume,
                MNAP, MANM);
            if (error) goto save_error;
            error = FSOpen((*map)->save_file, (*map)->save_volume,
                &file_refnum);
            if (error) goto save_error;
        }
        else if (error) goto save_error;
        store_map(map, file_refnum);
        if (error = FSClose(file_refnum)) goto save_error; .
    }
    return 0;
 save_error:
    (*map)->save_file[0] = 0;
    SysBeep(10);
    return SAVE_CANCEL;
}

/* Copy the second pascal string argument into the first */
pstring_assign(to, from)
    char *to, *from;
{
    char *end = from + *from + 1;

    for (*to++ = *from++; from < end;)
        *to++ = *from++;
}

/* Write the map structure and handles to columns in one write, and then
 * loop through the columns, writing each out. Here the handles are locked
 * because the FSWrite call expects a pointer.
 */
store_map(map, file_refnum)
    register map_handle map;
{
    long size = sizeof(struct map);
    OSErr error = noErr;
    register int x;

    HLock(map);
    if (error = FSWrite(file_refnum, &size, *map)) goto no_write;
    HUnlock(map);
    for (x = 0, size = (*map)->y_dim; x < (*map)->x_dim; x++)
    {   HLock((*map)->map_values[x]);
```

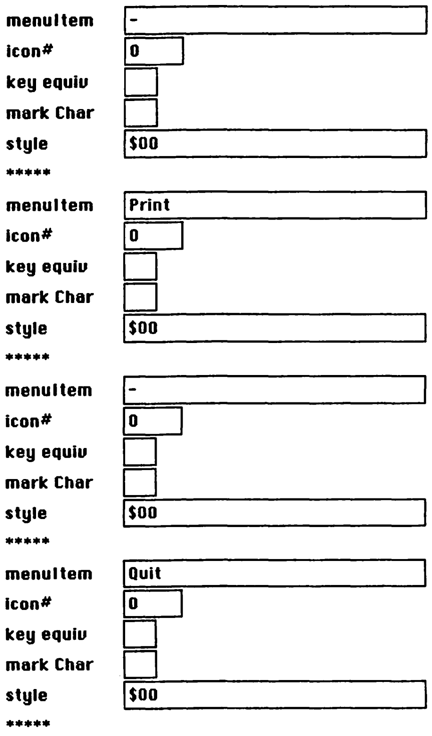
```
        error = FSWrite(file_refnum, &size, *((*map)->map_values[x]));
        if (error) goto no_write;
        HUnlock((*map)->map_values[x]);
    }
    (*map)->modified = 0;
    return;
 no_write:
    SysBeep(5);
    return;
}

do_print()
{
    WindowPtr window = hello_window;
    THPrint print_record;
    TPPrPort port_ptr;


    if (!window) return;
    PrDrvrOpen();
    PrintDefault(&print_record);
    (void)PrValidate(&print_record);
    PrCtlCall(iPrDevCtl, lPrReset, 0L, 0L);
    port_ptr = PrOpenDoc(&print_record, 0L, 0L);
    PrOpenPage(port_ptr, 0L);
    PrCtlCall(iPrBitsCtl, &window->portBits, &window->portRect,
        lPaintBits);
    PrClosePage(port_ptr);
    PrCloseDoc(port_ptr);
    PrDrvrClose();
}

do_revert()
{
}

/* Quit, check if the map has been saved */
do_quit()
{
    int sc_reply;
    WindowPtr map_window = foremost_window();
    map_handle map;


    if (!map_window) finish();
    map = (map_handle) GetWRefCon(map_window);
    if (!(*map)->modified) finish();
    if ((sc_reply = save_check()) == SC_YES)
    {   if (do_save(SAVE) == SAVE_CANCEL) return;
    }
    else if (sc_reply == SC_CANCEL) return;
    else finish();
}
```

Resources for the final version of the Mandelbrot program

In addition to the resources used in previous example programs in this book, we have added items to the file menu that enable the user to tell the program to save and read in files, and to print the contents of the window the map is drawn in. Shown below are the resource definitions for the new file menu:



```
menuID       256
width        -1
height       -1
procID       0
enableFlgs   $FFFFFD7F
title         File
  *****
  menuItem     New
  icon#        0
  key equiv
  mark Char
  style        $00
  *****
  menuItem     Open...
  icon#        0
  key equiv
  mark Char
  style        $00
  *****
  menuItem     Close
  icon#        0
  key equiv
  mark Char
  style        $00
  *****
  menuItem     Save
  icon#        0
  key equiv
  mark Char
  style        $00
  *****
  menuItem     Save As...
  icon#        0
  key equiv
  mark Char
  style        $00
  *****
  menuItem     Revert
  icon#        0
  key equiv
  mark Char
  style        $00
  *****
```



```
menuItem    -
icon#       0
key equiv
mark Char
style       $00
*****
menuItem    Print
icon#       0
key equiv
mark Char
style       $00
*****
menuItem    -
icon#       0
key equiv
mark Char
style       $00
*****
menuItem    Quit
icon#       0
key equiv
mark Char
style       $00
*****
```

POINTS TO CONSIDER

1. Where did this program succeed in its design goal of creating a software "instrument" for inspecting the Mandelbrot set? Where did it fail?

2. What would you add to the program? What would you do differently?

3. Identify the parts of the program that will have to change in order to support multiple documents. Are there more or less than you expected?

10

Debugging

- What you need to know about to debug
- What kind of debuggers are available
- How debuggers are used in general
- A list of Macintosh error numbers
- Which are the most common bugs in Macintosh programs
- How to create and execute a test plan

How to prepare for debugging

Debugging is the most intellectually demanding part of programming. It is also the most difficult to teach. Many software engineering cirriculae leave out debugging, or slight it, in favor of techniques that help to get programs working correctly in the first place. If you do not know it already, you will soon realize that debugging skill is the most important skill involved in getting programs done is a short amount of time.

While debugging is learned through experience, there are some things you can do to prepare yourself for your first experiences debugging Macintosh programs. You ought to be familiar with the 68000 instruction set. The chapter in this book on Macintosh hardware provides a brief overview. You do not need to have written 68000 assembly language code in order to read it — keep a 68000 reference manual handy. When you encounter an instruction you don't know about, look it up. You should also familiarize yourself with your compiler's conventions for global variable access, parameter passing, and register usage.

Common conventions followed by Macintosh programming languages and in assembly language programming are: The register "a7" is used to point to the top of the stack. The stack grows from higher to lower addresses. The global data area of your program is pointed to by the a5 register. The "LINK" instruction is used in conjunction with register a6 to build stack frames. Familiarity with these conventions will enable you to find global variables, examine the stack, and better figure out what piece of C source code corresponds to the machine code you are tracing. Your compiler's manual should describe any other conventions used in code generation by that compiler.

This chapter covers debugging on the Macintosh, and covers some of the specific characteristics of Macintosh debugging. It also covers some general principals of debugging and the tools you will have at hand. If you do not already have a debugger, get one! It will be your most valuable tool.

Two major Macintosh debuggers

There are two major Macintosh debuggers: MacDB, and TMON. The most significant difference between the two of them is the number of Macintoshes it takes to debug a program.

MacDB is split between two Macintoshes: One Macintosh runs the program being debugged along with a debugging "nub" that can set breakpoints and capture system errors and do some other low-level debugging chores. The user interface for MacDB runs on another Macintosh. The two Macintoshes are connected via a cable between the two machines' serial ports. By sending commands through this cable, the debugger's user interface controls the nub in the machine running the program being debugged.

The advantage of this approach is that the debugger is able to take advantage of the Macintosh user interface. It could not do so on the Macintosh being debugged. The debugger's nub also takes up little space in the machine being debugged. The user interface of MacDB also can not be damaged by an errant program, making it easier to use on some kinds of bugs. The main disadvantage is that it takes two Macintoshes to debug.

MacDB is published by Apple Computer and is available at Apple dealers.

TMON is a debugger that requires only one machine. It is installed in the Macintosh's memory and remains there, inactive, until some event occurs that causes it to wake up. Applications can be launched and terminated without disrupting TMON. The TMON user interface is not like most Macintosh applications because the ROM toolkit can not be used by two programs at once, and in the case of TMON it is already in use by the program being debugged.

TMON has a pleasant enough user interface, though, and the fact that it works with one Macintosh makes it convenient. For software-writers with only one Macintosh, TMON is the only usable debugger.

TMON can not be protected from damage if a buggy program overwrites the memory TMON occupies, but TMON can detect that such damage has occurred. This means that bugs that cause TMON to be overwritten are more difficult to find because the tools to examine the aftermath of the program error might not be working. But these programs can be traced to the point at which damage occurs.

TMON is available from ICOM Simulations Inc., 626 Wheeling Road, Wheeling IL, 60090.

Some compilers may come with their own debuggers. Compiler-specific debuggers have some advantages in that they know how the corresponding compiler passes arguments to subroutines.

Basic concepts in debugging

Tracing, breakpointing, dumping and disassembling are the fundamental activities of debugging.

Disassembly is an integral part of almost all debugging activity. To tell you what part of a program you are looking at, your debugger translates the assembled program back into assembler mnemonics, substituting, where it can, symbolic names for offsets, labels, and locations in global storage.

Tracing means following the program, instruction by instruction, through execution. Tracing often leads you right to the bug. To use tracing effectively with C, you will need to get used to the kind of code your compiler generates so that you can tell where you are in the source listing as you trace. The 68000 has a processor mode that allows the debugger to step a program one instruction at a time. This means that even ROM routines can be traced.

Breakpointing involves replacing instructions in the program with "breakpoints." The debugger does this for you, so all you see is the effect of the program stopping and the debugger waking up to tell you where the program has stopped. Breakpoints let you run a program at full speed up to a section of the program that you suspect has a bug.

Tracing and breakpoints can be used in combination to zero in on a bug. By setting breakpoints around where you think the buggy code is executed, you can cut down on the amount of tracing you have to do to find the bug.

Dumps of sections of memory can reveal invalid values. Three places to look in the Macintosh when it is running a program that you are debugging are:

- The top of the stack. Register `a7` usually points to the top of the stack. One way to see if the stack is being correctly maintained is to check to see if a plausible address is at the top of the stack just before an `RTS` instruction is executed.

- The application's global variables. Register a5 usually points to an application's global variables.

- Low memory. This is where the Macintosh system puts its global variables.

Deep S___

When a fundamental error has occurred and the processor can not continue executing a program, the processor branches to an error handler. On the Macintosh, the error handler determines which error occurred, and displays the error number on the screen. This is the only point where the usually user-friendly Macintosh reverts to displaying numbers where an explanatory phrase would be much more helpful. Errors that bring programs to a halt are called "DS" errors.

The following table lists the error code numbers are describes the errors that cause them to be displayed:

Error	Explanation
1	Bus error. This should never happen on a Macintosh. The Macintosh hardware is designed so that bus transactions always appear to have succeeded, no matter what actually happened.
2	Address error. The processor tried to read an instruction or a 16-bit word of data from an odd address. This can occur if a character-pointer is cast to an integer pointer while it has an odd value.
3	Illegal instruction. The processor tried to decode data as an instruction. This usually results from the wrong data used as a return address in a subroutine.
4	Divide by zero. One of the divide instructions was executed with a divisor of 0.
5	Bounds-check failed. The CHK instruction found a register out of bounds. C does no bounds-checking, so this error should be rare.
6	Overflow trap. if the "V" bit in the status register is set and a TRAPV instruction is executed, this trap occurs.
7	Privilege violation. The Macintosh always runs in "system mode" in which all instructions are permitted. In order to generate a privilege violation, the status register would have to be modified to put the processor in "user mode." The status register can be set explicitly with a MOVE instruction, or as a side effect of the RTE instruction. Invalid information on the stack

could cause the RTE instruction to put the wrong value in the status register.

8 Trace exception. Another symptom of a status register being loaded with invalid data. See the description of error 7.

9 Line 1010 exception. This means that the toolbox trap handler has stopped functioning.

10 Line 1111 exception. This group of traps is often used to set breakpoints. If an unexpected line 1111 trap occurs, it is equivalent to an illegal instruction. See error 3.

11 Miscellaneous exception. caused by all other 68000 exceptions.

12 Unimplemented trap. This error is reported when the trap dispatcher can not find a toolbox trap. It may mean the dispatcher is broken or that the equivalent of an illegal instruction error has occurred. It may also mean that you have left a debugger trap in a program you are not running under the debugger. See error 3.

13 Spurious interrupt. This error is reported when there is no interrupt handler for an interrupt. This usually means that the interrupt table has been overwritten.

14 I/O system error. This occurs when an I/O queue element contains bad data.

15 Segment loader error. This means the segment loader attempted to read in a segment and failed. The application file has become unreachable. This can also be caused by an error in the resource compiler file that puts an application's CODE resources together.

16 Floating point error.

17-24 Failed to load pack 0 to 7, respectively. This means that these packages are not present in the system file being used.

25 Out of memory.

26 Failed loading segment 0. This means that the application file was incorrectly made, or has been corrupted.

27 Bad file map. An inconsistency in a file operation was detected. This may mean the volume being accesses has been corrupted.

28	Stack overflow. The "stack sniffer" has detected that the stack has collided with a heap, usually the application heap.
32-53	Memory manager errors.
41	The Finder could not be found. It may have been removed, or the volume it is on has been corrupted.
100	Failed to mount the startup volume. Another symptom of a corrupted file system.

The most common bugs

Programming the Macintosh in C yields a telltale set of bugs that differ from those found in assembly language and Pascal programming. The commonest kind of bug in C programs in general is the family of bugs that arise from mismatched parameters. Mismatched parameters occur when subroutines or toolbox traps are passed more or fewer parameters than they require, or inappropriate parameters.

In Macintosh programming, mismatched parameter bugs are more common, nastier and more varied in their manifestations, and more difficult to track down than in other environments. They occur when programmers forget how many parameters a routine takes, whether a default value is -1 or 0, what size a parameter is, or that a parameter is a "VAR" parameter and, in C, must be explicitly passed by reference. These bugs are difficult to find because they often manifest themselves inside the toolbox trap that was supplied with flawed information.

If a session with the debugger reveals that your program fails inside a toolbox trap, a parameter mismatch should be your first suspicion. Check the parameters being passed to the routine that fails. Also check subroutine parameters being passed between routines in your own code. Because the caller of a C routine manipulates the stack, C programs can mask parameter mismatch across one or more calls. Pascal routines, and the stack-based toolbox traps split stack manipulation between the caller and the called routine, so a parameter mismatch is likely to cause immediate failure — typically an illegal instruction or address error upon returning when the rts instruction loads an invalid address into the program counter.

When you suspect a parameter mismatch, make sure all of the following conditions hold true:

- The number of parameters is correct.
- The size of parameters is correct. A common error is to pass an integer constant when a long constant is required.

- The parameter is passed in the correct form. Pascal VAR parameters require a pointer to a parameter value be passed. Make sure that you have correctly read the description of the routine you are calling.

Testing

When you are happy with the way your program works, wait! Do not go sell it or distribute it to people who will be relying on it. Test it. All responsible software developers put their software through (at least) two testing phases. These testing phases are typically called "alpha" and "beta."

The purpose of testing is to find bugs. The hard part is getting the bugs described clearly. Bug reports should contain a description of what occurred, and information about the setting in which the behavior occurred. If possible, the person reporting a bug should describe not only what happened, but how to make it happen again.

Alpha testing is the first testing phase. Alpha releases are usually released to technically adept users who understand the purpose of the application and who probably understand how some or all of the application was designed and implemented. Preparing an alpha release involves preliminary testing on all of the configurations the software will run on, and the preparation of the first draft of the application's documentation.

Alpha testing should tell you if you have made any fundamental errors, whether performance is adequate, and whether the documentation correctly corresponds to the way the program works. Testing on a variety of configurations is vital. You should plan on testing with a Macintosh 512k, and a Macintosh Plus, both with and without hard disks.

Alpha testing should proceed according to a test plan. A test plan is a set of exercises designed to bring out any weak spots in a program: How does it behave when it runs out of memory? How does it behave when windows are shrunk or expanded to extremes? What if the program's current save-file is deleted through a desk accessory? Usually such provocative use of a program will uncover many errors and their remedies will improve the robustness of the program in general.

If you are left with a sheaf of unresolved problems with your alpha release, you may want to cancel the beta release and spend some time fixing the problems, so that the beta release does not have to be accompanied by work-around hints and a bug list. Do not try to fix the problems with your alpha release while the beta release is being tested. If you find you have time on your hands during the beta release, count yourself among the fortunate!

Beta testing is the second phase of testing. Beta testing simulates the conditions under which the software will be sold or distributed. In other respects beta testing is like alpha testing — you are looking for bugs. The number of beta testers should be greater than the number of alpha testers, ideally including the alpha test group in its entirety. In addition, the beta testers should include representatives of the target group of users. Beta testing is probably the most nerve wracking experience you will go through as a developer. The deadlines for publication are looming, and you are dealing with a large group of testers, some of whom can not be relied on to describe their problems in clear terms. In order to make beta testing go more smoothly, use your cadre of alpha testers to help the less computer-savvy beta testers characterize the problems they run into.

The most valuable kind of beta tester is the "power user." The power user often is not a programmer at all. Instead, the power user pushes applications like spreadsheets to their limits. Power users are valuable because they often do things with an application that the designer and author has no idea anyone would want to do.

Testing Macintosh software differs from testing other kinds of software because it is event driven. Event driven software can have an infinite variety of interactions with the user, so it is not always possible to test every eventuality. Because of this difference, clear bug reporting is of paramount importance. You will have to rely on your testing phases and your careful selection of testers to exercise the software enough to find the obscure bugs.

POINTS TO CONSIDER

1. If the Macintosh reports that it attempted to execute an illegal instruction, how could the flow of the program reach an illegal instruction?

2. Two programs have the same parameter mismatch bug. One is written in Pascal, the other in C. Will the bug manifest itself differently? Why?

3. Unlike most systems that run Unix, the Macintosh has one address space. How does this make debugging more difficult? How does it make it easier?

Reference

QuickDraw

QuickDraw is the basis of all activity on the Macintosh screen. QuickDraw also performs calculations on the objects it can draw. By combining a set of data structures for representing graphics objects with routines that can draw and perform calculations on those objects, QuickDraw forms a comprehensive graphics environment. QuickDraw can fill a region with a pattern, calculate whether a point lies in a region, and represent that region in a data structure whether it has been drawn on the screen or not. QuickDraw provides these tools in multiple coordinate systems, so that whole graphics environments can be moved around the screen. QuickDraw provides all of the tools used by the Window Manager, but QuickDraw is not a windowing system in and of itself. The Window Manager uses QuickDraw calculations and tells QuickDraw where clipping should occur, but the illusion of scraps of paper on a desktop is created by the Window Manager, not by QuickDraw alone.

The most important QuickDraw data structure is the region. Regions can represent objects of any shape. Since QuickDraw can perform all of its fundamental calculations on regions — such as the calculations that determine the overlap of graphics entities and clipping calculations, QuickDraw has a qualitative advantage over most graphics environments that only deal in rectangles and not arbitrary shapes such as regions. This is one reason why the Macintosh user interface looks more sophisticated than most other windowed user interfaces.

Constants

```
#define srcCopy      0
#define srcOr        1
#define srcXor       2
#define srcBic       3
#define notSrcCopy   4
#define notSrcOr     5
#define notSrcXor    6
```

```
#define notSrcBic    7
#define patCopy      8
#define patOr        9
#define patXor       10
#define patBic       11
#define notPatCopy   12
#define notPatOr     13
#define notPatXor    14
#define notPatBic    15

#define normalBit    0
#define inverseBit   1
#define blueBit      2
#define greenBit     3
#define redBit       4
#define blackBit     5
#define magentaBit   7
#define yellowBit    6
#define cyanBit      8

#define whiteColor   30
#define blackColor   33
#define yellowColor  69
#define magentaColor 137
#define redColor     205
#define cyanColor    273
#define greenColor   341
#define blueColor    409

#define picLParen    0
#define picRParen    1

#define frameMode    0
#define paintMode    1
#define eraseMode    2
#define invertMode   3
#define fillMode     4

#define bold      0x01
#define italic    0x02
#define underline 0x04
#define outline   0x08
#define shadow    0x10
#define condense  0x20
#define extend    0x40
```

Data Structures

```
typedef unsigned char Byte;
typedef char SignedByte;
typedef char * Ptr;
typedef char ** Handle;
typedef int (*ProcPtr)();
typedef unsigned int Boolean;

typedef char QDByte, *QDPtr, **QDHandle;
typedef char Str255[256];
typedef unsigned char Pattern[8];
typedef int Bits16[16];

typedef unsigned int Style;

typedef struct
{  int ascent;
   int descent;
   int widMax;
   int leading;
} FontInfo;

typedef struct
{  int v;
   int h;
} Point;

typedef struct
{  Point pnLoc;
   Point pnSize;
   int pnMode;
   Pattern pnPat;
} PenState;

typedef struct
{  int top;
   int left;
   int bottom;
   int right;
} Rect;

typedef struct
{  QDPtr baseAddr;
   int rowBytes;
   Rect bounds;
} BitMap;

typedef struct
{  Bits16 data;
   Bits16 mask;
   Point hotSpot;
} Cursor;
```

```
typedef struct
{  int rgnSize;
   Rect rgnBBox;
   /* region definition data */
} Region, *RgnPtr, **RgnHandle;

typedef struct
{  int picSize;
   Rect picFrame;
   /* picture definition data */
} Picture, *PicPtr, **PicHandle;

typedef struct
{  int polySize;
   Rect polyBBox;
   Point polyPoints[1];
} Polygon Polygon, *PolyPtr, **PolyHandle;

typedef enum {frame, paint, erase, invert, fill} GrafVerb;

typedef struct
{  QDPtr textProc;
   QDPtr lineProc;
   QDPtr rectProc;
   QDPtr rRectProc;
   QDPtr arcProc;
   QDPtr polyProc;
   QDPtr rgnProc;
   QDPtr bitsProc;
   QDPtr commentProc;
   QDPtr txMeasProc;
   QDPtr getPicProc;
   QDPtr putPicProc;
} QDProcs, *QDProcsPtr;

typedef struct
{  int device;
   BitMap portBits;
   Rect portRect;
   RgnHandle visRgn;
   RgnHandle clipRgn;
   Pattern bkPat;
   Pattern fillPat;
   Point pnLoc;
   Point pnSize;
   int pnMode;
   Pattern pnPat;
   int pnVis;
   int txFont;
   Style txFace;
   int txMode;
   int txSize;
   int spExtra;
   long fgColor;
   long bkColor;
   int colrBit;
   int patStretch;
   Handle picSave;
   Handle rgnSave;
   Handle polySave;
   QDProcsPtr grafProcs;
} GrafPort, *GrafPtr;
```

The following global variables are used by QuickDraw. These are not low-memory globals. Most compilers provide preallocated space for these variables. This support parallels that of the Lisa Pascal development system.

```
GrafPtr thePort;
Pattern white;
Pattern black;
Pattern ltGray;
Pattern dkGray;
Cursor arrow;
BitMap screenBits;
long randSeed;
```

If your compiler does not predefine these variables, you will have to do so yourself. If you define them, they must be in the above order so that Quickdraw's initialization call works correctly.

Initial values of QuickDraw's Global Variables

Type	**Variable**	**Initial Value**
GrafPtr	thePort	NULL
Pattern	white	all-white
Pattern	black	all-black
Pattern	gray	50% gray
Pattern	ltGray	25% gray
Pattern	dkGray	75% gray
Cursor	arrow	arrow cursor
BitMap	screenbits	Macintosh screen
long	randSeed	1

Functions

GrafPort Routines

```
pascal void InitGraf(globalPtr)
   Ptr globalPtr;
```

InitGraf initializes the QuickDraw global variables. InitGraf should be called one time only, at the beginning of your program.

The parameter globalPtr tells QuickDraw where these global variables are stored. C programmers should use &thePort for this parameter.

```
pascal void OpenPort(gp)
   GrafPtr gp;
```

OpenPort sets up fields for a new grafPort gp. OpenPort allocates space for gp's visRgn and clipRgn by calling NewRgn and initialize the fields of the grafPort. OpenPort makes gp the current port. OpenPort is called by the Window Manager when a new window is created.

Initial Values of a GrafPort

Type	**Field**	**Initial value**
int	device	0
BitMap	portBits	screenBits(from InitGraf)
Rect	portRect	screenBits.bounds
RgnHandle	visRgn	handle to rectangular region equivalent to screenBits.bounds
RgnHandle	clipRgn	handle to rectangular region (-32767,-32767,32767,32767)
Pattern	bkPat	white
Pattern	fillPat	black
Point	pnLoc	(0,0)
Point	pnSize	(1,1)
int	pnMode	patCopy
Pattern	pnPat	black
int	pnVis	0 (visible)
int	txFont	0 (system font)
Style	txFace	plain
int	txMode	srcOr
int	txSize	0 (system font size)
int	spExtra	0
long	fgColor	blackColor
long	bkColor	whiteColor
int	colrBit	0
int	patStretch	0
Handle	picSave	NULL
Handle	rgnSave	NULL
Handle	polySave	NULL
QDProcsPtr	grafProcs	NULL

```
pascal void InitPort(gp)
   Grafptr gp;
```

InitPort sets the fields of gp's grafPort to the above initial values. InitPort makes gp the current port. Note that gp must have already been opened with OpenPort, as InitPort does not allocate space for visRgn and clipRgn.

```
pascal void ClosePort(gp)
   GrafPtr gp;
```

ClosePort frees the memory used by gp's visRgn and clipRgn. The Window Manager calls ClosePort when it closes or disposes a window.

```
pascal void SetPort(gp)
   GrafPtr gp;
```

SetPort makes gp the current port. SetPort does this by setting the global variable thePort equal to gp.

```
pascal void GetPort(gp)
   GrafPtr *gp;
```

GetPort sets gp to the current port.

```
pascal void GrafDevice(device)
   int device;
```

GrafDevice sets the current port's output device to device. Device zero is the Macintosh screen.

```
pascal void SetPortBits(bm)
   BitMap *bm;
```

SetPortBits sets the current port's portBits field to bitmap bm. Drawing is done in the portBits bitmap. Be sure that bm is set up correctly before calling SetPortBits. Drawing is not confined to the screen. You can set up bitmaps to act as output buffers or as areas to prepare images off-screen.

```
pascal void PortSize(width, height)
   int width, height;
```

PortSize changes the size of the current grafPort's portRect. The top left corner remains in the same location. The bottom right corner is adjusted so that the rectangle is of the specified width and height. Calling PortSize does not change what is already on the screen, but it will affect future drawing. Normally, only the Window Manager calls PortSize.

```
pascal void MovePortTo(leftGlobal, topGlobal)
   int leftGlobal, topGlobal;
```

MovePortTo changes the current portRect's position with respect to portBits.bounds. PortRect is adjusted so that its top left corner is leftGlobal and topGlobal units from the top left corner of portBits.bounds. MovePortTo does not affect anything currently on the screen but it will affect future activity in the port. MovePortTo is normally called only by the Window Manager.

```
pascal void SetOrigin(h,v)
   int h, v;
```

SetOrigin does a number of things. It sets the top left corner of the current grafPort's portRect to (h,v), adjusts the bottom right corner of portRect so that the height and width remain the same, and offsets the coordinates of portBits.bounds and visRgn. The net result of all these calculations is to change the local coordinate system of the current grafPort. Note that the areas changed by SetOrigin were those which are bound to the screen and *not* those bound to the coordinate system.

SetOrigin doesn't change the screen but it will affect any future drawing.

```
pascal void SetClip(rgn)
   RgnHandle rgn;
```

SetClip changes the clipRgn of the current grafPort to a region just like the region with handle rgn. This is done by copying region rgn to clipRgn. Since a copy is made, clipRgn can be changed without changing rgn.

```
pascal void GetClip(rgn)
   RgnHandle rgn;
```

GetClip copies the current grafPort's clipRgn to the region rgn. An actual copy is made: the returned region can be changed and it will not affect clipRgn. Rgn must exist before calling GetClip.

```
pascal void ClipRect(r)
   Rect *r;
```

ClipRect sets the current grafPort's clipRgn to a rectangular region equivalent to rectangle r.

```
pascal void BackPat(pat)
   Pattern *Pat;
```

BackPat makes pat the background pattern of the current grafPort.

Cursor Handling

To keep track of calls to HideCursor and ShowCursor, QuickDraw maintains a global variable known as the cursor level. The cursor is visible when the cursor level is zero and invisible when the cursor level is below zero. The cursor level never goes above zero.

```
pascal void InitCursor ()
```

InitCursor gives you the predefined arrow cursor and sets the cursor level to zero.

```
pascal void SetCursor(crsr)
   Cursor *crsr;
```

SetCursor changes the current cursor to crsr. If the cursor is visible, this change will occur immediately. If the cursor is hidden, you'll see the new cursor when the cursor is uncovered.

```
pascal void HideCursor()
```

HideCursor makes the cursor invisible. The bits where the cursor was are restored. HideCursor also decrements the cursor level. Calls to HideCursor should be balanced with calls to ShowCursor.

```
pascal void ShowCursor()
```

ShowCursor increments the cursor level if it's below zero and displays the cursor when the cursor level becomes zero.

```
pascal void ObscureCursor()
```

ObscureCursor temporarily hides the cursor. The cursor will reappear the moment that the mouse is moved. ObscureCursor does *not* change the cursor level.

Pen and Line Drawing

```
pascal void HidePen()
```

HidePen will decrement the pnVis field of the current grafPort. Drawing does not occur on the screen when pnVis is negative.

HidePen is called by OpenRgn, OpenPicture and OpenPoly so that regions, pictures and polygons can be defined without appearing on screen.

Calls to HidePen should be balanced by calls to ShowPen.

```
pascal void ShowPen()
```

ShowPen increments the pnVis field of the current grafPort. When pnVis is zero, on-screen drawing becomes visible. Unlike the cursor level, the pnVis field can become greater than zero.

Be sure to balance ShowPen and HidePen calls. ShowPen is called by CloseRgn, ClosePicture, and ClosePoly, thus balancing calls to HidePen made by OpenRgn, OpenPicture and OpenPoly.

```
pascal void GetPen(pt)
   Point *pt;
```

GetPen sets pt to the current location of the pen, using the local coordinate system of the current grafPort.

```
pascal void GetPenState(pnState)
   PenState *pnState;
```

GetPenState sets the fields of pnState to the location, size, mode and pattern of the current grafPort's pen.

```
pascal void SetPenState(pnState)
   PenState *pnState;
```

SetPenState sets the location, size, mode and pattern of the current grafPort's pen to the values given in pnState.

```
pascal void PenSize(width, height)
   int width, height;
```

PenSize sets the dimensions of the pen in the current grafPort, giving the graphics pen the specified width and height. The pen size can be found in the grafPort's pnSize field.

```
pascal void PenMode(mode)
   int mode;
```

PenMode sets the current grafPort's pen mode to mode. The pen mode specifies the mode through which the pattern is transferred to the bit map. Any pattern transfer mode can be used; if the pen mode is a source transfer mode or a negative value, no drawing is done. The pen mode can be found in the grafPort's pnMode field.

```
pascal void PenPat(pat)
   Pattern *pat;
```

PenPat sets the pattern (black, white, gray, dkGray, or ltGray) used by the current grafPort's pen to pat. The pen pattern can be found in the grafPort's pnPat field.

```
pascal void PenNormal()
```

PenNormal reinitializes the graphics pen with pnSize = (1,1), pnMode = patCopy, and pnPat = black.

```
pascal void MoveTo(h, v)
   int h, v;
```

MoveTo places the pen at location (h, v). H and v are in local coordinates. MoveTo is a non-drawing procedure.

```
pascal void Move(dh, dv)
   int dh, dv;
```

Move moves the pen from the current location to a location dh horizontal and dv vertical units away. Move is a non-drawing procedure.

```
pascal void LineTo(h,v)
   int h, v;
```

LineTo draws a line from the current location to the point (h,v). The pen remains at location (h,v).

```
pascal void Line(dh, dv)
   int dh, dv;
```

Line draws a line from the current location to a location dh horizontal and dv vertical units away. The pen remains at the new location.

Text Drawing

```
pascal void TextFont(font)
   int font;
```

TextFont sets the font of the current grafPort to font number font. You can find the current font at thePort->txFont.

```
pascal void TextFace(face)
   Style face;
```

TextFace sets the style for the current grafPort to face. Face can be one (or the sum of more than one) of the predefined style constants: bold, italic, underline, outline, shadow, condense, extend.

Some TextFace Examples

desired style	TextFace parameter
bold	bold
bold & italic	bold + italic
current value & italic	thePort->txFace + italic
current value & not italic	thePort->txFace - italic
normal	zero

```
pascal void TextMode(mode)
   int mode;
```

TextMode sets the current grafPort's text transfer mode to mode. Mode should be one of the following *source* transfer modes: srcOr, srcXor or srcBic.

```
pascal void TextSize(size)
   int size;
```

TextSize sets the current grafPort's text size to size. Size is the point size of the font.

For best results, use a size the Font Manager has available. Otherwise an available size will be scaled. Even multiples of an available size are the second best choice. If size is zero, the Font Manager uses an available size which is closest to the system font size.

```
pascal void SpaceExtra(extra)
   int extra;
```

SpaceExtra sets the current grafPort's spExtra field to extra. Used primarily to implement right and left justified text, spExtra specifies the number of pixels that each space will be widened by when text is drawn. Typically, this is the difference between the length of the text (in pixels) and the space between the margins, divided by the number of spaces in the text. By padding each space with this number of pixels, the text will occupy all of the space between the margins.

```
pascal void DrawChar(ch)
   char ch;
```

DrawChar draws the character ch using the current font, style, size and source transfer mode. The left end of the character's base line is at the current pen location. After drawing the character, the pen's horizontal coordinate will have increased by the character's width. The font's "missing" symbol is drawn if the character is not available.

```
pascal void DrawString(s)
   Str255 s;
```

DrawString draws the string s by calling DrawChar for each character in the string. The toolbox always expects pascal strings.

```
pascal void DrawText(textBuf, firstByte, byteCount)
   Ptr textBuf;
   int firstByte, byteCount;
```

DrawText draws characters from the buffer pointed to by textBuf. ByteCount characters are drawn, starting with the character at offset firstByte. The drawing starts to the right of the pen's location. The pen ends up to the right of the last character drawn.

```
pascal int CharWidth(ch)
   char ch;
```

CharWidth returns the width (in pixels) of ch if you were to draw it in the current grafPort. The width calculation uses the current font, size, and style as well as spExtra when ch is a space.

```
pascal int StringWidth(s)
   Str255 s;
```

StringWidth calls CharWidth for each character in the string s, and returns the total width of the string.

```
pascal int TextWidth(textBuf, firstByte, byteCount)
   Ptr textBuf;
   int firstByte, byteCount;
```

TextWidth calls CharWidth for byteCount characters in the buffer textBuf, starting with the character at offset firstByte. The total width of the these characters is returned.

```
void GetFontInfo(info)
   FontInfo *info;
```

GetFontInfo places the current grafPort's font information into the fields of info. The font information is determined using the current font, size and style. The font information includes: ascent, descent, width of widest character, and leading (the distance between descent of a line and ascent of the line below it).

Drawing in Color

```
pascal void ForeColor(color)
   long color;
```

ForeColor sets the current grafPort's foreground color to color.

```
pascal void BackColor(color)
   long color;
```

BackColor sets the current grafPort's background color to color.

```
pascal void ColorBit(whichBit)
   int whichBit;
```

ColorBit tells QuickDraw which bit plane to draw in. ColorBit is used to support color devices with up to 32 bits of color information per pixel.

Calculations with Rectangles

```
pascal void SetRect(r, left, top, right, bottom)
   Rect *r;
   int left, top, right, bottom;
```

SetRect sets the coordinates of the rectangle r to (left, top, right, bottom).

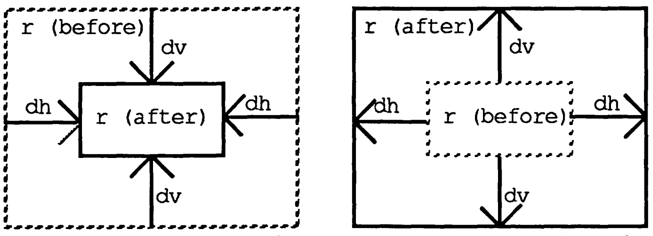
```
pascal void OffsetRect(r, dh, dv)
   Rect *r;
   int dh, dv;
```

OffsetRect changes the coordinates of rectangle r. The coordinates are changed dh units horizontally and dv units vertically.

```
pascal void InsetRect(r, dh, dv)
   Rect *r;
   int dh, dv;
```

InsetRect moves the sides of rectangle r inward by dh (or outward if dh is negative). The top and bottom of r move toward the center by dv (or they'll move outward if dv is negative). If the value of dh or dv causes the width or height of the rectangle to become less than one, then r is set to the empty rectangle: (0,0,0,0).

Results of InsetRect



InsetRect when dh & dv are positive.

InsetRect when dh & dv are negative

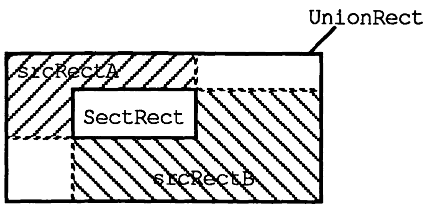
```
pascal Boolean SectRect(srcRectA, srcRectB, dstRect)
   Rect *srcRectA, *srcRectB, *dstRect;
```

SectRect makes dstRect the intersection of the two rectangles srcRectA and srcRectB. If srcRectA and srcRectB do not intersect, then dstRect becomes (0,0,0,0) and SectRect is FALSE. If srcRectA and srcRectB touch only along an edge or at a point, they are not intersecting rectangles because lines and points are infinitely small on the Macintosh.

```
pascal void UnionRect(srcRectA, srcRectB, dstRect)
   Rect *srcRectA, *srcRectB, *dstRect;
```

UnionRect sets dstRect to the smallest rectangle which encloses srcRectA and srcRectB.

Intersection and Union of Rectangles



```
pascal Boolean PtInRect(pt, r)
   long pt;
   Rect *r;
```

PtInRect returns TRUE if the pixel below and to the right of point pt is inside rectangle r. If this pixel is not inside r, PtInRect is FALSE.

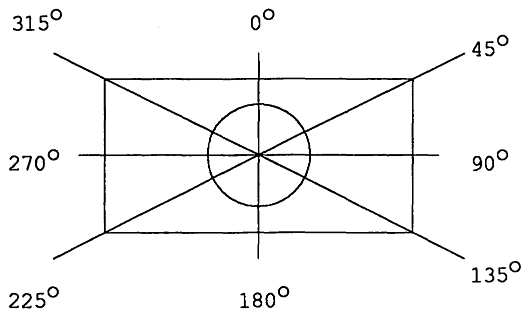
```
pascal void Pt2Rect(ptA, ptB, dstRect)
   long ptA, ptB;
   Rect *dstRect;
```

Pt2Rect sets dstRect to the smallest rectangle enclosing PtA and PtB.

```
pascal void PtToAngle(r, pt, angle)
   Rect *r;
   long pt;
   int *angle;
```

PtToAngle sets angle to the number of degrees (zero to 359) from the center of the rectangle r to the line from the center through the point pt. Quickdraw angles are not "true" angles, rather they are measured relative to rectangles. The line straight up from the center is at zero degrees, the line straight out to the right is at 90 degrees and so on. The angle of a line that goes from the center through a corner of the rectangle is always a multiple of 45 degrees.

Angles in QuickDraw



All QuickDraw angles are
measured relative to rectangles.

```
pascal Boolean EqualRect(rectA, rectB)
   Rect *rectA, *rectB;
```

EqualRect is TRUE if rectA and rectB have the same coordinates, FALSE if they do not.

```
pascal Boolean EmptyRect(r)
   Rect *r;
```

EmptyRect is TRUE if r is an empty rectangle and FALSE if it's not. An empty rectangle is one where the right coordinate is less than or equal to the left coordinate or the bottom coordinate is less than or equal to the top coordinate.

Graphic Operations on Rectangles

```
pascal void FrameRect(r)
   Rect *r;
```

FrameRect uses the current graphics pen to draw a hollow outline just inside rectangle r. The location of the pen is not changed by FrameRect.

If FrameRect is called while a region is open and being formed, the outside outline of the rectangle is added to the region's boundary.

```
pascal void PaintRect(r)
   Rect *r;
```

PaintRect fills the rectangle r with the current grafPort's pnPat, using the current pnMode. The pen location does not change.

```
pascal void EraseRect(r)
   Rect *r;
```

EraseRect fills the rectangle r with the background pattern using patCopy mode. The pen location does not change.

```
pascal void InvertRect(r)
   Rect *r;
```

InvertRect toggles all the pixels inside rectangle r: all white pixels become black and all black pixels become white. The pen location does not change.

```
pascal void FillRect(r, pat)
   Rect *r;
   Pattern pat;
```

FillRect uses patCopy mode to fill rectangle r with pattern pat. The pen location does not change.

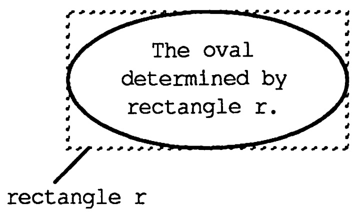
Graphic Operations on Ovals

```
pascal void FrameOval(r)
   Rect *r;
```

FrameOval uses the characteristics of the current graphics pen to draw a hollow outline inside the oval that fits inside rectangle r. The pen location does not change.

FrameOval will add the outside outline of the oval to the boundary of an open region.

Creating an Oval using a Rectangle



```
pascal void PaintOval(r)
   Rect *r;
```

PaintOval fills the oval determined by rectangle r with the current pnPat using the current pnMode. The pen location does not change.

```
pascal void EraseOval(r)
   Rect *r;
```

EraseOval paints the oval determined by rectangle r with the background pattern using the patCopy mode. The pen location does not change.

```
pascal void InvertOval(r)
   Rect *r;
```

InvertOval toggles all the pixels inside the oval determined by rectangle r: all white pixels become black pixels and all black pixels become white pixels. The pen location does not change.

```
pascal void FillOval(r, pat)
   Rect *r;
   Pattern pat;
```

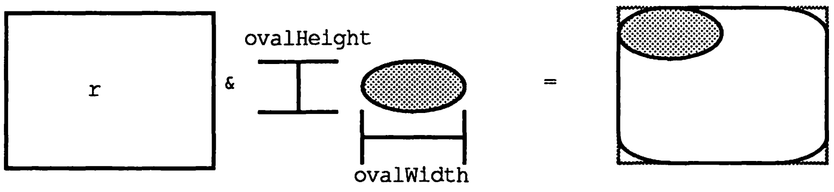
FillOval uses patCopy mode to fill the oval determined by r with pattern pat. The pen location does not change.

Graphic Operations on Rounded-Corner Rectangles

```
pascal void FrameRoundRect(r, ovalWidth, ovalHeight)
   Rect *r;
   int ovalWidth, ovalHeight;
```

FrameRoundRect uses the attributes of the current graphics pen to draw a hollow outline just inside the rounded-corner rectangle determined by r, ovalWidth and ovalHeight. FrameRoundRect does not change the pen location.

For open regions, the outside outline of this rounded-corner rectangle is added to the region's boundary.



Making a RoundRect using r, ovalWidth and ovalHeight

```
pascal void PaintRoundRect(r, ovalWidth, ovalHeight)
   Rect *r;
   int ovalWidth, ovalHeight;
```

PaintRoundRect uses the mode and pattern of the current graphics pen to paint the rounded-corner rectangle determined by r, ovalWidth and ovalHeight. The pen location does not change.

```
pascal void EraseRoundRect(r, ovalWidth, ovalHeight)
   Rect *r;
   int ovalWidth, ovalHeight;
```

EraseRoundRect uses patCopy mode to paint the rounded-corner rectangle determined by r, ovalWidth and ovalHeight with the current grafPort's background pattern. The pen location does not change.

```
pascal void InvertRoundRect(r, ovalWidth, ovalHeight)
    Rect *r;
    int ovalWidth, ovalHeight;
```

`InvertRoundRect` toggles all the pixels inside the rounded-corner rectangle determined by `r`, `ovalWidth` and `ovalHeight`. All black pixels become white, all white pixels become black. The pen location does not change.

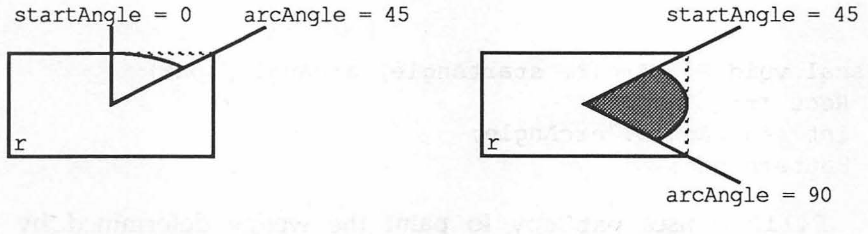
```
pascal void FillRoundRect(r, ovalWidth, ovalHeight, pat)
    Rect *r;
    int ovalWidth, ovalHeight;
    Pattern pat;
```

`FillRoundRect` paints the rounded-corner rectangle determined by `r`, `ovalWidth` and `ovalHeight` with the pattern `pat`. `FillRoundRect` uses `patCopy` mode. The pen location does not change.

Graphic Operations on Arcs and Wedges

QuickDraw arcs and wedges are determined by three components: a rectangle, a start angle, and an arc angle.

QuickDraw Wedges and Arcs



An Arc determined by r, startAngle, and arcAngle

A Wedge determined by r, startAngle, and arcAngle

```
pascal void FrameArc(r, startAngle, arcAngle)
    Rect *r;
    int startAngle, arcAngle;
```

`FrameArc` will use the current graphics pen to draw a hollow outline just inside of the arc determined by `r`, `startAngle` and `arcAngle`. The pen location does not change.

For open regions, `FrameArc` is unlike any of the other frame procedures in that it does *not* add to the boundary of the region.

```
pascal void PaintArc(r, startAngle, arcAngle)
   Rect *r;
   int startAngle, arcAngle;
```

PaintArc uses the current pnPat and pnMode to paint the wedge determined by r, startAngle and arcAngle. The pen location does not change.

```
pascal void EraseArc(r, startAngle, arcAngle)
   Rect *r;
   int startAngle, arcAngle;
```

EraseArc paints the wedge determined by r, startAngle and arcAngle with the background pattern bkPat using patCopy mode. The pen location does not change.

```
pascal void InvertArc(r, startAngle, arcAngle)
   Rect *r;
   int startAngle, arcAngle;
```

InvertArc toggles all of the pixels contained in the wedge determined by r, startAngle and arcAngle. Each white pixel becomes black, each pixel that was black becomes white. The pen location does not change.

```
pascal void FillArc(r, startAngle, arcAngle, pat)
   Rect *r;
   int startAngle, arcAngle;
   Pattern pat;
```

FillArc uses patCopy to paint the wedge determined by r, startAngle and arcAngle with pattern pat. The pen location does not change.

Calculations with Regions

```
pascal RgnHandle NewRgn()
```

NewRgn creates a new region. Heap space is allocated for the new region. The region starts off as the empty region (0,0,0,0). A handle to the new region is returned.

NewRgn *must* be called for a region before the region can be used.

```
pascal void DisposeRgn(rgn)
   RgnHandle rgn;
```

DisposeRgn frees the memory used by region rgn. When you no longer need a region, call DisposeRgn to get rid of it.

```
pascal void CopyRgn(srcRgn, dstRgn)
   RgnHandle srcRgn, dstRgn;
```

CopyRgn copies srcRgn to the region with handle dstRgn. DstRgn must already have had space allocated for it before CopyRgn is called.

```
pascal void SetEmptyRgn(rgn)
   RgnHandle rgn;
```

SetEmptyRgn reinitializes rgn to the empty region (0,0,0,0).

```
pascal void SetRectRgn(rgn, left, top, right, bottom)
   RgnHandle rgn;
   int left, top, right, bottom;
```

SetRectRgn wipes out region rgn's current structure, and makes rgn the rectangular region (left, top, right, bottom). If the rectangle is an empty rectangle, rgn becomes the empty region (0,0,0,0).

```
pascal void RectRgn(rgn, r)
   RgnHandle rgn;
   Rect *r;
```

RectRgn wipes out rgn's current structure, and makes the region the rectangular region specified by r. If r is an empty rectangle, rgn becomes the empty region.

```
pascal void OpenRgn()
```

OpenRgn opens a QuickDraw region. QuickDraw begins saving information about all lines and framed shapes drawn up until CloseRgn is called. The information QuickDraw saved is then organized into a region.

OpenRgn calls HidePen, so no drawing appears on screen while a region is being defined. You can get around that by calling ShowPen just after OpenRgn (but be sure *you* make a balancing HidePen call).

```
pascal void CloseRgn(dstRgn)
   RgnHandle dstRgn;
```

CloseRgn stops the formation of a region. The collected information is organized into a region which is accessible using dstRgn.

CloseRgn calls ShowPen, balancing OpenRgn's HidePen call.

```
pascal void OffsetRgn(rgn, dh, dv)
   RgnHandle rgn;
   int dh, dv;
```

OffsetRgn moves region rgn dh units in the horizontal direction, dv units vertically. This will not affect the screen but will affect future drawing.

OffsetRgn is a very efficient method for translational movement of regions: a region is stored relative to it's bounding rectangle, so only that rectangle needs to be changed.

```
pascal void InsetRgn(rgn, dh, dv)
   RgnHandle rgn;
   int dh, dv;
```

InsetRgn moves the boundary of region rgn in or out, thus shrinking or expanding the region. The boundary is moved toward the center a distance of dh units horizontally and dv units vertically. Negative values of dh and dv cause movement away from the center.

```
pascal void SectRgn(srcRgnA, srcRgnB, dstRgn)
   RgnHandle srcRgnA, srcRgnB, dstRgn;
```

SectRgn calculates the region that is the intersection of the two regions srcRgnA and srcRgnB. DstRgn tells QuickDraw where to store the resulting intersection. SectRgn works if dstRgn is either srcRgnA or srcRgnB.

```
pascal void UnionRgn(srcRgnA, srcRgnB, dstRgn)
   RgnHandle srcRgnA, srcRgnB, dstRgn;
```

UnionRgn calculates the region which is the union of regions srcRgnA and srcRgnB. DstRgn is the resulting region. DstRgn can be equal to either srcRgnA or srcRgnB.

```
pascal void DiffRgn(srcRgnA, srcRgnB, dstRgn)
   RgnHandle srcRgnA, srcRgnB, dstRgn;
```

DiffRgn calculates a new region by subtracting srcRgnB from srcRgnA. The resulting region is stored at dstRgn. DstRgn can be equal to either srcRgnA or srcRgnB.

If srcRgnA is the empty region, dstRgn automatically becomes an empty region.

```
pascal void XorRgn(srcRgnA, srcRgnB, dstRgn)
   RgnHandle srcRgnA, srcRgnB, dstRgn;
```

XorRgn makes dstRgn the union of srcRgnA and srcRgnB minus the intersection of srcRgnA and srcRgnB. DstRgn can be equal to either srcRgnA or srcRgnB.

```
pascal Boolean PtInRgn(pt, rgn)
   Point pt;
   RgnHandle rgn;
```

PtInRgn is TRUE if the pixel below and to the right of point pt is in the region rgn. PtInRgn is FALSE otherwise.

```
pascal Boolean RectInRgn(r, rgn)
   Rect *r;
   RgnHandle rgn;
```

RectInRgn is TRUE if the intersection of the rectangle r and the region rgn contains at least one point. If the intersection is empty, RectInRgn is FALSE.

```
pascal Boolean EqualRgn(rgnA, rgnB)
   RgnHandle rgnA, rgnB;
```

EqualRgn is TRUE if the two regions, rgnA and rgnB, are equal. EqualRgn is FALSE otherwise. Two regions must have the same size, shape and location to be considered equal.

```
pascal Boolean EmptyRgn(rgn)
   RgnHandle rgn;
```

EmptyRgn returns TRUE when region rgn is the empty region. EmptyRgn is FALSE if rgn is not empty.

Graphic Operations on Regions

```
pascal void FrameRgn(rgn)
   RgnHandle rgn;
```

FrameRgn uses characteristics of the current grafPort's pen to draw an outline just inside region rgn's boundary. The frame is as wide and as tall as the pen, but it does not go outside of the region boundary.

```
pascal void PaintRgn(rgn)
   RgnHandle rgn;
```

PaintRgn paints region rgn in the current grafPort using the current pnPat and pnMode.

```
pascal void EraseRgn(rgn)
   RgnHandle rgn;
```

PaintRgn paints region rgn in the current grafPort using the current bkPat in patCopy mode.

```
pascal void InvertRgn(rgn)
   RgnHandle rgn;
```

InvertRgn toggles all the pixels inside region rgn: all white pixels become black, all black pixels become white.

```
pascal void FillRgn(rgn, pat)
   RgnHandle rgn;
   Pattern pat;
```

FillRgn uses patCopy mode to fill the region rgn with pattern pat.

Bit Transfer Operations

```
pascal void ScrollRect(r, dh, dv, updateRgn)
   Rect *r;
   int dh, dv;
   RgnHandle updateRgn;
```

ScrollRect moves all the visible bits in rectangle r (the bits contained in r, visRgn, clipRgn, portRect and portBits.bounds) a distance of dh units horizontally, dv units vertically. Bits scrolled outside of the area are gone. Vacated areas are filled with pattern bkPat, and this area becomes the updateRgn.

```
pascal void CopyBits(srcBits, dstBits, srcRect, dstRect,
 mode, maskRgn)
   BitMap *srcBits, *dstBits;
   Rect *srcRect, *dstRect;
   int mode;
   RgnHandle maskRgn;
```

CopyBits copies a bit image from from one bitMap (srcBits) to another (dstBits) using the mode transfer mode. SrcRect specifies a rectangle in srcBits that is to be copied. Use the srcBits.bounds coordinate system when specifying srcRect. DstRect is the rectangle in dstBits where the bit image will be transferred. DstRect is in the dstBits.bounds coordinate system. If srcRect and dstRect are not the same size, the bit image will be scaled to fit dstRect.

MaskRgn is in the dstBits.bounds coordinate system. The bit image is always clipped to the region given by maskRgn. If you don't want to clip to a region use NULL for maskRgn.

Pictures

```
pascal PicHandle OpenPicture(picFrame)
   Rect *picFrame;
```

OpenPicture creates a new picture with picFrame as the picture frame. A handle to the picture is returned. The picture is now open. Until the picture is closed, all drawing routines and picture comments become part of the picture.

Drawing does not normally occur on screen when a picture is open because OpenPicture calls HidePen. You can change this by calling ShowPen just after the picture has been opened.

You may need to do some drawing that is not part of a picture while a picture is being formed. Temporarily setting the grafPort's picSave field to NULL will allow you to do this. QuickDraw uses the grafPort's picSave field while forming pictures. When PicSave is NULL QuickDraw assumes it is not forming a picture. To resume making the picture, restore picSave to its previous value.

```
pascal void ClosePicture()
```

ClosePicture closes the currently open QuickDraw picture.

ClosePicture calls ShowPen to balance OpenPicture's call to HidePen.

```
pascal void PicComment(kind, dataSize, dataHandle)
   int kind, datasize;
   Handle dataHandle;
```

PicComment is used to insert application specific data into a QuickDraw picture. DataHandle is a handle to the data, dataSize is the size (in bytes) of that data. Kind can be used by the application to keep track of different types of picture comments.

```
pascal void DrawPicture(myPicture, dstRect)
   PicHandle myPicture;
   Rect *dstRect;
```

DrawPicture draws myPicture in the current grafPort. The picture frame is scaled to rectangle dstRect. Any picture comments in myPicture are passed along to the commentProc procedure referenced through the grafProcs field of the current grafPort.

```
pascal void KillPicture(myPicture)
   Pichandle myPicture;
```

KillPicture gets rid of myPicture. Any memory used by myPicture is released. Call KillPicture when you'll never need myPicture again.

Calculations with Polygons

```
pascal PolyHandle OpenPoly()
```

OpenPoly opens a new polygon and returns a handle to it. OpenPoly calls HidePen so drawing will not appear on screen. While the polygon is open, QuickDraw saves information about calls to line-drawing routines: endpoints of the lines are used to define the polygon. To close the polygon, call ClosePoly.

You may need to do draw lines that are not part of a polygon while a polygon is being formed. Temporarily setting the grafPort's polySave field to NULL will allow you to do this. QuickDraw uses the grafPort's polySave field while forming polygons. When polySave is NULL QuickDraw assumes it is not forming a polygon. To resume making the polygon, restore polySave to its previous value.

```
pascal void ClosePoly()
```

ClosePoly closes the open polygon. The bounding rectangle polyBBox is computed. ClosePoly calls ShowPen to resume on-screen drawing.

```
pascal void KillPoly(poly)
   PolyHandle poly;
```

KillPoly gets rid of the polygon with handle poly. All memory used for the polygon is released. Be sure you no longer need poly before you kill it.

```
pascal void OffsetPoly(poly, dh, dv)
   PolyHandle poly;
   int dh, dv;
```

OffsetPoly translates polygon poly on the coordinate plane. It's moved a distance of dh horizontal and dv vertical units.

OffsetPoly is an efficient method of moving the polygon — all points are stored relative to the starting point, so only one change is made.

Graphic Operations on Polygons

```
pascal void FramePoly(poly)
   PolyHandle poly;
```

FramePoly uses the current grafPort's pen to draw an outline just inside the polygon poly. Because the QuickDraw pen is to the right and below the point, the outline will be outside of the polyBBox.

```
pascal void PaintPoly(poly)
   PolyHandle poly;
```

PaintPoly fills polygon poly with the pnPat using the pnMode of the current grafPort. The pen location does not change.

```
pascal void ErasePoly(poly)
   PolyHandle poly;
```

ErasePoly fills polygon poly with the current grafPort's bkPat and using patCopy transfer mode. The pen location does not change.

```
pascal void InvertPoly(poly)
   PolyHandle poly;
```

InvertPoly toggles all pixels in polygon poly: all white pixels become black and all black pixels become white. The pen location does not change.

```
pascal void FillPoly(poly, pat)
   PolyHandle poly;
   Pattern pat;
```

FillPoly paints polygon poly with pattern pat using the patCopy transfer mode. The pen location does not change.

Calculations with Points

```
pascal void AddPt(srcPt, dstPt)
   Point srcPt, *dstPt;
```

AddPt adds the coordinates of srcPt and dstPt and stores the result in dstPt.

```
pascal void SubPt(srcPt, dstPt)
   Point srcPt, *dstPt;
```

SubPt subtracts the coordinates of srcPt from dstPt and stores the result in dstPt.

```
pascal void SetPt(pt, h, v)
   Point *pt;
   int h, v;
```

SetPt sets point pt's horizontal coordinate to h and and its vertical coordinate v.

```
pascal Boolean EqualPt (ptA, ptB)
   Point ptA, ptB;
```

EqualPt is TRUE if point ptA has the same coordinates as point ptB. EqualPt is FALSE when ptA has coordinates different than ptB.

```
pascal void LocalToGlobal (pt)
   Point *pt;
```

LocalToGlobal transforms point pt from the current grafPort's coordinate system to the global coordinate system.

```
pascal void GlobalToLocal(pt)
   Point *pt;
```

GlobalToLocal transforms the point pt from the global coordinate system to the current grafPort's coordinate system.

Miscellaneous Utilities

```
pascal int Random()
```

Random returns an integer between -32768 and 32767. The integer is from a uniform pseudo-random distribution. The seed for this function is the global variable randSeed. RandSeed is initialized to 1 by InitGraf.

```
pascal Boolean GetPixel(h, v)
   int h, v;
```

GetPixel is TRUE when the pixel corresponding to the point (h,v) is black, FALSE when the pixel is white. H and v should be in the current grafPort's local coordinate system.

GetPixel doesn't check if the pixel actually belongs to the current grafPort. You can do this yourself by calling:

```
PtInRgn(pt, thePort->visRgn)
```

```
pascal void StuffHex(thingPtr, s)
   Ptr thingPtr;
   Str255 s;
```

StuffHex allows you to stuff bytes into a data structure. The byte sequence is given by s — a pascal string of hexadecimal digits. The bytes are placed into the memory pointed to by thingPtr.

StuffHex stuffs with no questions asked. *You* have to make sure the bit sequence is not longer than it should be.

```
pascal void ScalePt(pt, srcRect, dstRect)
   Point *pt;
   Rect *srcRect, *dstRect;
```

ScalePt scales a width and height in rectangle srcRect to the width and height it would be if srcRect were scaled to dstRect. The width and height to be scaled are given by pt. The horizontal coordinate contains the width and the vertical coordinate contains the height. Upon return pt contains the scaled values. Pt will never be less than (1,1).

```
pascal void MapPt(pt, srcRect, dstRect)
   Point *pt;
   rect *srcRect, *dstRect;
```

MapPt maps point pt in rectangle srcRect to a point with the same relative location in rectangle dstRect.

```
pascal void MapRect(r, srcRect, dstRect)
   Rect *r, *srcRect, *dstRect;
```

MapRect maps rectangle r in rectangle srcRect to the rectangle in dstRect that has the same relative location and dimensions. This is done by calling MapPt for the top left and bottom right points in rectangle r.

```
pascal void MapRgn(rgn, srcRect, dstRect)
   RgnHandle rgn;
   Rect *srcRect, *dstRect;
```

MapRgn maps region rgn from a region in srcRect to the region it would be if srcRect where scaled to dstRect. MapRgn accomplishes this by calling MapPt for all the points in the region.

```
pascal void MapPoly(poly, srcRect, dstRect)
   PolyHandle poly;
   Rect *srcRect, *dstRect;
```

MapPoly maps polygon poly from a polygon in srcRect to the polygon it would be if srcRect where scaled to dstRect. MapPoly accomplishes this by calling MapPt for all the points in the polygon.

Customizing QuickDraw Operations

Each grafPort has a set of routines associated with it that QuickDraw uses for the lowest level operations. These are the only QuickDraw routines that actually modify the locations in a bitmap. By changing these routines, QuickDraw can be customized for drawing on external graphics devices such as the Imagewriter.

```
pascal void SetStdProcs(procs)
   QDProcs *procs;
```

SetStdProcs is used to change the low-level QuickDraw routines of the current grafPort. Procs points to a structure of function pointers for the low-level functions to be used.

```
pascal void StdText(byteCount, textBuf, numer, denom)
   int byteCount;
   Ptr textBuf;
   Point numer, denom;
```

StdText implements text drawing. TextBuf points to the text to be drawn. Bytecount is the number of bytes of text to be drawn. Numer and denom together specify scaling factors: (numer.h/denom.h) is the horizontal scaling factor, (numer.v/denom.v) is the vertical scaling factor.

```
pascal void StdLine(newPt)
   Point newPt;
```

StdLine draws a line from the current pen location to newPt.

```
pascal void StdRect(verb, r)
   GrafVerb verb;
   Rect *r;
```

StdRect implements all drawing operations on rectangles. R is the rectangle, verb specifies the operation (fill, invert, frame, etc.).

```
pascal void StdRRect(verb, r, ovalWidth, ovalHeight)
   GrafVerb verb;
   Rect *r;
   int ovalWidth, ovalHeight;
```

StdRRect implements all drawing operations on rounded-corner rectangles. R, ovalWidth and ovalHeight determine the rounded-corner rectangle, verb tells which drawing method to use.

```
pascal void StdOval(verb, r)
   GrafVerb verb;
   Rect *r;
```

StdOval implements all drawing operations on ovals. R is the rectangle that determines the oval, verb tells which drawing method to use.

```
pascal void StdArc(verb, r, startAngle, arcAngle)
   GrafVerb verb;
   Rect *r;
   int startAngle, arcAngle;
```

StdArc implements all drawing operations on arcs and wedges. R, startAngle and arcAngle determine the arc, verb tells which drawing method to use.

```
pascal void StdPoly(verb, poly)
   GrafVerb verb;
   PolyHandle poly;
```

StdPoly implements all drawing operations on polygons. Poly is a handle to the polygon, verb tells which drawing method to use.

```
pascal void StdRgn(verb, rgn)
   GrafVerb verb;
   RgnHandle rgn;
```

StdRgn implements all drawing operations on regions. Rgn is a handle to the region, verb tells which drawing method to use.

```
pascal void StdBits(srcBits,srcRect,dstRect,mode,maskRgn)
   BitMap *srcBits;
   Rect *srcRect,*dstRect;
   int mode;
   RgnHandle maskRgn;
```

StdBits implements bit transfer between the bitmaps. StdBits scales the image if the source rectangle srcRect and the destination rectangle dstRect have different dimensions. Mode specifies the transfer mode, e.g. xor, or, and, etc. The bit transfer is clipped to MaskRgn.

```
pascal void StdComment(kind, dataSize, dataHandle)
   int kind, dataSize;
   Handle dataHandle;
```

StdComment processes picture comments. Kind is the type of comment, dataSize is the number of bytes to insert, dataHandle holds the data. StdComment ignores the picture comment.

```
pascal int StdTxMeas(byteCount, textAddr, numer, denom,
 info)
   int byteCount;
   Ptr textAddr;
   Point *numer, *denom;
   FontInfo *info;
```

StdTxMeas measures the text width as though the text (byteCount characters starting with the first character pointed to by textAddr) had been drawn using StdText.

```
pascal void StdGetPic(dataPtr, byteCount)
   Ptr dataPtr;
   int byteCount;
```

StdGetPic is used to access QuickDraw pictures. It retrieves bytecount bytes from the current open picture and puts them in the location pointed to by dataPtr.

```
pascal void StdPutPic(dataPtr, byteCount)
   Ptr dataPtr;
   int byteCount;
```

StdPutPic stores the definition (byteCount bytes pointed to by dataPtr) of the currently open picture.

Event Manager

The Event Manager drives every Macintosh application. Unlike most systems in which programs read from input streams that might be files or devices (such as a keyboard), Macintosh programs react to a stream of events. These events may be caused by keystrokes, mouse button clicks, ejected disks, the need to update a window, etc. So without explicitly listening for input from all possible sources, Macintosh applications get all of their input from one source: the event queue.

The event queue is managed and controlled by the Event Manager. The Event Manger provides routines for getting events from the event queue, classifying events, posting events, and removing events from consideration.

Constants

```
#define nullEvent         0
#define mouseDown         1
#define mouseUp           2
#define keyDown           3
#define keyUp             4
#define autoKey           5
#define updateEvt         6
#define diskEvt           7
#define activateEvt       8
#define abortEvt          9
#define networkEvt       10
#define driverEvt        11
#define app1Evt          12
#define app2Evt          13
#define app3Evt          14
#define app4Evt          15

#define charCodeMask   0x00FF
#define keyCodeMask    0xFF00
```

```
#define nullMask       0x0001
#define mDownMask      0x0002
#define mUpMask        0x0004
#define keyDownMask    0x0008
#define keyUpMask      0x0010
#define autoKeyMask    0x0020
#define updateMask     0x0040
#define diskMask       0x0080
#define activMask      0x0100
#define abortMask      0x0200
#define networkMask    0x0400
#define driverMask     0x0800
#define app1Mask       0x1000
#define app2Mask       0x2000
#define app3Mask       0x4000
#define app4Mask       0x8000

#define everyEvent     0xFFFF
```

Data Structures

```
typedef struct
{  int what;
   long message;
   long when;
   Point where;
   int modifiers;
} EventRecord;

typedef long KeyMap[4];
```

Functions

Accessing Events

```
pascal Boolean GetNextEvent(eventMask, theEvent)
   int eventMask;
   EventRecord *theEvent;
```

GetNextEvent sets theEvent equal to the next available event of the type (or types) specified by eventMask. GetNextEvent removes theEvent from the event queue.

GetNextEvent calls SystemEvent (a Desk Manager function) so that the system can intercept any events that the system (rather than your application) should respond to. GetNextEvent returns TRUE if there is an event for the application. If GetNextEvent is FALSE, there is no event for your application and theEvent is a null event.

```
pascal Boolean EventAvail(eventMask, theEvent)
   int eventMask;
   EventRecord *theEvent;
```

EventAvail is the same as GetNextEvent with the exception that theEvent is not removed from the event queue.

Posting and Removing Events

```
pascal OSErr PostEvent(eventCode, eventMsg)
   int eventCode;
   long eventMsg;
```

PostEvent posts an event with the what field set to eventCode and the message field set to eventMsg. Typically, PostEvent is used to post application-events.

```
pascal void FlushEvents(eventMask, stopMask)
   int eventMask, stopMask;
```

FlushEvents removes events of the type(s) given by eventMask from the event queue. FlushEvents stops removing events when it gets to the first event of the type(s) specified by stopMask. If stopMask is zero, all events are removed from the event queue.

Reading the Mouse

```
pascal void GetMouse(mouseLoc)
   Point *mouseLoc;
```

GetMouse sets mouseLoc equal to the current mouse location. MouseLoc will be in the current grafPort's local coordinate system.

```
pascal Boolean Button()
```

Button returns TRUE if the mouse button is currently down, FALSE if the button is up.

```
pascal Boolean StillDown()
```

StillDown returns TRUE if the mouse button is down and there are no mouse events in the event queue meaning that the button is still down from the previous mouse-down event. StillDown returns FALSE if the mouse button is up or the button is down because of a new mouse-down event.

```
pascal Boolean WaitMouseUp()
```

WaitMouseUp returns TRUE if the mouse button is still down from a previous mouse-down event. If the mouse button is down because of a new mouse-down event, WaitMouseUp will be FALSE and the mouse-up event associated with the previous mouse-down event will be removed from the event queue. WaitMouseUp returns FALSE if the mouse button is currently up.

Reading the KeyBoard and KeyPad

```
pascal void GetKeys(theKeys)
   KeyMap *theKeys;
```

GetKeys sets theKeys equal to the current state of the keyboard and keypad (if there is a keypad). An element in the key map will be TRUE if the corresponding key is down, FALSE otherwise.

Miscellaneous Utilities

```
pascal void SetEventMask(theMask)
   int theMask;
```

SetEventMask sets the system event mask to theMask. The system posts only those event types specified by theMask.

```
pascal long TickCount()
```

TickCount returns the number of ticks since the system was last started up. Ticks are one sixtieth of a second.

```
pascal long GetDblTime()
```

GetDblTime returns the threshold time value that should exist between a mouse-up and mouse-down event in order for two mouse clicks to be considered a double-click. The time is measured in ticks.

```
pascal long GetCaretTime()
```

GetCaretTime returns the number of ticks between blinks of the caret. The caret is used to mark the insertion point in editable text. If you aren't using TextEdit for editable text your application is responsible for making the caret blink.

Window Manager

The Window Manager is responsible for creating the "desktop metaphor." The Window Manager relies on QuickDraw to provide independent coordinate systems for each window, to clip to boundaries set up by the Window Manager and to do all of the drawing. But without the Window Manager's routines that draw window frames, keep track of which parts of which windows need updating, and which is the active window, Macintosh applications would have a tough time taking advantage of Quickdraw's abilities.

In addition to windowing functions built on top of Quickdraw's grafPort and clipping abilities, the Window Manager provides routines for creating windows based on templates in a resource file, deleting windows, moving, sizing, and titling windows.

Constants

```
#define documentProc 0
#define dBoxProc     1
#define dBoxZero     2
#define altDBoxProc  3
#define rDocProc     16

#define dialogKind   2
#define userKind     8

#define inDesk       0
#define inMenuBar    1
#define inSysWindow  2
#define inContent    3
#define inDrag       4
#define inGrow       5
#define inGoAway     6

#define noConstraint 0
```

```
#define hAxisOnly    1
#define vAxisOnly    2

#define wDraw        0
#define wHit         1
#define wCalcRgns    2
#define wNew         3
#define wDispose     4
#define wGrow        5
#define wDrawGIcon   6

#define wNoHit       0
#define wInContent   1
#define wInDrag      2
#define wInGrow      3
#define wInGoAway    4
```

Data Structures

```
typedef struct
{  GrafPort port;
   int WindowKind;
   char visible;
   char hilited;
   char goAwayFlag;
   char spareFlag;
   RgnHandle strucRgn;
   RgnHandle contRgn;
   RgnHandle updateRgn;
   Handle windowDefProc;
   Handle dataHandle;
   StringHandle titleHandle;
   int titleWidth;
   Handle controlList;
   WindowPeek nextWindow;
   PicHandle windowPic;
   long refCon;
} WindowRecord, *WindowPeek;

typedef GrafPtr WindowPtr;
```

Functions

Initialization and Allocation

```
pascal void InitWindows()
```

InitWindows must be called once before you use any other Window Manager procedures, as this function initializes the Window Manager. The Window Manager port is created and the desktop is drawn with an empty menu bar.

```
pascal void GetWMgrPort(wPort)
   GrafPtr *wPort;
```

GetWMgrPort sets wPort equal to the Window Manager port.

```
pascal WindowPtr NewWindow(wStorage, boundsRect, title,
 visible, procID, behind, goAwayFlag, refCon)
   Ptr wStorage;
   Rect *boundsRect;
   Str255 title;
   Boolean visible, goAwayFlag;
   int procID;
   WindowPtr behind;
   long refCon;
```

NewWindow creates a new window, adds it to the window list, and returns a pointer to the new window. Space is allocated for the window's structure and content regions. These regions and the window record fields are initialized according to NewWindow parameters and the window definition procedure.

WStorage is a pointer to a window record. If wStorage is NULL, NewWindow will allocate the window record for you.

BoundsRect is the bounding rectangle of the window. BoundsRect should be in global coordinates.

Title is the title of the window. It appears in the window according to the window definition procedure.

The window will be visible if visible is TRUE. The new window will be drawn if it is visible.

ProcID is the ID of the window definition procedure. The procID can be a predefined value (such as documentProc, dBoxProc, dBoxZero, etc.) or you can supply an ID for your own custom routine.

The new window will be behind the window pointed to by behind. If behind is -1, the new window will be in front of all existing windows. If behind is NULL, the new window will be behind all existing windows.

If goAwayFlag is TRUE, the window will have a go away region. The window definition procedure is called on to draw the go away region.

RefCon is available for use by the application. It is not used by other ToolBox routines.

```
pascal WindowPtr GetNewWindow(windowID, wStorage, behind)
   int windowID;
   Ptr wStorage;
   WindowPtr behind;
```

GetNewWindow uses resources to create a new window. The new window is added to the window list and a pointer to the window record is returned. WindowID is the resource ID of the new window's resource template. The window structure is initialized using the information in the window resource. Behind points to the window the new window should be behind. If behind is -1, the new window will be the frontmost window. If wStorage is not NULL, GetNewWindow assumes it is a pointer to a window record and uses that record. If wStorage is NULL, GetNewWindow allocates a window record as a nonrelocatable object in the heap.

```
pascal void CloseWindow(theWindow)
   WindowPtr theWindow;
```

CloseWindow erases theWindow from the screen and removes it from the window list. The memory used by all the data structures associated with theWindow (such as the clipRgn and visRgn) will be freed. CloseWindow will *not* release the memory used by the window record. If the application allocated theWindow's window record, CloseWindow rather than DisposeWindow should be used to get rid of this window.

```
pascal void DisposeWindow(theWindow)
   WindowPtr theWindow;
```

DisposeWindow calls CloseWindow for theWindow then frees the memory used for theWindow's window record. If the Window Manager allocated theWindow's window record, DisposeWindow is the method to use to get rid of theWindow.

Window Display

```
pascal void SetWTitle(theWindow, title)
   WindowPtr theWindow;
   Str255 title;
```

SetWTitle sets the title of window theWindow to title. TheWindow's frame will be redrawn if the title changed.

```
pascal void GetWTitle(theWindow, title)
   WindowPtr theWindow;
   Str255 title;
```

GetWTitle sets title to the title of window theWindow.

```
pascal void SelectWindow(theWindow)
   WindowPtr theWindow;
```

SelectWindow makes theWindow the active window. This is done by: unhighlighting the previously highlighted window, putting theWindow in front of all other windows, highlighting theWindow, and generating deactivate and activate events. Call SelectWindow when you find out there was a mouse-down event in the content region of an inactive window.

```
pascal void HideWindow(theWindow)
   WindowPtr theWindow;
```

HideWindow hides window theWindow by making it invisible. If theWindow is the active window, then the next visible window behind theWindow (if there is one) becomes the active window.

```
pascal void ShowWindow(theWindow)
   WindowPtr theWindow;
```

ShowWindow makes window theWindow visible. If theWindow is already visible, then ShowWindow has no effect. ShowWindow does not change the window list. The front-to-back ordering stays the same.

If theWindow is the front-most window, it gets highlighted (if it's not already highlighted) and an activate event is generated.

```
pascal void ShowHide(theWindow, showFlag)
   WindowPtr theWindow;
   Boolean showFlag;
```

ShowHide changes the visibility of theWindow depending on showFlag. If showFlag is TRUE, ShowHide makes theWindow visible if it's not already visible. If showFlag is FALSE, ShowHide makes theWindow visible if it's not already invisible. ShowHide does not change the active window. None of the events associated with the activation process occur when ShowHide is used.

```
pascal void HiliteWindow(theWindow, fHilite)
   WindowPtr theWindow;
   Boolean fHilite;
```

HiliteWindow changes the highlighting of theWindow depending on the value of fHilite. If fHilite is TRUE, HiliteWindow highlights theWindow if it's not already highlighted. If fHilite is FALSE, HiliteWindow unhighlights theWindow if it's not already unhighlighted. Your application shouldn't ever have to call HiliteWindow, since highlighting of active windows and unhighlighting of deactivated windows is taken care of in SelectWindow.

```
pascal void BringToFront(theWindow)
   WindowPtr theWindow;
```

BringToFront puts theWindow in front of all other windows. TheWindow is redrawn if necessary. Your application needn't ever call BringToFront. BringToFront is called for you by SelectWindow. If you decide to use BringToFront, your application must make sure that windows are unhighlighted and highlighted as is appropriate.

```
pascal void SendBehind(theWindow, behindWindow)
   WindowPtr theWindow, behindWindow;
```

SendBehind changes the front-to-back ordering of windows. TheWindow is placed in back of behindWindow. Any necessary redrawing is done. If behindWindow is NULL, then theWindow goes behind all windows on the window list. If theWindow is the active window, it gets unhighlighted, the new active window (the next visible window on list) gets highlighted and the appropriate activate events are generated.

SendBehind should *not* be used to deactivate a previously active window, instead SelectWindow should be called.

If you want to move theWindow closer to the front (theWindow is already somewhere in back of behindWindow) you'll need to include the following just after calling SendBehind:

```
wPeek = *theWindow;
PaintOne(wPeek,wPeek->strucRgn);
CalcVis(wPeek);
```

This will ensure that theWindow appears as it should on the screen.

```
pascal WindowPtr FrontWindow()
```

FrontWindow will return a pointer to the first visible window in the window list (a.k.a. the active window). If there is no such window, a NULL value is returned.

```
pascal void DrawGrowIcon(theWindow)
   WindowPtr theWindow;
```

DrawGrowIcon uses theWindow's window definition function to draw theWindow's grow region. If theWindow is the active window, the grow region will be drawn. If theWindow is not active, DrawGrowIcon draws whatever is appropriate to indicate that theWindow cannot be sized at this time.

Mouse Location

```
pascal int FindWindow(thePt, whichWindow)
   Point thePt;
   WindowPtr *whichWindow;
```

FindWindow looks through the window list to determine which window, if any, thePt is in. If thePt is inside a window, then whichWindow will point to that window. If thePt is not in a window, whichWindow will be NULL. The return value indicates which part of the window contains thePt. It will be one of the predefined constants: inDesk, inMenuBar, inSysWindow, inContent, inDrag, inGrow, or inGoAway.

FindWindow should be called after a mouse-down event occurs. FindWindow assumes thePt is in global coordinates.

```
pascal Boolean TrackGoAway(theWindow, thePt)
   WindowPtr theWindow;
   Point thePt;
```

TrackGoAway highlights and unhighlights theWindow's go-away region while the mouse button is down. TrackGoAway returns TRUE if the mouse up occurred inside the go-away region, otherwise, TrackGoAway returns FALSE.

TrackGoAway should be called when a mouse-down event occurs in theWindow's go-away region with thePt set to the point (in global coordinates) where the mouse-down event occurred. TrackGoAway takes control until the mouse button is released. The window definition function is called upon to draw the go-away box.

Window Movement and Sizing

```
pascal void MoveWindow(theWindow, hGlobal, vGlobal, front)
   WindowPtr theWindow;
   int hGlobal, vGlobal;
   Boolean front;
```

MoveWindow moves theWindow to the global coordinate (vGlobal, hGlobal). The top left corner of theWindow's portRect is moved to this point. The size, plane and local coordinate system of theWindow remain the same. If front is TRUE, then MoveWindow will make theWindow the active window (if it isn't already) by calling SelectWindow.

```
pascal void DragWindow(theWindow, startPt, boundsRect)
   WindowPtr theWindow;
   Point startPt;
   Rect *boundsRect;
```

DragWindow draws a gray outline of theWindow which follows the movements of the mouse until the mouse button is released. If the button is released at a point inside of boundsRect, then DragWindow will call MoveWindow to move theWindow to that point. If the command key is not being held down, theWindow will become the active window. If the mouse button is released at a point outside the limit set by boundsRect, then DragWindow does not move the window.

DragWindow should be called when a mouse-down event occurs inside theWindow's drag region with startPt set to the point where the mouse-down event occurred. Both startPt and boundsRect should be in global coordinates.

```
pascal long GrowWindow(theWindow, startPt, sizeRect)
   WindowPtr theWindow;
   Point startPt;
   Rect *sizeRect;
```

GrowWindow draws a "grow image" of theWindow. This grow image follows the mouse until the mouse button is released. GrowWindow returns the new size of theWindow's portRect: the high-order word contains the vertical dimensions, the low-order word contains the horizontal. GrowWindow returns zero if the size did not change.

GrowWindow should be called when a mouse-down event occurs in theWindow's grow region with startPt set to the location of the mouse-down event. GrowWindow calls on the window definition function draw the grow image. SizeRect limits the size of theWindow's portRect.

Constraining Window Growth with SizeRect

SizeRect Coordinate	used to set
top	min. # of pixels in vertical direction
left	min. # of pixels in horizontal direction
bottom	max. # of pixels in vertical direction
right	max. # of pixels in horizontal direction

```
pascal void SizeWindow(theWindow, w, h, fUpdate)
   WindowPtr theWindow;
   int w, h;
   Boolean fUpdate;
```

SizeWindow changes the size of theWindow's portRect to the width and height given by w and h. SizeWindow then calls on the window definition function to draw the frame for theWindow using the new size. New areas of theWindow's content region are added to theWindow's update region if fUpdate is TRUE. If fUpdate is FALSE, your application should do the right thing.

SizeWindow does nothing if w and h are zero.

Update Region Maintenance

```
pascal void InvalRect(badRect)
   Rect *badRect;
```

InvalRect adds badRect to the update region of the window whose grafPort is the current port. BadRect is in the window's content region and should be specified in the local coordinate system.

```
pascal void InvalRgn(badRgn)
   RgnHandle badRgn;
```

InvalRgn adds badRgn to the update region of the window whose grafPort is the current port.

```
pascal void ValidRect(goodRect)
   Rect *goodRect;
```

ValidRect removes goodRect from the current grafPort's update region. GoodRect should be in local coordinates.

```
pascal void ValidRgn(goodRgn)
   RgnHandle goodRgn;
```

ValidRgn removes goodRgn from the current grafPort's update region.

```
pascal void BeginUpdate(theWindow)
   WindowPtr theWindow;
```

BeginUpdate should be called when you get an update event for theWindow. BeginUpdate stores the current visRgn in the global variable SaveVisRgn. TheWindow's visRgn is replaced by a region that is the intersection of the visRgn and the updateRgn. The updateRgn is then set to the empty region. After BeginUpdate, the application should draw theWindow's content region. Because of clipping done by the Window Manager, only areas of theWindow requiring updating will then be drawn. After drawing, call EndUpdate to restore theWindow's visRgn.

```
pascal void EndUpdate(theWindow)
   WindowPtr theWindow;
```

EndUpdate sets theWindow's visRgn to the value stored in the global variable SaveVisRgn. Each call to BeginUpdate should be balanced by a call to EndUpdate. Because a variable is used to store the visRgn, nesting BeginUpdate calls will not work.

Miscellaneous Utilities

```
pascal void SetWRefCon(theWindow, data)
   WindowPtr theWindow;
   long data;
```

SetWRefCon sets theWindow's refCon field equal to data.

```
pascal long GetWRefCon(theWindow)
   WindowPtr theWindow;
```

GetWRefCon returns the value stored in theWindow's refCon field.

```
pascal void SetWindowPic(theWindow, pic)
   WindowPtr theWindow;
   PicHandle pic;
```

SetWindowPic sets theWindow's windowPic field to pic. When a window with a non-NULL windowPic field requires an update, the Window Manager draws the windowPic picture instead of generating an update event for the window.

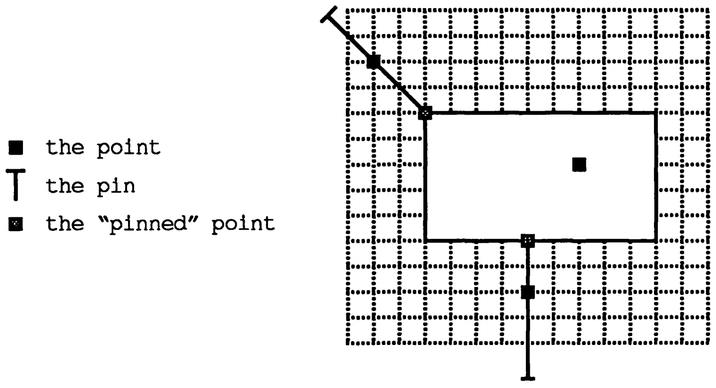
```
pascal PicHandle GetWindowPic(theWindow)
   WindowPtr theWindow;
```

GetWindowPic returns a handle to the theWindow's windowPic picture.

```
pascal long PinRect(theRect, thePt)
   Rect *theRect;
   Point thePt;
```

PinRect returns a point which is the projection of point thePt onto rectangle theRect. If thePt is inside theRect, thePt is returned. If thePt is outside theRect, the "pinned" point is returned. PinRect returns the point as a long: the high-order word is the vertical component, the low-order word is the horizontal.

Some "pinned" points



```
pascal long DragGrayRgn(theRgn, startPt, limitRect,
 slopRect, axis, actionProc)
   RgnHandle theRgn;
   Point startPt;
   Rect *limitRect, *slopRect;
   int axis;
   ProcPtr actionProc;
```

DragGrayRgn draws a gray outline of region theRgn which follows the mouse until the mouse button is released. If actionProc is not NULL, DragGrayRgn repeatedly calls this routine while the mouse is still down.

DragGrayRgn should be called when a mouse-down occurs inside a drag-able region, with startPt set to the location of the mouse-down. Movement can be constrained to a particular axis, or not at all by using noConstraint, hAxisOnly, or vAxisOnly for axis. DragGrayRgn returns a long that tells how far vertically and horizontally you would have to offset theRgn in order to move it to the place it was dragged to. The high-order word is the vertical offset, the low-order word is the horizontal offset.

LimitRect and slopRect are used to limit the dragging area. The gray outline will not move outside of rectangle limitRect. Rectangle slopRect allows the user a bit of sloppiness. If the mouse is let up while inside slopRect but outside of limitRect, the point where the mouse-up occurred is pinned to the limitRect, and the appropriate offset is returned. If the mouse-up occurs outside slopRect, DragGrayRgn returns 0x80008000.

StartPt, slopRect and limitRect should be in the current grafPort's local coordinate system.

Low-level Routines

The following are low level routines. They are not normally called by applications.

```
pascal Boolean CheckUpdate(theEvent)
   EventRecord *theEvent;
```

CheckUpdate is called by the Event Manager. It checks all the visible windows on the window list (going from front to back) looking for non-empty update regions. When it finds a non-empty update region, it will look in the window record to see if this window has a picture handle. If it does, the picture is drawn. If there is no picture handle, an update event for this window is stored in theEvent and CheckUpdate returns TRUE. If no update events are required, then CheckUpdate returns FALSE.

```
pascal void ClipAbove(window)
   WindowPeek window;
```

ClipAbove sets the clipRgn of the Window Manager port to the intersection of the desktop with the Window Manager's current clipRgn minus structure regions for all the windows in front of window.

```
pascal void SaveOld(window)
   WindowPeek window;
```

SaveOld saves window's content and structure regions. Each SaveOld call must be balanced by a call to DrawNew.

```
pascal void DrawNew(window, update)
   WindowPeek window;
   Boolean update;
```

DrawNew erases an area, the area being:
`(oldStruct XOR newStruct) AND (oldContent XOR newContent)`
where oldStruct and oldContent were both saved during SaveOld and newStruct and newContent are window's current structure and content regions. If update is TRUE then the area is added to window's update region.

Do *not* nest SaveOld and DrawNew calls.

```
pascal void PaintOne(window, clobberedRgn)
   WindowPeek window;
   RgnHandle clobberedRgn;
```

PaintOne paints window clipped to the region clobberedRgn and all visible windows in front of window. PaintOne draws window's frame, erases any unobscured content region, then adds this content region to window's update region. If window is NULL, it is assumed to be the desktop and gets painted with the desktop pattern.

```
pascal void PaintBehind(startWindow, clobberedRgn)
   WindowPeek startWindow;
   RgnHandle clobbered;
```

PaintBehind calls PaintOne for startWindow and all windows behind startWindow. ClobberedRgn is the clipping region for all drawing.

```
pascal void CalcVis(window)
   WindowPeek window;
```

CalcVis will determine the visRgn for window. VisRgn is window's content region minus the structure regions of all windows in front of window.

```
pascal void CalcVisBehind(startWindow, clobberedRgn)
   WindowPeek startWindow;
   RgnHandle clobbered;
```

CalcVisBehind determines the visRgns for startWindow and all windows behind startWindow. All visRgns calculated by CalcVisBehind are clipped to clobberedRgn.

CalcVisBehind should be called after PaintBehind.

Dialog Manager

The Dialog Manager is a set of high-level tools for getting information from users. The Dialog Manager uses the Window Manager, the Control Manger, and Text Edit to create and conduct dialogs. Dialogs keep the application from having to deal with each keystroke and every other eventuality in conducting a dialog with the user. Various levels of control over dialogs are available, from "hands-off" operation to modes in which each keystroke is checked by one of your application's routines.

Constants

```
#define btnCtrl      0x00
#define chkCtrl      0x01
#define radCtrl      0x02
#define resCtrl      0x03
#define statText     0x08
#define editText     0x10
#define iconItem     0x20
#define picItem      0x40
#define userItem     0x00
#define itemDisable  0x80

#define OK     1
#define Cancel 2

#define stopIcon     0
#define noteIcon     1
#define cautionIcon  2

#define volBits      0x3
#define alBit        0x4
#define OKDismissal  0x8
```

Data Structures

```
typedef struct
{  WindowRecord window;
   Handle items;
   TEHandle textH;
   int editField;
   int editOpen;
   int aDefItem;
} DialogRecord, *DialogPeek;
typedef WindowPtr DialogPtr;

typedef struct
{  Rect boundsRect;
   int procID;
   char visible;
   char filler1;
   char goAwayFlag;
   char filler2;
   long refCon;
   int itemsID;
   Str255 title;
} DialogTemplate, *DialogTPtr, **DialogTHandle;

struct StageList
{  char boldItem;
   char boxDrawn;
   char sound;
};

typedef struct StageList StageList[4];

struct AlertTemplate
{  Rect boundsRect;
   int itemsID;
   StageList stages;
};
```

Functions

Initialization

```
pascal void InitDialogs(restartProc)
   ProcPtr restartProc;
```

`InitDialogs` initializes the Dialog Manager. `RestartProc` is a procedure capable of restarting the application if a system error occurs. If `restartProc` is `NULL`, the application will not restart after a system error.

InitDialogs should be called once after having initialized QuickDraw, the Font Manager, the Window Manager, the Menu Manager, TextEdit and the Control Manager. In addition to initializing the Dialog Manager, InitDialogs installs the standard sound procedure and passes empty strings to ParamText (below).

```
pascal void ErrorSound(soundProc)
   ProcPtr soundProc;
```

ErrorSound makes soundProc the sound procedure used by the Dialog Manager for dialogs and alerts. If ErrorSound is not called, the standard sound procedure is used. If soundProc is NULL, there is no sound and no blinking on the menu bar.

```
pascal void SetDAFont(fontNum)
   int fontNum;
```

SetDAFont sets the font that will be used for all dialogs and alerts created after SetDAFont is called. FontNum specifies the font to be used. If you don't call this procedure, the system font is used. SetDAFont can not be used to change control titles — these are always in the system font.

Creating and Disposing of Dialogs

```
pascal DialogPtr NewDialog(dStorage, boundsRect, title,
 visible, procID, behind, goAwayFlag, refCon, items)
   Ptr dStorage;
   Rect *boundsRect;
   Str255 title;
   Boolean visible, goAwayFlag;
   int procID;
   WindowPtr behind;
   long refCon;
   Handle items;
```

NewDialog creates a new dialog as described by the parameters. NewDialog is a superset of NewWindow, much in the way the Dialog Manager is a superset of the Window Manager. The first eight parameters are passed on to NewWindow to create the dialog's window. Items is a handle to the dialog's item list. NewDialog returns a pointer to the new dialog.

```
pascal DialogPtr GetNewDialog(dialogID, dStorage, behind)
   int dialogID;
   Ptr dStorage;
   WindowPtr behind;
```

GetNewDialog uses resources to create a dialog. The Resource Manager reads in the 'DLOG' resource with ID dialogID, then reads in the dialog item list ('DITL') for the dialog (unless it's already in memory). GetNewDialog then makes a copy of the item list for use by the Dialog Manager. GetNewDialog returns a pointer to the new dialog.

```
pascal void CloseDialog(theDialog)
   DialogPtr theDialog;
```

CloseDialog closes a dialog, removing its window from the screen and the window list. Memory used by data structures of the dialog window is released. Memory used by items in theDialog is also released. The dialog record and the item list remain in memory.

```
pascal void DisposDialog(theDialog)
   DialogPtr theDialog;
```

DisposDialog closes theDialog by calling CloseDialog and then frees the memory used by theDialog's item list and dialog record. DisposDialog should be used if the dialog record was allocated for you by the Dialog Manager.

```
pascal void CouldDialog(dialogID)
   int dialogID;
```

CouldDialog loads all the information used by the dialog with id dialogID (the dialog's template, window definition function, item list resource, and all it's items defined as resources) into memory, and makes it unpurgeable. By storing these items in memory, the dialog can function when the resource file is inaccessible, such as during disk swapping.

```
pascal void FreeDialog(dialogID)
   int dialogID;
```

FreeDialog makes the information used by the dialog with id dialogID purgeable, thereby undoing the effects of CouldDialog. FreeDialog should be called when the resource file becomes accessible.

Handling Dialog Events

```
pascal void ModalDialog(filterProc, itemHit)
   ProcPtr filterProc;
   int *itemHit;
```

ModalDialog handles all events which occur while a modal dialog is the active window. When an event involving an enabled dialog item occurs, the event is filtered and handled. ModalDialog then returns with itemHit equal to the number of that item.

While ModalDialog is in control, it polls for events, first calling SystemTask (thus supporting desk accessories) then calling GetNextEvent with a mask which excludes disk-inserted events. If the event is a mouse-down event outside the dialog window's content region, ModalDialog beeps and continues polling, otherwise the event is filtered and handled. This continues until an enabled item is handled.

FilterProc allows you to filter events in various ways. When filterProc is NULL the standard filter is used, which causes ModalDialog to return 1 if the return or enter key has been hit. When filterProc is not NULL, ModalDialog uses the procedure pointed to by filterProc. FilterProc should be declared as follows:

```
    pascal Boolean filterProc(theDialog, theEvent, itemHit)
       DialogPtr theDialog;
       EventRecord *theEvent;
       int *itemHit;
```

```
pascal Boolean IsDialogEvent(theEvent)
   EventRecord *theEvent;
```

IsDialogEvent tells whether or not theEvent should be handled as part of a dialog. TheEvent should be handled as part of a dialog if it is an update or activate event for a dialog window, a mouse-down event in a dialog window's content region, or theEvent occurred when a dialog window is active. If theEvent is determined to be a dialog event, IsDialogEvent returns TRUE, otherwise IsDialogEvent returns FALSE.

IsDialogEvent is used with modeless dialogs. If your application includes any modeless dialogs, then call IsDialogEvent after calling GetNextEvent. If theEvent is a dialog event, DialogSelect can be called to handle it.

```
pascal Boolean DialogSelect(theEvent, theDialog, itemHit)
   EventRecord *theEvent;
   DialogPtr *theDialog;
   int *itemHit;
```

DialogSelect is used to handle events involving modeless dialogs. If the routine IsDialogEvent returned TRUE, your program should call DialogSelect to determine whether the event involved an active part of the current modeless dialog. Upon return, dialogPtr is a pointer to the dialog and itemHit is the item number of the item involved.

```
pascal void DlgCut(theDialog)
   DialogPtr theDialog;
```

DlgCut handles the "cut" editing command when a modeless dialog is active. If theDialog has any editable text items, DlgCut calls TECut with the currently selected editable text item.

```
pascal void DlgCopy(theDialog)
   DialogPtr theDialog;
```

DlgCopy handles the "copy" editing command for active modeless dialogs. If theDialog has any editable text items, DlgCopy calls TECopy.

```
pascal void DlgPaste(theDialog)
   DialogPtr theDialog;
```

DlgPaste handles the "paste" editing command for active modeless dialogs. It checks if there are any editable text items in theDialog, and if so, TEPaste is called.

```
pascal void DlgDelete(theDialog)
   DialogPtr theDialog;
```

DlgDelete handles the "clear" editing command when a modeless dialog is active. DlgDelete calls TEDelete if theDialog has any editText items.

```
pascal void DrawDialog(theDialog)
   DialogPtr theDialog;
```

DrawDialog draws theDialog's window. Normally, you won't need to call DrawDialog as DialogSelect and ModalDialog take care of updating the dialog. However, DrawDialog is useful to display dialogs which don't require any response. An example of this is a window which tells the user what is happening during a lengthy process, such as printing.

Invoking Alerts

```
pascal int Alert(alertId, filterProc)
   int alertID;
   ProcPtr filterProc;
```

`Alert` starts up the alert with ID `alertID`. The stage of the alert is checked. The current sound procedure is called to make whatever noise is appropriate for the stage of the alert. If the alert box should be drawn for this stage, then `Alert` calls `NewDialog` to draw the box and `ModalDialog` (passing along `filterProc`) to take care of the processing. `Alert's` return value is `-1` if the alert box has not been drawn. If the alert has been drawn the return value is the number of the item hit.

```
pascal int StopAlert(alertID, filterProc)
   int alertID;
   ProcPtr filterProc;
```

`StopAlert` is the same as `Alert` except that it draws the stop icon in the top left corner of the box, in the rectangle (10,20,42,52). The stop icon is the icon with id `stopIcon`.

```
pascal int NoteAlert(alertID, filterProc)
   int alertID;
   ProcPtr filterProc;
```

`NoteAlert` is the same as `Alert` except that it draws the note icon in the top left corner of the box, in the rectangle (10,20,42,52). The note icon is the icon with id `noteIcon`.

```
pascal int CautionAlert(alertID, filterProc)
   int alertID;
   ProcPtr filterProc;
```

`CautionAlert` is like `Alert` except that that it draws the caution icon in the top left corner of the box, in the rectangle (10,20,42,52). The caution icon is the icon with id `cautionIcon`.

```
pascal void CouldAlert(alertID)
   int alertID;
```

`CouldAlert` makes sure that all the data needed for the alert with id `alertID` is in memory and is unpurgeable. Call `CouldAlert` just before situations where the alert could occur while the resource file is inaccessible.

```
pascal void FreeAlert(alertID)
   int alertID;
```

FreeAlert makes the information used by the alert with id alertID purgeable, thereby undoing the effects of CouldAlert. FreeAlert should be called when the resource file becomes accessible .

Manipulating Items in Dialogs and Alerts

```
pascal void ParamText(param0, param1, param2, param3)
   Str255 param0, param1, param2, param3;
```

ParamText substitutes the strings param0, param1, param2, and param3 for the strings '^0', '^1', '^2', and '^3'. All dialogs and alerts that follow the call to ParamText will make the substitutions. Empty strings should be used as parameters where no substitution is desired. InitDialogs initialization process includes a call to ParamText using four empty strings as parameters.

```
pascal void GetDItem(theDialog, itemNo, type, item, box)
   DialogPtr theDialog;
   int itemNo, *type;
   Handle *item;
   Rect *box;
```

GetDItem gets information about the itemNo numbered item in theDialog. Type is set to the item type, item becomes a handle to the item, and box is set equal to the item's display rectangle.

```
pascal void SetDItem(theDialog, itemNo, type, item, box)
   DialogPtr theDialog;
   int itemNo, type;
   Handle item;
   Rect *box;
```

SetDItem sets theDialog's itemNo item to the given item. Type tells what type of item it is. Item is a handle to the item, and box provides the display rectangle for the item.

```
pascal void GetIText(item, text)
   Handle item;
   Str255 *text;
```

GetIText sets text equal to the text of item. Item should be a dialog item of type statText or editText.

```
pascal void SetIText(item, text)
   Handle item;
   Str255 text;
```

SetIText sets the text of statText or editText dialog item item to the string text.

```
pascal void SelIText(theDialog, itemNo, strtSel, endSel)
   DialogPtr theDialog;
   int itemNo, strtSel, endSel;
```

SelIText sets the text selection range in theDialog's itemNo item to the range given by strtSel and endSel. StrtSel is the character position of the first character in the selection range, endSel is the character position of the first character just after (but not in) the selection range. The selected range is highlighted. If strtSel = endSel, or the item contains no text, the selection range is an insertion point and a blinking vertical bar is displayed.

SelIText should be called for editable text items only.

```
pascal int GetAlrtStage()
```

GetAlrtStage returns the stage number of the last occurrence of an alert. The stage is a number from zero to three.

```
pascal void ResetAlrtStage()
```

ResetAlrtStage sets the stage number of an alert to -1, so the next occurrence of the alert will be as if it were the first.

Memory Manager

The Memory Manager allocates memory for Macintosh programs and data. Many Macintosh data structures are held in blocks of relocatable memory. These relocatable blocks are addressed through "handles." Handles point to "master pointers" which in turn point to the relocatable blocks of memory. When memory is compacted, only the master pointers need to updated to reflect the new position of relocatable blocks. This memory management scheme helps prevent available memory from becoming fragmented into pieces too small to be useful.

The Memory Manager provides tools for allocating and freeing memory, for changing the properties of memory (locking it in place for instance), and for creating "heaps" from which memory is allocated.

Constants

```
#define noErr        0
#define memFullErr   -108
#define nilHandleErr -109
#define memWZErr     -111
#define memPurErr    -112
#define memLockedErr -117

#define maxSize   0x800000
```

Data Structures

```
typedef long Size;
typedef int MemErr;
typedef struct Zone *THz;

typedef struct
{  Ptr bkLim;
   Ptr purgePtr;
   Ptr hFstFree;
   long zcbFree;
   ProcPtr gzProc;
   int moreMast;
   int flags;
   int cntRel;
   int maxRel;
   int cntNRel;
   int maxNRel;
   int cntEmpty;
   int cntHandles;
   long minCBFree;
   ProcPtr purgeProc;
   Ptr sparePtr;
   Ptr allocPtr;
   int heapData;
} Zone;
```

Functions

Initialization and Allocation

```
pascal void InitApplZone()
```

`InitApplZone` initializes the application heap zone and makes it the current zone. `InitApplZone` is called by the Segment Loader when an application is started up. Your application needn't call this routine.

The initialized zone:

- has size of 64K.
- can be expanded by 1K increments if necessary.
- has allocated space for 64 master pointers.
- can have additional master pointers, added 64 at a time.
- has empty pointer for grow zone function (`gzProc`).

`MemError` Codes

`noErr`	no error

```
pascal void SetApplBase(startPtr)
   Ptr startPtr;
```

`SetApplBase` sets the base of the application heap to the address specified by `startPtr`.

The application heap zone starts immediately after the system zone. Changing the starting address of the application heap zone changes the size of the system zone. When `startPtr` contains an address larger than the end of the system zone the result is a bigger system zone. The system zone can only be made bigger, attempts to make it smaller will be ignored.

The system calls `SetApplBase` before calling `InitApplZone`.

MemError Codes	
noErr	no error

```
pascal void InitZone(pGrowZone, cMoreMasters, limitPtr,
 startPtr)
   ProcPtr pGrowZone;
   int cMoreMasters;
   Ptr limitPtr, startPtr;
```

`InitZone` creates a new heap zone and makes this the current zone. The new heap zone will be initialized with a header and trailer. The first byte of the new zone is the address specified by `startPtr`. `LimitPtr` points to the first byte beyond the end of the zone. The parameter `pGrowZone` is a pointer to the grow zone routine for the zone if there is one, `NULL` otherwise. `CMoreMasters` tells how many master pointers should be allocated whenever more master pointers are called for. `CMoreMasters` master pointers are created when `InitZone` is called.

Overhead for the zone includes a 52 byte header, a 12 byte trailer, 8 bytes for the master pointer block and 4 bytes for each master pointer. Usable space in the zone should never be zero. It can be calculated using:

```
  (limitPtr - startPtr ) - (52 + 12) - (8 + 4*cMoreMasters)
```

Usable space will decrease as more master pointers are allocated.

MemError Codes	
noErr	no error

```
pascal void SetApplLimit(zoneLimit)
   Ptr zoneLimit;
```

`SetApplLimit` sets a size limit for the application heap zone. This limit is specified by `zoneLimit` (a `Ptr`, not a byte count). The application zone can grow up to the byte just before `zoneLimit`, but no further. If it happens that the zone is already beyond `zoneLimit`, then it will not grow any larger.

MemError Codes	
noErr	no error

```
pascal void MaxApplZone()
```

MaxApplZone grows the application heap zone to its maximum size. The maximum size will reflect any size limitations you may have set with SetApplLimit.

MemError Codes

noErr	no error

```
pascal void MoreMasters()
```

MoreMasters allocates another block of master pointers in the current heap zone. MoreMasters should be called early in an application to avoid heap fragmentation.

MemError Codes

noErr	no error
memFullErr	memory too full

Heap Zone Access

```
pascal THz GetZone()
```

GetZone returns a pointer to the current heap zone.

MemError Codes

noErr	no error

```
pascal void SetZone(hz)
   THz hz;
```

SetZone makes the zone pointed to by hz the current heap zone.

MemError Codes

noErr	no error

```
pascal THz ApplicZone()
```

ApplicZone returns a pointer to the original application heap zone.

MemError Codes	
noErr	no error

Allocating and Releasing Relocatable Blocks

```
pascal Handle NewHandle(logicalSize)
   Size logicalSize;
```

NewHandle creates a relocatable block of logicalSize bytes in the current heap zone. A handle to the block is returned. The new block is unlocked and unpurgeable.

If NewHandle can't create a block of logicalSize, then NewHandle returns a NULL value. But before it will return NULL, NewHandle will try every trick it knows: compacting the heap zone, increasing the zone's size, purging blocks, and calling the grow zone function.

MemError Codes	
noErr	no error
memFullErr	Not enough room in zone

```
pascal void DisposHandle(h)
   Handle h;
```

DisposHandle frees the memory used by the relocatable block with handle h. Other handles which access this block become invalid.

MemError Codes	
noErr	no error
memWZErr	attempt to operate on a free block

```
pascal Size GetHandleSize(h)
   Handle h;
```

GetHandleSize returns the number of bytes in the relocatable block with handle h. GetHandleSize returns zero in the case of an error.

MemError Codes

noErr	no error
nilHandleErr	empty master pointer
memWZErr	attempt to operate on a free block

```
pascal void SetHandleSize(h, newSize)
   Handle h;
   Size newSize;
```

SetHandleSize sets the logical size of the relocatable block with handle h to the number of bytes given by newSize.

Growing a locked block is likely to fail, since a block above it may be locked or nonrelocatable.

MemError Codes

noErr	no error
memFullErr	memory too full
nilHandleErr	empty master pointer
memWZErr	attempt to operate on a free block

```
pascal Thz HandleZone(h)
   Handle h;
```

HandleZone returns a handle to whichever heap zone contains the relocatable block with handle h. If h is empty, then the current zone is the return value. If an error occurs, you should ignore HandleZone's return value.

MemError Codes

noErr	no error
memWZErr	attempt to operate on a free block

```
pascal Handle RecoverHandle(p)
   Ptr p;
```

RecoverHandle returns a handle to the relocatable block pointed to by p.

MemError Codes

noErr	no error

```
pascal void ReallocHandle(h, logicalSize)
   Handle h;
   Size logicalSize;
```

`ReallocHandle` allocates a relocatable block of `logicalSize` bytes. Handle `h`'s master pointer is updated to point to this newly allocated block. `ReallocHandle` will work whether or not `h` is an empty handle. If `h` is not empty, the block associated with `h` will be released before the new block is allocated.

`MemError` Codes

`noErr`	no error
`memFullErr`	memory too full
`memWZErr`	attempt to operate on a free block
`memPurErr`	locked block

Allocating and Releasing Nonrelocatable Blocks

```
pascal Ptr NewPtr(logicalSize)
   Size logicalSize;
```

`NewPtr` allocates a nonrelocatable block of `logicalSize` bytes from the current heap zone. If a block is allocated, `NewPtr` returns a pointer to the block, otherwise `NewPtr` returns `NULL`.

`NewPtr` will attempt the following before returning `NULL`: compacting the current zone, increasing the zone's size, purging blocks, and calling the grow zone function if there is one.

`MemError` Codes

`noErr`	no error
`memFullErr`	memory too full

```
pascal void DisposPtr(p)
   Ptr p;
```

`DisposPtr` frees the memory used by the nonrelocatable block pointed to by `p`. Other pointers to this block are invalid after `DisposPtr`.

`MemError` Codes

`noErr`	no error
`memFullErr`	memory too full

```
pascal Size GetPtrSize(p)
   Ptr p;
```

GetPtrSize returns the logical size (in bytes) of the nonrelocatable block pointed to by p. GetPtrSize returns zero if an error occurs.

MemError Codes

noErr	no error
memWZErr	attempt to operate on a free block

```
pascal void SetPtrSize(p, newSize)
   Ptr p;
   Size newSize;
```

SetPtrSize sets the logical size of the nonrelocatable block pointed to by p to newSize.

MemError Codes

noErr	no error
memFullErr	memory too full
memWZErr	attempt to operate on a free block

```
pascal THz PtrZone(p)
   Ptr p;
```

PtrZone returns a pointer to the heap zone which contains the nonrelocatable block pointed to by p. The return value is invalid in case of error.

MemError Codes

noErr	no error
memWZErr	attempt to operate on a free block

Freeing Space on the Heap

```
pascal long FreeMem()
```

FreeMem returns the total number of free bytes in the current heap zone. The number returned is usually greater than the amount of space that can be allocated due to fragmentation of the zone.

MemError Codes

noErr	no error

```
pascal Size MaxMem(grow)
   Size *grow;
```

MaxMem compacts the current heap zone, purges all purgeable blocks, then returns the number of bytes contained in its largest contiguous area.

If the current heap is the original application heap zone, then grow is set equal to the maximum number of bytes which the zone can grow. For all heap zones other than the original application heap zone, grow is set to zero.

MaxMem does not expand the zone, nor does it call the zone's grow function.

```
pascal Size CompactMem(cbNeeded)
   Size cbNeeded;
```

CompactMem moves all relocatable blocks (as best as possible) down until a contiguous block of at least cbNeeded bytes is found or the whole zone has been compacted. When done with compacting, CompactMem will return the number of bytes available in the zone's largest contiguous free block.

MemError Codes	
noErr	no error

```
pascal void ResrvMem(cbNeeded)
   Size cbNeeded;
```

ResrvMem creates (but does not allocate) a block of cbNeeded bytes as low as possible in the current heap zone. To create the block, ResrvMem moves other blocks upward in memory, expands the zone, or purges blocks from the zone.

A block created by ResrvMem will not interfere much with compaction, as it is low in the heap. ResrvMem is automatically called for nonrelocatable blocks by NewPtr.

MemError Codes	
noErr	no error
memFullErr	memory too full

```
pascal void PurgeMem(cbNeeded)
   Size cbNeeded;
```

`PurgeMem` purges relocatable, unlocked, purgeable blocks from the current heap zone until it frees a contiguous block of at least `cbNeeded` bytes or the entire zone is purged.

MemError Codes

noErr	no error
memFullErr	memory too full

```
pascal void EmptyHandle(h)
   Handle h;
```

`EmptyHandle` frees the memory used by the relocatable block with handle `h`. The block's master pointer becomes `NULL`. If `h` is an empty handle, `EmptyHandle` does nothing.

MemError Codes

noErr	no error
memWZErr	attempt to operate on a free block
memPurErr	locked block

Properties of Relocatable Blocks

```
pascal void HLock(h)
   Handle h;
```

`HLock` locks handle `h`'s relocatable block by setting the master pointer's lock bit. Once locked, a block cannot be moved. `HLock` has no effect if the block is already locked.

MemError Codes

noErr	no error
nilHandleErr	empty master pointer
memWZErr	attempt to operate on a free block

```
pascal void HUnlock(h)
   Handle h;
```

`HUnlock` unlocks handle `h`'s relocatable block by clearing the lock bit in the master pointer. An unlocked block can be moved in its heap zone if necessary. `HUnlock` has no effect if the block is already unlocked.

MemError Codes

noErr	no error
nilHandleErr	empty master pointer
memWZErr	attempt to operate on a free block

```
pascal void HPurge(h)
   Handle h;
```

HPurge marks the relocatable block with handle h as purgeable by setting the purge bit in the master pointer. If this block is already purgeable, HPurge has no effect.

MemError Codes

noErr	no error
nilHandleErr	empty master pointer
memWZErr	attempt to operate on a free block

```
pascal void HNoPurge(h)
   Handle h;
```

HNoPurge clears the purge bit in handle h's master pointer, indicating that its block is not to be purged. If the block is already unpurgeable, then HNoPurge has no effect.

MemError Codes

noErr	no error
nilHandleErr	empty master pointer
memWZErr	attempt to operate on a free block

Utility Routines

```
pascal void BlockMove(sourcePtr, destPtr, byteCount)
   Ptr sourcePtr, destPtr;
   Size byteCount;
```

BlockMove moves a block of byteCount contiguous bytes from the address sourcePtr to address destPtr. BlockMove just moves the block – it doesn't care where from or where to, and it doesn't update any pointers.

MemError Codes

noErr	no error

```
pascal Ptr TopMem()
```

TopMem returns a pointer to the address which is one byte beyond the last byte of RAM.

MemError Codes	
noErr	no error

```
pascal void MoveHHi(h)
   Handle h;
```

MoveHHi moves handle h's relocatable block toward the top of its heap zone. Calling MoveHHi before locking a handle will help avoid fragmentation.

MemError Codes	
noErr	no error
nilHandleErr	null master pointer
memLockedErr	block is locked

```
pascal OSErr MemError()
```

MemError returns the result code due to the last Memory Manager routine that was called.

Menu Manager

The Menu Manager controls the contents of the Macintosh's pull-down menus. Using Menu Manager routines, menus can be created, deleted, and their contents changed. The Menu Manager can also process keyboard equivalents of menu items. Menu items can be turned off if they are inactive in certain contexts.

Constants

```
#define noMark        0
#define commandMark   17
#define checkMark     18
#define diamondMark   19
#define appleSymbol   20

#define mDrawMsg      0
#define mChooseMsg    1
#define mSizeMsg      2

#define textMenuProc 0
```

Data Structures

```
typedef struct
{  int menuId;
   int menuWidth;
   int menuHeight;
   Handle menuProc;
   unsigned long enableFlags;
   Str255 menuData;
} MenuInfo, *MenuPtr, **MenuHandle;
```

Functions

Initialization and Allocation

```
pascal void InitMenus()
```

InitMenus initializes the Menu Manager by allocating a relocatable block on the heap (large enough for the largest menu list) and redrawing the empty menu bar. InitWindows draws the menu bar the first time. Call InitMenus only once. Other Menu Manager routines should be used to change the menus.

```
pascal MenuHandle NewMenu(menuID, menuTitle)
   int menuID;
   Str255 menuTitle;
```

NewMenu creates an empty menu with the specified menuId and menuTitle. NewMenu returns a handle to the new menu. The new menu is set up to use the standard menu definition procedure. For applications, menuID should be positive. Negative menu ids are for desk accessories. No menu can use zero for a menu id.

Items can be added to the new menu using AppendMenu or AddResMenu. Use InsertMenu to add the new menu to the menu list. DrawMenuBar will draw the menu bar, including any recent changes.

```
pascal MenuHandle GetMenu(resourceID)
   int resourceID;
```

GetMenu reads the 'MENU' resource with ID resourceID into memory. If this menu has a non-standard definition procedure, the menu definition procedure is read in and a handle to the procedure goes into the menu record. GetMenu returns a handle to the new menu. The menu has items but it is not on the menu list. It must be added the menubar and the menubar must be redrawn.

Because the menu obtained by GetMenu is from a resource file, memory used by the menu should be freed using ReleaseResource.

```
pascal void DisposeMenu(theMenu)
   MenuHandle theMenu;
```

DisposeMenu releases memory used by theMenu, where theMenu is a menu created by using NewMenu.

Forming the Menus

```
pascal void AppendMenu(theMenu, data)
   MenuHandle theMenu;
   Str255 data;
```

AppendMenu adds an item (or items) to the end of theMenu. TheMenu must exist before calling AppendMenu. The text for the menu item(s) is given by string data. AppendMenu interprets the meta-characters used by the Menu Manager.

Meta-characters in Menus

character	**meaning**
; or Return	separates menu items
^	followed by an icon number, adds icon to item
!	marks item with character that follows !
<	followed by B,I,U,O, or S sets style as bold,italic, underline, outline or shadow (only one per item)
/	sets key equivalent to character that follows /
(	disables item

Once an item is on the menu, it is there to stay. You cannot remove items from the menu or change their order. TheMenu needn't be on the menu list, AppendMenu works for any existing menu.

```
pascal void AddResMenu(theMenu, theType)
   MenuHandle theMenu;
   ResType theType;
```

AddResMenu gets almost all items of theType, and appends them to theMenu. Items of theType are found by searching through all the open resource files. Once found, they are added to theMenu as enabled items, without any icons, marks, and in the normal style.

Resources with names that begin with . or % are *not* appended to theMenu by AddResMenu. This allows you to have resources of theType which will not appear on theMenu.

```
pascal void InsertResMenu(theMenu, theType, afterItem)
   MenuHandle theMenu;
   ResType theType;
   int afterItem;
```

InsertResMenu does the same thing that AddResMenu does, but it allows you to specify where in menu theMenu items of theType will occur. InsertResMenu inserts the items after item number afterItem. If afterItem is zero, new items are added before all existing items. If afterItem is greater than the last item number, new items are appended to theMenu.

The order of the items added to a menu by InsertResMenu will be the reverse of the order obtained using AddResMenu. Be sure the ordering of menu items in your application is consistent with that of other applications.

Forming the Menu Bar

```
pascal void InsertMenu(theMenu, beforeID)
   MenuHandle theMenu;
   int beforeID;
```

InsertMenu adds theMenu to the menu list, just before the menu having menu id equal to beforeID. TheMenu is added to the end of the list if beforeID is zero. If theMenu is already on the menu list, or if the menu list is full, InsertMenu does nothing.

```
pascal void DrawMenuBar()
```

DrawMenuBar draws the menu bar, according to the current menu list. DrawMenuBar should be called after any operation (or sequence of operations) which effects the menu list, such as DeleteMenu, InsertMenu, ClearMenu, and SetMenu.

```
pascal void DeleteMenu(menuID)
   int menuID;
```

DeleteMenu removes the menu with ID menuID from the menu list. The menu still exists, it's just not on the menu list anymore. If there is no menu with ID menuID, DeleteMenu does nothing.

```
pascal void ClearMenuBar()
```

ClearMenuBar removes all menus from the current menu list. ClearMenuBar just removes menus from the menu list. It doesn't free any memory and the menus still exist.

```
pascal Handle GetNewMBar(menuBarID)
   int menuBarID;
```

GetNewMBar uses the 'MBAR' resource with ID menuBarID to create a new menu list. A handle to this new list is returned. GetNewMBar reads in the menu bar resource if its not already in memory, then it calls GetMenu for each menu on the menu list.

The menu list created by GetNewMBar is *not* the current list. To make it the current list, use SetMenuBar.

```
pascal Handle GetMenuBar()
```

GetMenuBar makes a copy of the current menu list, and returns a handle to the copy.

```
pascal void SetMenuBar(menuList)
   Handle menuList;
```

SetMenuBar makes menuList the current menu list.

Using GetMenuBar and SetMenuBar allows you to save the state of the menu list, change the list as needed, and then restore the saved state of the list at some later time.

Choosing from a Menu

```
pascal long MenuSelect(startPt)
   Point startPt;
```

MenuSelect determines in which item of which menu the mouse button was released. MenuSelect should be called when a mouse down event occurs in the menubar. StartPt should be the location (in global coordinates) where the mouse-down occurred. MenuSelect maintains control until the mouse button is released. MenuSelect calls on the menu definition procedure to draw the pulled down menus and do the appropriate highlighting and menu flashing.

When the mouse button is released, MenuSelect returns a long integer whose high-order word contains the menu id of the selected item's menu, and whose low-order word contains the item number. If no item was selected, or the item was disabled, MenuSelect returns zero for the menu id and the low-order word is undefined.

If a desk accessory menu item was selected, MenuSelect sends the item number and menu id to the system, and returns zero as the menu id.

```
pascal long MenuKey(ch)
   char ch;
```

MenuKey returns the menu id and item number of the menu item whose key equivalent is ch. A long integer is returned by MenuKey: the high-order word contains the menu id, the low-order word contains the item number.

MenuKey should be called if a key was pressed with the command key held down. If there are no menu items with key equivalent ch, MenuKey returns menu id zero. If there is a menu item with the given key equivalent, the menu is highlighted on the menu bar.

```
pascal void HiliteMenu(menuID)
   int menuID;
```

HiLiteMenu highlights the menu with ID menuID. If menuID is zero, the currently highlighted menu is unhighlighted.

Controlling Appearance of Items

```
pascal void SetItem(theMenu, item, itemString)
   MenuHandle theMenu;
   int item;
   Str255 itemString;
```

SetItem changes the text of item number item in menu theMenu to itemString. SetItem does not interpret meta-characters, so these characters can appear in an item's text.

```
pascal void GetItem(theMenu, item, itemString)
   MenuHandle theMenu;
   int item;
   Str255 itemString;
```

GetItem sets itemString equal to the text of item number item in menu theMenu. Like SetItem, GetItem does not interpret meta-characters. If these characters appear in the text of item, they'll appear in itemString.

Use GetItem and SetItem for switching between menu items, such as "Undo" and "Redo".

```
pascal void DisableItem(theMenu, item)
   MenuHandle theMenu;
   int item;
```

DisableItem disables item number item in menu theMenu. If item is zero, theMenu is disabled. If theMenu is disabled, all items in it are disabled. Be sure to call DrawMenuBar after disabling theMenu.

Disabled items appear dimmed on theMenu, they cannot be selected and are not highlighted when the cursor moves over them. Disabled menus appear dimmed on the menu bar. When the cursor moves over the disabled menu, the menu drops down and all items in the menu are dimmed. Menus (or menu items) should be disabled when they are not applicable, letting users know what they can and cannot do while using the program.

```
pascal void EnableItem(theMenu, item)
   MenuHandle theMenu;
   int item;
```

`EnableItem` enables the item number `item` in menu `theMenu`. Using `item = 0` will enable `theMenu`.

Enabled items appear normal. They are highlighted as the cursor moves over them, and they can be selected. Enabled menus should not be dimmed in the menu bar, so call `DrawMenuBar` after enabling `theMenu`.

```
pascal void CheckItem(theMenu, item, checked)
   MenuHandle theMenu;
   int item;
   Boolean checked;
```

`CheckItem` checks or unchecks item number `item` in menu `theMenu`. If `checked` is `TRUE`, `item` is checked. A check mark will appear to the left of the item (and it's icon, if any). If `checked` is `FALSE`, the check mark, if there is one, is removed from `item`.

```
pascal void SetItemMark(theMenu, item, markChar)
   MenuHandle theMenu;
   int item;
   char markChar;
```

`SetItemMark` marks item number `item` in menu `theMenu` with the character indicated by `markChar`. `MarkChar` can be any character in the system font, or one of the predefined "marking" characters (see constants above). The mark will appear to the left of the item and its icon, if any.

```
pascal void GetItemMark(theMenu, item, markChar)
   MenuHandle theMenu;
   int item;
   char *markChar;
```

`GetItemMark` sets `markChar` equal to the ASCII value of the character that is marking item number `item` in menu `theMenu`. If the item is not marked, then `markChar` is set to zero.

```
pascal void SetItemIcon(theMenu, item, icon)
   MenuHandle theMenu;
   int item, icon;
```

SetIconItem assigns an icon to item number item in menu theMenu. The parameter icon is an integer from 1 to 255. This integer is the *icon number* of the icon assigned to the item. The icon number is not the same as the resource id of the icon. The Menu Manager adds 256 to the icon number to get the resource id of the icon.

```
pascal void GetItemIcon(theMenu, item, icon)
   MenuHandle theMenu;
   int item, *icon;
```

GetItemIcon sets icon equal to the icon number of the icon assigned to item number item in theMenu. If the item has no icon associated with it, icon is set to zero. The icon number is 256 less than the resource id of the icon.

```
pascal void SetItemStyle(theMenu, item, chStyle)
   MenuHandle theMenu;
   int item;
   Style chStyle;
```

SetItemStyle sets the style of the item number item in menu theMenu to the style specified by chStyle.

```
pascal void GetItemStyle(theMenu, item, chStyle)
   MenuHandle theMenu;
   int item;
   Style *chStyle;
```

GetItemStyle sets chStyle to the style used by item number item in menu theMenu.

Miscellaneous Utilities

```
pascal void SetMenuFlash(count)
   int count;
```

SetMenuFlash sets the number of times a selected menu item will flash equal to count. Count should be an integer between zero and three. Values greater than three will be too slow. If count is zero, flashing is disabled.

SetMenuFlash is called by the control panel. Your application should not call SetMenuFlash.

```
pascal void CalcMenuSize(theMenu)
   MenuHandle theMenu;
```

CalcMenuSize calculates and stores the horizontal and vertical dimensions of menu theMenu. CalcMenuSize is called automatically by the Menu Manager after every call to AppendMenu, SetItem, SetItemIcon, and SetItemStyle.

```
pascal int CountMItems(theMenu)
   MenuHandle theMenu;
```

CountMItems returns the number of items in menu theMenu.

```
pascal MenuHandle GetMHandle(menuID)
   int menuID;
```

GetMHandle returns a handle to the menu having ID menuID, if such a menu is on the menu list. If there is no such menu, GetMHandle returns NULL.

```
pascal void FlashMenuBar(menuID)
   int menuID;
```

FlashMenuBar inverts the menu bar title of the menu having ID menuID. If there is no such menu on the menu list or if menuID is zero, the entire menu bar is inverted.

Control Manager

The Control Manager provides a set of high-level tools such as buttons and scroll bars, and a set of low-level interfaces for creating new kinds of controls. Controls range in complexity from buttons that may be "pressed" or "toggled" to more elaborate controls such as scroll bars. Complex controls such as scroll bars are a composite of buttons and indicators, each of which is responsive to the mouse in different ways. The Control Manager sorts out activity in these complex controls and calls on your application's routines to react to the way such a control is used.

The Control Manager also defines a protocol that can be followed to create new controls. By creating a control definition function that correctly follows the Control Manager's rules, you can add new controls to the Control Manager repertoire.

Constants

```
/* Control definition IDs */
#define pushButProc     0
#define checkBoxProc    1
#define radioButProc    2
#define useWFont        8
#define scrollBarProc   16

/* Part Codes: part code 128 is reserved
 * for the Control Manager.
 */

#define inButton     10
#define inCheckBox   11
#define inUpButton   20
#define inDownButton 21
#define inPageUp     22
#define inPageDown   23
#define inThumb      129
```

```
/* Constraints for DragControl */

#define noConstraint 0
#define hAxisOnly    1
#define vAxisOnly    2

/* Messages to use when defining your own controls */

#define drawCntl  0
#define testCntl  1
#define calcCrgns 2
#define initCntl  3
#define dispCntl  4
#define posCntl   5
#define thumbCntl 6
#define dragCntl  7
#define autoTrack 8
```

Data Structures

```
typedef struct
{  ControlHandle nextControl;
   WindowPtr contrlOwner;
   Rect contrlRect;
   char contrlVis;
   char contrlHilite;
   int contrlValue;
   int contrlMin;
   int contrlMax;
   Handle contrlDefProc;
   Handle contrlData;
   ProcPtr contrlAction;
   long contrlRfCon;
   Str255 contrlTitle;
}ControlRecord, *ControlPtr, **ControlHandle;
```

Functions

Initialization and Allocation

```
pascal ControlHandle NewControl(theWindow, boundsRect,
 title, visible, value, min, max, procID, refCon)
   WindowPtr theWindow;
   Rect *boundsRect;
   Str255 title;
   Boolean visible;
   int value, min, max, procID;
   long refCon;
```

`NewControl` creates a control which is added to the beginning of theWindow's control list. A handle to the new control is returned. The values passed to NewControl are placed into the fields of the control record. Highlighting is off, and there is no default action (contrlAction is NULL).

The newly created control will be in theWindow, therefore any coordinates for the control should be in theWindow's local coordinate system. The rectangle that encloses the control is boundsRect. This rectangle also determines the control's size and location. For standard controls, note the following:

- Simple buttons fit the rectangle exactly. A 20 point difference between the top and bottom of the rectangle is needed so that the tallest characters will fit inside the button.
- Check boxes and radio buttons need at least a 16 point top to bottom difference.
- For a normal size scroll bar, a rectangle with a 16 pixel top to bottom (or left to right) difference is needed. If the difference is less than 16, the scroll bar will be scaled to fit the rectangle.

The control's title (if any) is the string title. If the title is too long to fit in the control's rectangle, then it will be truncated. For simple buttons, the title is centered and truncated on both ends. For check boxes and radio buttons, the title is truncated on the right.

If visible is TRUE, NewControl draws the control immediately in theWindow.

Value is the initial setting for the control. The parameters min and max define the range of the control. If the control is a button type (or one that doesn't have an initial value and for which a range is meaningless), then it doesn't matter what values you use for value, min and max as they are ignored. If the control is an on-or-off type (check box or radio button), then min should be zero (meaning the control is off) and max should be one (the control is on). The initial value must be either on or off.

ProcId is the resource id of the control definition function. ProcID can be one of the predefined values (such as pushButProc or radioButProc) or one you have defined.

The control's reference value is refCon. RefCon is a structure element reserved for your application. It is not used by other Toolbox routines.

```
pascal ControlHandle GetNewControl(controlID, theWindow)
   int controlID;
   WindowPtr theWindow;
```

GetNewControl has the same end result as NewControl, but creates the control using resources. GetNewControl calls on the Resource Manager to get a 'CNTL' resource (the resource template for controls) with ID controlID. If such a resource exists, GetNewControl reads it in and adds the control to the beginning of theWindow's control list. A handle to the newly created control is returned.

```
pascal void DisposeControl(theControl)
   ControlHandle theControl;
```

DisposeControl removes theControl from the screen, and its window's control list. Memory used by theControl, including any data structures associated with theControl, is freed.

```
pascal void KillControls(theWindow)
   WindowPtr theWindow;
```

KillControls calls DisposeControl for each control in theWindow's control list.

Control Display

```
pascal void SetCTitle(theControl, title)
   ControlHandle theControl;
   Str255 title;
```

SetCTitle sets theControl's title to the string title. TheControl is redrawn.

```
pascal void GetCTitle(theControl,title)
   ControlHandle theControl;
   Str255 *title;
```

GetCTitle gets theControl's title and returns it in the string title.

```
pascal void HideControl(theControl)
   ControlHandle theControl;
```

HideControl makes a visible control invisible. The region theControl occupies in its window will be filled with the window's background pattern. The rectangle which encloses theControl is added to the window's update region. If theControl is already invisible, HideControl does nothing.

```
pascal void ShowControl(theControl)
   ControlHandle theControl;
```

ShowControl makes an invisible control visible. ShowControl draws theControl in its window, subject to the Window Manager's clipping rules. ShowControl has no effect on controls which are already visible.

```
pascal void DrawControls(theWindow)
   WindowPtr theWindow;
```

DrawControls draws all the visible controls in theWindow. The order in which they appear will be the reverse of the order they were created. The first control appears last (also foremost) in theWindow. Window Manager routines do not generate calls to DrawControls. If you get an update event for a window which has controls, your application should call DrawControls.

```
pascal void HiliteControl(theControl, hiliteState)
   ControlHandle theControl;
   int hiliteState;
```

HiliteControl changes the highlighting of theControl. The value of hiliteState (zero to 255) determines the highlighting as follows:

- Zero means no highlighting.
- HiliteState between 1 and 253 represents a part code indicating which part of the control is to be highlighted.
- HiliteState 254 or 255 means that the control is to be made inactive and gets the 'inactive' highlighting scheme. If hiliteState is 254, you will be able to detect mouse clicks inside the control, if hiliteState is 255, you won't be able to.

HiliteControl generates a call to the control definition function, redrawing theControl with the new hiliteState.

Mouse Location

```
pascal int TestControl(theControl,thePoint)
   ControlHandle theControl;
   Point thePoint;
```

TestControl determines which part of theControl contains thePoint. ThePoint is expected to be in the local coordinates. Normally, TestControl is called only by FindControl and

`TrackControl`.

The results of `TestControl` are as follows:

• for visible and active controls, if `thePoint` is not in `theControl`, zero is returned. If `thePoint` is inside `theControl`, then the part code containing `thePoint` is returned.

• for inactive but visible controls, if `theControl` has `hiliteState` 254, `TestControl` returns 254. If the `hiliteState` is 255, `TestControl` returns zero.

• for invisible controls, `TestControl` returns zero.

```
pascal int FindControl(thePoint, theWindow, whichControl)
   Point thePoint;
   WindowPtr theWindow;
   ControlHandle *whichControl;
```

`FindControl` determines which (if any) of `theWindow`'s controls the `thePoint` is in.

Normally, `FindControl` is called after learning that the mouse button was pressed in the content region of a window with controls. `TheWindow` is the window where the mouse button was pressed, `thePoint` is the location of the mouse-down event, expressed in `theWindow`'s local coordinate system.

If the mouse button was pressed in:

• a visible, active control, `whichControl` becomes a control handle for that control. `FindControl` returns the part code of the part containing `thePoint`.

• a visible, inactive control with 254 highlighting, `whichControl` is becomes a control handle for that control, and 254 is the return value.

• an invisible control, an inactive control with 255 highlighting, or not in any control, `whichControl` is `NULL` and zero is returned.

• an invisible window, or if `thePoint` is not actually in `theWindow`, `whichControl` is `NULL` and zero is returned.

```
pascal int TrackControl(theControl, startPt, actionProc)
   ControlHandle theControl;
   Point startPt;
   ProcPtr actionProc;
```

`TrackControl` tracks the movements of the mouse and takes all the appropriate actions for `theControl` until the mouse button is released.

Call TrackControl after learning that the mouse button was pressed in a visible, active control. StartPt is the location (in local coordinates) of the mouse-down event, and actionProc is a routine invoked by TrackControl while the mouse button is down. If highlighting is called for by the control definition function, TrackControl will do that. It'll also undo the highlighting before returning.

If the mouse button is released with the mouse in the same part that it was in when tracking began, then the part code for that part is returned and the current value is stored in the control record. Your application should take actions appropriate for the part and its new value. If the mouse up occurs while the mouse is no longer in the same part, then a zero is returned and the control's value remains the same. In this case, your application should take no action as a result of tracking.

Suppose startPt is in an indicator, such as the thumb box in a scroll bar. TrackControl drags a gray outline of the box as the mouse is moved. When the mouse button is released,the box is repositioned using the control definition function. The relative position of the thumb box is used to calculate (and store) the new scroll bar setting. Your application is responsible for doing the scrolling.

You can have TrackControl do more than just highlighting and dragging by passing an actionProc. For example, if you wanted to show the page number in the vertical scroll bar's thumb box, you can supply an actionProc that will do this.

If actionProc is:

- NULL, no additional action occurs.
- a pointer to an action procedure, then you can have some action performed until the mouse button is released.
- -1, then TrackControl will look in theControl's control record for the default action procedure. If the default action procedure is a routine pointer, then TrackControl will call that routine. If the default action procedure is -1 then TrackControl will call the control definition function to take action. If the default action is NULL, TrackControl does nothing.

Control Movement and Sizing

```
pascal void MoveControl(theControl, h, v)
   ControlHandle theControl;
   int h, v;
```

MoveControl moves theControl to a new location inside theControl's window. The new location is specified (in local coordinates) by h and v. These are the horizontal and vertical coordinates of the top left corner of theControl's bounding rectangle. The bottom right corner of the rectangle is calculated so that theControl is the same size as before. If theControl is visible, MoveControl hides it, then redraws it at the new location.

```
pascal void DragControl(theControl, startPt, limitRect,
 slopRect, axis)
   ControlHandle theControl;
   Point startPt;
   Rect *limitRect, *slopRect;
   int axis;
```

DragControl drags a gray outline of theControl by calling the Window Manager's DragGrayRgn routine. The outline will follow the movements of the mouse, using DragGrayRgn's rules. DragGrayRgn expects startPt, limitRect, slopRect and axis to be as follows:

- StartPt is the point where the mouse button was originally pressed, in the local coordinate system of theControl's window.
- LimitRect bounds the area in which theControl's outline can travel. This area should be the content region of theControl's window, or some subset of that region.
- SlopRect allows the user a bit of sloppiness when dragging theControl. As long as the mouse is in slopRect the outline will follow the mouse, but theControl cannot move outside the limitRect.
- Axis lets you constrain movement of theControl. If axis is noConstraint, there is no constraint. If axis is hAxisOnly, only horizontal movement occurs. If axis is vAxisOnly, only vertical movement occurs.

```
pascal void SizeControl(theControl, w, h)
   ControlHandle theControl;
   int w,h;
```

SizeControl sets the size of theControl's enclosing rectangle to width w and height h. The top left corner of theControl remains in the same location. The bottom right corner is adjusted so that theControl is the specified size. If theControl is visible, SizeControl hides it before redrawing it in the new size.

Control Setting and Range

```
pascal void SetCtlValue(theControl, theValue)
   ControlHandle theControl;
   int theValue;
```

SetCtlValue sets theControl's value to theValue and redraws theControl. If theControl is a scroll bar, the thumb will be redrawn in the correct position. For on-or-off type controls (check boxes and radio buttons), a value of one will draw theControl in the on position, a value of zero will draw it as being off.

If theValue is out of theControl's range, theControl is set to its maximum or minimum value, whichever is closest to theValue.

```
pascal int GetCtlValue(theControl)
   ControlHandle theControl;
```

GetCtlValue returns theControl's current setting.

```
pascal void SetCtlMin(theControl, minValue)
   ControlHandle theControl;
   int minValue;
```

SetCtlMin changes the minimum range setting of theControl to minValue. If the current value of theControl is below minValue, the value is set to minValue. SetCtlMin redraws theControl reflecting the any new values.

```
pascal int GetCtlMin(theControl)
   ControlHandle theControl;
```

GetCtlMin returns theControl's minimum range setting.

```
pascal void SetCtlMax(theControl, maxValue)
   ControlHandle theControl;
   int maxValue;
```

SetCtlMax sets theControl's the maximum value to maxValue. If the current value of theControl is greater than maxValue, the value is set to maxValue. SetCtlMax redraws theControl reflecting any new values.

```
pascal int GetCtlMax(theControl)
   ControlHandle theControl;
```

GetCtlMax returns the maximum range value of theControl.

Miscellaneous Utilities

```
pascal void SetCRefCon(theControl, data)
   ControlHandle theControl;
   long data;
```

SetCRefCon sets theControl's reference value to data.

```
pascal long GetCRefCon(theControl)
   ControlHandle theControl;
```

GetCRefCon returns theControl's reference value.

```
pascal void SetCtlAction(theControl, actionProc)
   ControlHandle theControl;
   ProcPtr actionProc;
```

SetCtlAction sets theControl's default action procedure to actionProc.

```
pascal ProcPtr GetCtlAction(theControl)
   ControlHandle theControl;
```

GetCtlAction returns a pointer to theControl's default action procedure.

TextEdit

TextEdit provides a uniform way for users to enter text. Often TextEdit is used indirectly, as part of a dialog that the Dialog Manager conducts or as part of a Standard File Package dialog. Because all Macintosh applications use TextEdit, editing capabilities for entering text are uniform throughout all Macintosh applications.

Constants

```
#define teJustLeft   0
#define teJustCenter 1
#define teJustRight  -1
```

Data Structures

```
typedef char Chars[32001], *CharsPtr, **CharsHandle;

typedef struct
{  Rect destRect;
   Rect viewRect;
   int lineHeight;
   int firstBL;
   int selStart;
   int selEnd;
   int just;
   int length;
   Handle hText;
   int txFont;
   int txFace;
   int txMode;
   int txSize;
   GrafPtr inPort;
   int crOnly;
   int nLines;
   int lineStarts[32001];
} TERec, *TEPtr, **TEHandle;
```

Functions

Initialization

```
pascal void TEInit()
```

`TEInit` allocates a handle for the application's scrap. This serves to initialize TextEdit. Call `TEInit` just once at the beginning of the program.

```
pascal TEHandle TENew(destRect, viewRect)
   Rect *destRect, *viewRect;
```

`TENew` creates and initializes an edit record with the destination rectangle equal to `destRect` and the view rectangle equal to `viewRect`. A handle to the new edit record is returned.

The edit record created by `TENew` uses the environment of the current grafPort, so `destRect` and `viewRect` should be given in local coordinates. The edit record is initialized as left-justified and single-spaced with insertion point at position zero. `TENew` also allocates a handle for the edit record's `text` field.

`TENew` must be called once for each edit record.

Manipulating Edit Records

```
pascal void TESetText(text, length, hTE)
   Ptr text;
   long length;
   TEHandle hTE;
```

`TESetText` changes the text in `hTE`'s edit record to the text pointed to by `text`. `Text` is `length` characters long. The selection range is an insertion point at the end of the text. Call `TEUpdate` to show that the text has been changed.

```
pascal CharsHandle TEGetText(hTE)
   TEHandle hTE;
```

`TEGetText` returns a handle to the text in `hTE`'s edit record.

```
pascal void TEDispose(hTE)
   TEHandle hTE;
```

TEDispose frees the memory used for hTE: memory used by both the text and the edit record. Call TEDispose when you are totally done using an edit record.

Editing

```
pascal void TEKey(key, hTE)
   char key;
   TEHandle hTE;
```

TEKey replaces hTE's selection range with the character key. If the selection range is just an insertion point, key is inserted. The insertion point is positioned just after key.

```
pascal void TECut(hTE)
   TEHandle hTE;
```

TECut cuts the selection range from hTE's text and puts it into the scrap, completely replacing the scrap's contents. If the selection range is an insertion point, the scrap will be emptied.

```
pascal void TECopy(hTE)
   TEHandle hTE;
```

TECopy copies hTE's selection range into the scrap, completely replacing the scrap's contents. When TECopy is called with an empty selection range (an insertion point), the scrap becomes empty.

```
pascal void TEPaste(hTE)
   TEHandle hTE;
```

TEPaste replaces hTE's selection range with a copy of the scrap, and positions the insertion point just beyond the last character copied from the scrap. For an empty scrap, TEPaste deletes the selection range. For an empty selection range (insertion point), TEPaste inserts the scrap.

```
pascal void TEDelete(hTE)
   TEHandle hTE;
```

TEDelete deletes hTE's selection range but does not place it in the scrap. If the selection range is an insertion point, TEDelete does nothing.

```
pascal void TEInsert(text, length, hTE)
   Ptr text;
   long length;
   TEHandle hTE;
```

`TEInsert` inserts `length` characters pointed to by `text` into `hTE`'s `text` handle, placing the characters just before the selection range (or insertion point). `TEInsert` redraws the text.

Selection Range and Justification

```
pascal void TESetSelect(selStart, selEnd, hTE)
   long selStart, selEnd;
   TEHandle hTE;
```

`TESetSelect` sets `hTE`'s selection range to the range given by `selStart` and `selEnd`. To do this, `TESetSelect` unhighlights the current selection range (if any), then highlights the new selection range. If `selStart` is equal to `selEnd`, the selection range is an insertion point. For insertion points, the caret is displayed and there is no highlighting.

Legal values for `selStart` and `selEnd` are from zero to 65535. If `selEnd` is beyond the last character, then the position of the last character plus one is used for `selEnd`.

```
pascal void TESetJust(j, hTE)
   int j;
   TEHandle hTE;
```

`TESetJust` sets the justification for `hTE` to the justification specified by `j`. `J` should be one of the following: `teJustLeft`, `teJustCenter`, or `teJustRight`.

Call `TEUpdate` to show the new justification.

Mice and Carets

```
pascal void TEClick(pt, extend, hTE)
   Point pt;
   Boolean extend;
   hTE TEHandle;
```

`TEClick` is used for setting the selection range through mouse down events. `TEClick` should be called when a mouse down event occurs in `hTE`'s view rectangle. Point `pt` is the location where the mouse button was pressed, in local coordinates. If `extend` is `TRUE`, the current selection range is extended. `Extend` should be `TRUE` if the shift key was down when the mouse-down occurred.

Once control is passed to TEClick, it takes care of highlighting the selection range. The selection range expands or shrinks, according to the movements of the mouse. TEClick also takes care of word selection when a double click occurs.

```
pascal void TEIdle(hTE)
   TEHandle hTE;
```

TEIdle checks to see if it is time for the blinking caret at hTE's insertion point to blink again. To maintain a constant blinking frequency, your application should call TEIdle often. TEIdle cannot be called too often. Blinking will not occur unless a minimum time period (which can be adjusted using the control panel) has elapsed.

```
pascal void TEActivate(hTE)
   TEHandle hTE;
```

TEActivate highlights the selection range in hTE's view rectangle. If the selection range is an insertion point, a blinking caret is displayed at the insertion point. TEActivate should be called whenever a text editing window becomes active.

```
pascal void TEDeactivate(hTE)
   TEHandle hTE;
```

TEDeactivate is the opposite of TEActivate: it unhighlights the selection range in hTE's view rectangle, or removes the blinking caret if the selection range is an insertion point. TEDeactivate should be called whenever a text editing window becomes inactive.

Text Display

```
pascal void TEUpdate(rUpdate, hTE)
   Rect *rUpdate;
   TEHandle hTE;
```

TEUpdate redraws hTE's text inside the rectangle rUpdate, where rUpdate is in the grafport's local coordinates. Using hTE's viewRect for rUpdate will cause hTE's entire view rectangle to be redrawn.

TEUpdate should be called whenever an update event occurs (after BeginUpdate and before EndUpdate) or to show the results of another TextEdit routine.

```
pascal void TextBox(text, length, box, j)
   Ptr text;
   long length;
   Rect *box;
   int j;
```

TextBox draws the text pointed to by text, in the rectangle box. Box is in local coordinates. The parameter length tells TextBox the number of characters to draw and j specifies the justification. J should be one of the following: teJustLeft, teJustCenter or teJustRight. TextBox does not use any edit record, it is just used for drawing text.

Advanced Routines

```
pascal void TEScroll(dh, dv, hTE)
   int dh, dv;
   TEHandle hTE;
```

TEScroll scrolls the text in hTE's viewRect. The amount scrolled is specified in pixels by dh and dv: positive dh moves the text to the right, negative dh moves the text to the left; positive dv moves the text up, negative dv moves the text down.

After calling TEScroll, call TEUpdate with hTE's viewRect to show the results of scrolling.

```
pascal void TECalText(hTE)
   TEHandle hTE;
```

TECalText recalculates the beginnings of all the lines of text in hTE and updates hTE's lineStarts array.

TECalText should be called after any operation which changes the number of characters per line, such as changing the destination rectangle or the font.

Standard File Package

The Standard File Package provides a uniform way for users to select files for opening and saving. The Standard File Package does not actually open or write to the files, File Manager routines are used for those functions.

Constants

```
#define putDlgID  -3999
#define putSave   2
#define putCancel 5
#define putEject  6
#define putName   7

#define getDlgID  -4000
#define getCancel 3
#define getEject  5
#define getDrive  6
#define getNmList 7
#define getScroll 8
```

Data Structures

```
typedef struct
{  char good;
   char copy;
   OSType fType;
   int vRefNum;
   int version;
   char fName[64];
} SFReply;

typedef OSType SFTypeList[4];
```

Functions

```
pascal void SFPutFile(where, prompt, origName, dlgHook,
 reply)
   Point where;
   Str255 prompt, origName;
   ProcPtr dlgHook;
   SFReply *reply;
```

`SFPutFile` uses a standard file dialog to get a file name from the user. Typically, this file is used to save the current document. `Where` is the position of the top left corner of the dialog. `Prompt` provides brief, application specific instructions. If the document came from a file, `OrigName` should be the name of that file. `DlgHook` lets you specify a function to be called *after* each call to `ModalDialog`. `Reply` holds the information returned from the dialog.

```
pascal void SFPPutFile(where, prompt, origName, dlgHook,
 reply, dlgID, filterProc)
   Point where;
   Str255 prompt, origName;
   ProcPtr dlgHook;
   SFReply *reply;
   int dlgID;
   ProcPtr filterProc;
```

`SFPPutFile` works like `SFPutFile` except for two things: it allows you to use the dialog with resource ID `dlgID`, and it allows you to specify `filterProc` as a filter procedure *for* calls to `ModalDialog`.

```
pascal void SFGetFile(where, prompt, fileFilter, numTypes,
 typeList, dlgHook, reply);
   Point where;
   Str255 prompt;
   ProcPtr fileFilter, dlgHook;
   int numTypes;
   SFTypeList *typeList;
   SFReply *reply;
```

`SFGetFile` uses a standard file dialog to display a list of files of the types specified in `typeList`. `TypeList` is typically used in opening documents. `Where` is the location of the upper left corner of the dialog on the screen. `Prompt` gives brief instructions to the user. `FileFilter` allows you to specify a function that can be used to further qualify files for display. `DlgHook` is a procedure that is called *after* each call to `ModalDialog`. `Reply` holds the information returned from the dialog.

```
pascal void SFPGetFile (where, prompt, fileFilter, numTypes,
 typeList, dlgHook, reply, dlgID, filterProc);
   Point where;
   Str255 prompt;
   ProcPtr fileFilter, dlgHook, filterProc;
   int numTypes, dlgID;
   SFTypeList *typeList;
   SFReply *reply;
```

`SFPGetFile` works like `SFGetFile` except for two things: it allows you to use the dialog with resource ID `dlgID`, and it allows you to specify `filterProc` as a filter procedure *for* calls to `ModalDialog`.

File Manager

The File Manager provides tools for opening, closing, creating, deleting, reading, and writing files. The File Manager has two sets of routines: one is a set of high-level routines that are easy to use and can handle the filing needs of most applications. The more complex "parameter-block" routines are so-named because they take a data structure, known as a parameter block, as their argument. These low-level routines allow more control over the file system, and in some cases, where several file-system routines must be called in sequence to find information about a file, they can be more efficient.

Constants

```
#define fHasBundle   0x20
#define fInvisible   0x40

#define fTrash         -3
#define fDeskTop       -2
#define fDisk           0

#define fsAtMark        0
#define fsFromStart     1
#define fsFromLEOF      2
#define fsFromMark      3

#define fsCurPerm       0
#define fsRdPerm        1
#define fsWrPerm        2
#define fsRdWrPerm      3
```

Data Structures

```
typedef long OSType;
typedef int OSErr;
typedef struct
{  OSType fdType;
   OSType fdCreator;
   int fdFlags;
   Point fdLocation;
   int fdFldr;
} Finfo;

struct ioParam
{  int ioRefNum;
   SignedByte ioVersNum;
   SignedByte ioPermssn;
   Ptr ioMisc;
   Ptr ioBuffer;
   long ioReqCount;
   long ioActCount;
   int ioPosMode;
   long ioPosOffset;
};

struct fileParam
{  int ioFRefNum;
   SignedByte ioFVersNum;
   SignedByte filler1;
   int ioFDirIndex;
   SignedByte ioFlAttrib;
   SignedByte ioFlVersNum;
   Finfo ioFlFndrInfo;
   long ioFlNum;
   int ioFlStBlk;
   long ioFlLgLen;
   long ioFlPyLen;
   int ioFlRStBlk;
   long ioFlRLgLen;
   long ioFlRPyLen;
   long ioFlCrDat;
   long ioFlMdDat;
};

struct volumeParam
{  long filler2;
   int ioVolIndex;
   long ioVCrDate;
   long ioVLsBkUp;
   int ioVAtrb;
   int ioVNmFls;
   int ioVDirSt;
   int ioVBlLn;
   int ioVNmAlBlks;
   long ioVAlBlkSiz;
```

```
    long ioVClpSiz;
    int ioAlBlSt;
    long ioVNxtFnum;
    int ioVFrBlk;
};

struct drvQElRec
{   struct drvQElRec *drvLink;
    int drvFlags;
    int drvRefNum;
    int drvFSID;
    int drvBlkSize;
};

typedef union
{   int sndVal;
    int asncConfig;
    struct
    {   Ptr asncBPtr;
        int asncBLen;
    } asyncInBuff;
    struct
    {   unsigned char fXOn;
        unsigned char fCTS;
        char xon;
        char xoff;
        unsigned char errs;
        unsigned char evts;
        unsigned char fInX;
        unsigned char null;
    } asyncShk;
    struct
    {   Ptr fontRecPtr;
        int fontCurDev;
    } fontMgr;
    Ptr diskBuff;
    long asyncNBytes;
    struct
    {   int asncs1;
        int asncs2;
        int asncs3;
    } asyncStatus;
    struct
    {   int dskTrackLock;
        long dskInfoBits;
        struct drvQElRec dskQElem;
        int dskPrime;
        int dskErrCnt;
    } diskStat;
} OpParamType, *OpParamPtr;
```

```
struct cntrlParam
{  int csRefNum;
   int csCode;
   OpParamType csParam;
};

typedef struct
{  struct ParamBlkRec *ioLink;
   int ioType;
   int ioTrap;
   Ptr ioCmdAddr;
   ProcPtr ioCompletion;
   int ioResult;
   char *ioNamePtr;
   int ioVRefNum;
   union
   {  struct ioParam iop;
      struct fileParam fp;
      struct volumeParam vp;
      struct cntrlParam cp;
   } u;
} ParamBlkRec, *ParmBlkPtr;
```

Functions: High-level

Specifying Volumes and files for High-level Routines

To specify a volume for the high-level File Manager routines, you can use the volume name, the volume reference number or the drive number of its drive. The File Manager will try the following methods (in the given order) until it has determined a volume:

- Use the volume name given by `volName`. If `volName` is a zero-length string, return an error. If `volName` is `NULL` or an improper volume name, try the next method.
- Use the volume reference number `vRefNum` or the volume's drive number `drvNum`, whichever the routine calls for. If this number is zero, try the next method.
- Use the default volume.

You may use whichever method you like.

To specify a closed file, you must specify the volume (as described above) and the file name `fileName`. `FileName` can be the file name or the volume name followed by the file name. To specify an open file, the access path reference number `refNum` is used.

Accessing Volumes

```
pascal OSErr GetVInfo(drvNum, volName, vRefNum, freeBytes)
   int drvNum, *vRefNum;
   Str255 volName;
   long *freeBytes;
```

GetVInfo gets volume information for the volume in drive number drvNum. Upon return, volName is the volume name, vRefNum is the volume reference number and freeBytes is the number of bytes available on the volume.

Result Codes

noErr	no error
nsvErr	no such volume error
paramErr	bad drive number

```
pascal OSErr GetVol(volName, vRefNum)
   Str255 volName;
   int *vRefNum;
```

GetVol sets volName to the name of the default volume and sets vRefNum to its volume reference number.

Result Codes

noErr	no error
nsvErr	no such volume error

```
pascal OSErr SetVol(volName, vRefNum)
    Str255 volName;
    int vRefNum;
```

SetVol makes the volume specified by volName or vRefNum the default volume. The volume must be mounted before it can become the default volume.

Result Codes

noErr	no error
bdNamErr	bad volume name
nsvErr	no such volume error
paramErr	no default volume

```
pascal OSErr FlushVol(volName, vRefNum)
   str255 volName;
   int vRefNum;
```

`FlushVol` writes the descriptive information and volume buffer contents for the volume specified by `volName` or `vRefNum`.

Result Codes

`noErr`	no error
`bdNamErr`	bad volume name
`extFSErr`	external file system
`ioErr`	disk I/O error
`nsDrvErr`	no such drive error
`nsvErr`	no such volume error
`paramErr`	no default volume

```
pascal OSErr UnmountVol(volName, vRefNum)
   Str255 volName;
   int vRefNum;
```

`UnmountVol` unmounts the volume given by `volName` or `vRefNum`. `UnmountVol` calls `FlushVol` for the volume, closes all the volume's open files, and releases any memory used by the volume.

You shouldn't allow the startup volume to be unmounted.

Result Codes

`noErr`	no error
`bdNamErr`	bad volume name
`extFSErr`	external file system
`ioErr`	disk I/O error
`nsDrvErr`	no such drive error
`nsvErr`	no such volume error
`paramErr`	no default volume

```
pascal OSErr Eject(volName, vRefNum)
   Str255 volName;
   int vRefNum;
```

`Eject` ejects the volume specified by `volName` or `vRefNum`. `Eject` calls `FlushVol` to flush the volume, then takes the volume off-line and ejects it.

Result Codes

noErr	no error
bdNamErr	bad volume name
extFSErr	external file system
ioErr	disk I/O error
nsDrvErr	no such drive error
nsvErr	no such volume error
paramErr	no default volume

Changing File Contents

```
pascal OSErr Create(fileName, vRefNum, creator, fileType)
   Str255 fileName;
   int vRefNum;
   OSType creator, fileType;
```

Create creates a new (unlocked and empty) file on the volume with volume reference number vRefNum. The new file's name, type and creator are given by fileName, fileType and creator. The file modification and creation dates are set to the date on the system clock.

Result Codes

noErr	no error
bdNamErr	bad volume name
dupFNErr	duplicate file name error
dirFulErr	directory full error
extFSErr	external file system
ioErr	disk I/O error
nsvErr	no such volume error
vLckdErr	software volume lock
wPrErr	hardware volume lock

```
pascal OSErr FSOpen(fileName, vRefNum, refNum)
   Str255 fileName;
   int vRefNum, *refNum;
```

FSOpen opens the file with name fileName on the volume with volume reference number vRefNum. An access path with the same read/write permission as the file is created for the file. RefNum is set to the file access path reference number.

Result Codes

`noErr`	no error
`bdNamErr`	bad volume name
`extFSErr`	external file system
`fnfErr`	file not found error
`ioErr`	disk I/O error
`nsvErr`	no such volume error
`opWrErr`	file already open for writing
`tmfoErr`	too many files open error

```
pascal OSErr FSRead(refNum, count, buffPtr)
   int refNum;
   long *count;
   Ptr buffPtr;
```

`FSRead` reads data from the open file with access path reference number `refNum`. Starting at the current position of the file marker, `FSRead` reads `count` bytes. The data read in is placed in the buffer pointed to by `buffPtr`. If the logical end-of-file is encountered before `count` bytes have been read in, the mark is moved to the end-of-file, `count` is set to the number of bytes *actually* read in and an end-of-file error is returned.

Result Codes

`noErr`	no error
`eofErr`	end-of-file error
`extFSErr`	external file system
`fnfErr`	file not found error
`ioErr`	disk I/O error
`paramErr`	negative count
`rfNumErr`	bad reference number

```
pascal OSErr FSWrite(refNum, count, buffPtr)
   int refNum;
   long *count;
   Ptr buffPtr;
```

`FSWrite` writes `count` bytes from the location pointed to by `buffPtr` to the open file with access path reference number `refNum`. Writing begins at the file marker. `Count` is set equal to the number of bytes *actually* written to the file.

Result Codes

`noErr`	no error
`dskFulErr`	disk full error
`fLckdErr`	file locked error
`fnOpnErr`	file not open error
`ioErr`	disk I/O error
`paramErr`	negative count
`rfNumErr`	bad reference number
`vLckdErr`	software volume lock
`wPrErr`	hardware volume lock
`wrpermErr`	write permission error

```
pascal OSErr GetFPos(refNum, filePos)
   int refNum;
   long *filePos;
```

`GetFPos` gets the position of the file marker for the file with access path reference number `refNum` and sets `filePos` to this number.

Result Codes

`noErr`	no error
`extFSErr`	external file system error
`fnOpnErr`	file not open error
`ioErr`	disk I/O error
`rfNumErr`	bad reference number

```
pascal OSErr SetFPos(refNum, posMode, posOff)
   int refNum, posMode;
   long posOff;
```

`SetFPos` sets the position of the file marker for the file with access path reference number `refNum`. The placement of the marker is determined by `posMode` and `posOff`. `PosMode` is a position in the file, and `posOff` is an offset from that position.

Positioning the File Marker

posMode values	**file marker position**
`fsAtMark`	remains the same, `posOff` is ignored
`fsFromStart`	`posOff` bytes from start of file
`fsFromLEOF`	`posOff` bytes from logical end-of-file
`fsFromMark`	`posOff` bytes from current position

Result Codes

noErr	no error
eofErr	end-of-file error
extFSErr	external file system error
fnOpnErr	file not open error
ioErr	disk I/O error
posErr	position is before start of file
rfNumErr	bad reference number

```
pascal OSErr GetEOF(refNum, logEOF)
   int refNum;
   long *logEOF;
```

GetEOF gets the logical end-of-file for the file with access path reference number refNum and sets logEOF equal to this number.

Result Codes

noErr	no error
extFSErr	external file system error
fnOpnErr	file not open error
ioErr	disk I/O error
rfNumErr	bad reference number

```
pascal OSErr SetEOF(refNum, logEOF)
   int refNum;
   long logEOF;
```

SetEOF sets the logical end-of-file file for the file with access path reference number refNum. The logical end-of-file is set to logEOF. If logEOF is beyond the physical end-of-file, another block on the volume is allocated for the file. If there is not enough room to set the specified logical end-of-file, a disk full error is returned and no change is made. If logEof is zero, all space used by the file is released.

Result Codes

noErr	no error
dskFulErr	disk full error
extFSErr	external file system error
fLckdErr	file locked error
fnOpnErr	file not open error
ioErr	disk I/O error
rfNumErr	bad reference number
vLckdErr	software volume lock
wPrErr	hardware volume lock
wrpermErr	write permission error

```
pascal OSErr Allocate(refNum, count)
   int refNum;
   long *count;
```

Allocate adds count bytes to the file with access path reference number refNum. If count is not a multiple of the block allocation size, it is rounded up to the next multiple, and this number of bytes is added to the file. If there are not enough bytes available on the volume, then whatever space is available is allocated for the file and Allocate returns a disk full error. Count is set to the number of bytes *actually* allocated. The physical end-of-file is set one byte beyond the last byte allocated.

Result Codes

noErr	no error
dskFulErr	disk full error
fLckdErr	file locked error
fnOpnErr	file not open error
ioErr	disk I/O error
rfNumErr	bad reference number
vLckdErr	software volume lock
wPrErr	hardware volume lock
wrpermErr	write permission error

```
pascal OSErr FSClose(refNum)
   int refNum;
```

FSClose closes the file with access path reference number refNum. The file access path is removed, the volume buffer contents are written to the volume, and the file directory information is updated.

Note that not all information stored on the volume is correct until FlushVol is called for the volume.

Result Codes

noErr	no error
extFSErr	external file system
fnfErr	file not found error
fnOpnErr	file not open error
ioErr	disk I/O error
nsvErr	no such volume error
rfNumErr	bad reference number

Changing Information About Files

```
pascal OSErr GetFInfo(fileName, vRefNum, fndrInfo)
   Str255 fileName;
   int refNum;
   FInfo *fndrInfo;
```

`GetFInfo` gets the Finder information for the file with name `fileName` and volume reference number `vRefNum`. The information is returned in `fndrInfo`.

Result Codes

`noErr`	no error
`bdNamErr`	bad file name
`extFSErr`	external file system
`fnfErr`	file not found error
`ioErr`	disk I/O error
`nsvErr`	no such volume error
`paramErr`	no default volume

```
pascal OSErr SetFInfo(fileName, vRefNum, fndrInfo)
   Str255 fileName;
   int refNum;
   FInfo *fndrInfo;
```

`SetFInfo` changes the Finder information about the file with name `fileName` on the volume with volume reference number `vRefNum`. The Finder information is set to that given by `fndrInfo`.

Result Codes

`noErr`	no error
`extFSErr`	external file system
`fLckdErr`	file locked error
`fnfErr`	file not found error
`ioErr`	disk I/O error
`nsvErr`	no such volume error
`vLckedErr`	software volume lock
`wPrErr`	hardware volume lock

```
pascal OSErr SetFLock(fileName, vRefNum)
   Str255 fileName;
   int vRefNum;
```

`SetFLock` locks the file with name `fileName` on volume with reference number `vRefNum`. Locking will not affect existing access paths.

Result Codes

noErr	no error
extFSErr	external file system
fnfErr	file not found error
ioErr	disk I/O error
nsvErr	no such volume error
vLckedErr	software volume lock
wPrErr	hardware volume lock

```
pascal OSErr RstFLock(fileName, vRefNum)
   Str255 fileName;
   int vRefNum;
```

RstFLock unlocks the file with name fileName on the volume with volume reference number vRefNum. Existing file access paths are not affected.

Result Codes

noErr	no error
extFSErr	external file system
fnfErr	file not found error
ioErr	disk I/O error
nsvErr	no such volume error
vLckedErr	software volume lock
wPrErr	hardware volume lock

```
pascal OSErr Rename(oldName, vRefNum, newName)
   Str255 oldName, newName;
   int vRefNum;
```

Rename changes the names of files or volumes. If oldName is a file name, then the file name is set to newName (currently used access paths are unaffected by the change). If oldName is a volume name and vRefNum is its volume reference number, the volume name is set to newName.

Result Codes

noErr	no error
bdNamErr	bad name error
dirFulErr	directory full error
dupFNErr	duplicate file name error
extFSErr	external file system
fLckedErr	file locked error
fnfErr	file not found error
fsRnErr	file system renaming error
ioErr	disk I/O error
nsvErr	no such volume error
paramErr	no default volume
vLckedErr	software volume lock
wPrErr	hardware volume lock

```
pascal OSErr FSDelete(fileName, vRefNum)
   Str255 fileName;
   int vRefNum;
```

FSDelete removes the file named fileName from the volume with volume reference number vRefNum. FSDelete removes both the resource and data forks of the file.

Result Codes

noErr	no error
bdNamErr	bad name error
extFSErr	external file system
fBsyErr	file busy error
fLckedErr	file locked error
fnfErr	file not found error
ioErr	disk I/O error
nsvErr	no such volume error
vLckedErr	software volume lock
wPrErr	hardware volume lock

Functions: Low-Level

Most of the low-level File Manager routines can be executed synchronously or asynchronously. Synchronous means the application cannot continue until the routine has completed. To execute a routine synchronously, the parameter async should be FALSE. Asynchronous means the application can continue without waiting for completion of the routine. In this case, the file request is placed on the file I/O queue and control is returned to the application. You may use the parameter block's `ioCompletion` field to specify a routine to be executed upon completion of the I/O routine. The parameter `async` should be `TRUE` if you want the routine to be executed asynchronously.

Specifying Volumes and Files for Low-Level Routines

There are a number of ways to specify a volume for the low-level File Manager routines. You can use the volume name, the volume reference number or the drive number of its drive. The File Manager will try the following methods (in the given order) until it has determined the volume:

- Use the volume name given by `ioNamePtr`. If `ioNamePtr` is `NULL` or points to an improper volume name, try the next method.
- Use the number `ioVRefNum`. If `ioVRefNum` is negative, it is a volume reference number. If it's positive, `ioVRefNum` is a drive number. If this `ioVRefNum` is zero, try the next method.
- Use the default volume.

You may use whichever method you like.

To specify a closed file, you must specify the both volume and the file name. `IoNamePtr` is a pointer to the file name. The file name can include the volume name, but this is not necessary. If the file name does not include the volume name, `ioVRefNum` is used (as listed above) to determine the volume. Open files are specified by the file access path reference number `ioRefNum`.

Initialization

```
pascal void FInitQueue()
```

`FInitQueue` removes all but the present File Manager call from the I/O queue.

Accessing Volumes

```
pascal OSErr PBMountVol(paramBlock)
   ParmBlkPtr paramBlock;
```

`PBMountVol` mounts the volume in the drive numbered `ioVRefNum`, and `ioVRefNum` is set to the volume reference number. If no other volumes have been mounted, this volume becomes the default volume. `PBMountVol` is always synchronous.

Result Codes

noErr	no error
bdMDBErr	bad master directory block
extFSErr	external file system
ioErr	disk I/O error
memFullErr	memory full error
noMacDskErr	not a Macintosh disk error
nsDrvErr	no such drive error
paramErr	bad drive number
volOnLinErr	volume already on-line

```
pascal OSErr PBGetVInfo(paramBlock, async)
   ParmBlkPtr paramBlock;
   Boolean async;
```

`PBGetVInfo` gets information about a specific volume. The File Manager determines the volume in question by checking `ioVolIndex` as follows:

- when `ioVolIndex` is positive, it is used to determine the volume. For example, use three for `ioVolindex` to get information about the volume that was mounted third.
- when `ioVolIndex` is negative, `ioNamePtr` or `ioVRefNum` are used to determine the volume.
- when `ioVolIndex` is zero, `ioVRefNum` is used to determine the volume. When this happens, `ioVRefNum` is set to the volume reference number and `ioNamePtr` returns the volume's name.

Result Codes

noErr	no error
nsvErr	no such volume error
paramErr	no default volume

```
pascal OSErr PBGetVol(paramBlock, async)
   ParmBlkPtr paramBlock;
   Boolean async;
```

`PBGetVol` returns the default volume's reference number in `ioVRefNum` and its name in `ioNamePtr`.

Result Codes

noErr	no error
nsvErr	no such volume error

```
pascal OSErr PBSetVol(paramBlock, async)
   ParmBlkPtr paramBlock;
   Boolean async;
```

`PBSetVol` makes the volume specified by `ioNamePtr` or `ioVRefNum` the default volume. The volume must be mounted before it can become the default volume.

Result Codes

noErr	no error
bdNamErr	bad volume name
nsvErr	no such volume error
paramErr	no default error

```
OSErr PBFlushVol(paramBlock, async)
    ParmBlkPtr paramBlock;
    Boolean async;
```

`PBFlushVol` flushes the volume given by `ioNamePtr` or `ioVRefNum`. Flushing a volume consists writing the following items to the volume: descriptive information, volume buffer contents, all the volume's access path buffers, and the modification date (which is the current time).

Result Codes

noErr	no error
bdNamErr	bad volume name
extFSErr	external file system
ioErr	disk I/O error
nsDrvErr	no such drive error
nsvErr	no such volume error
paramErr	no default volume

```
pascal OSErr PBUnmountVol(paramBlock)
   ParmBlkPtr paramBlock;
```

`PBUnmountVol` unmounts the volume given by `ioNamePtr` or `ioVRefNum`. To unmount a volume, the File Manager flushes the volume, closes all open files on the volume, and releases all memory used for the volume. `PBUnmountVol` is always synchronous.

Your application should not allow the startup volume to be unmounted.

Result Codes

`noErr`	no error
`bdNamErr`	bad volume name
`extFSErr`	external file system
`ioErr`	disk I/O error
`nsDrvErr`	no such drive error
`nsvErr`	no such volume error
`paramErr`	no default volume

```
pascal OSErr PBOffLine(paramBlock)
   ParmBlkPtr paramBlock;
```

`PBOffLine` takes the volume specified by `ioNamePtr` or `ioVRefNum` and places it off-line. Taking a volume off-line means flushing the volume and releasing most of the memory used by the volume – 94 bytes of descriptive information remain in memory.

Result Codes

`noErr`	no error
`bdNamErr`	bad volume name
`extFSErr`	external file system
`ioErr`	disk I/O error
`nsDrvErr`	no such drive error
`nsvErr`	no such volume error
`paramErr`	no default volume

```
pascal OSErr PBEject(paramBlock)
   ParmBlkPtr paramBlock;
```

`PBEject` ejects the volume specified by `ioNamePtr` or `ioVRefNum` after taking it off-line by calling `PBOffLine`.

Result Codes

`noErr`	no error
`bdNamErr`	bad volume name
`extFSErr`	external file system
`ioErr`	disk I/O error
`nsDrvErr`	no such drive error
`nsvErr`	no such volume error
`paramErr`	no default volume

Changing File Contents

```
pascal OSErr PBCreate(paramBlock, async)
   ParmBlkPtr paramBlock;
   Boolean async;
```

PBCreate creates a new unlocked and empty file on the volume specified by ioVRefNum. The name of the new file is given by ioNamePtr, its version number is given by ioVersNum. The file's creation and modification dates are set to the current time as given by the system clock.

After creating the file, your application should call PBSetFinfo to provide the Finder information for the file.

Result Codes

noErr	no error
bdNamErr	bad volume name
dupFNErr	duplicate file name
dirFulErr	directory full error
extFSErr	external file system
ioErr	disk I/O error
nsvErr	no such volume error
vLckdErr	software volume lock
wPrErr	hardware volume lock

```
pascal OSErr PBOpen(paramBlock, async)
   ParmBlkPtr paramBlock;
   Boolean async;
```

PBOpen opens the file with name ioNamePtr and version number ioVersNum on volume ioVRefNum. The resulting access path reference number is returned by ioRefNum.

Result Codes

noErr	no error
bdNamErr	bad volume name
extFSErr	external file system
fnfErr	file not found error
ioErr	disk I/O error
memFullErr	memory full error
nsvErr	no such volume error
opWrErr	file already opened for writing
tmfoErr	too many files open

```
pascal OSErr PBOpenRF(paramBlock, async)
   ParmBlkPtr paramBlock;
   Boolean async;
```

`PBOpenRF` is identical to the `PBOpen` call, except that the resource fork is opened.

Result Codes

noErr	no error
bdNamErr	bad volume name
extFSErr	external file system
fnfErr	file not found error
ioErr	disk I/O error
memFullErr	memory full error
nsvErr	no such volume error
opWrErr	file already opened for writing
permErr	no permission to read file
tmfoErr	too many files open

```
pascal OSErr PBRead(paramBlock, async)
   ParmBlkPtr paramBlock;
   Boolean async;
```

`PBRead` reads `ioReqCount` bytes from the file with access path `ioRefNum` to the buffer pointed to by `ioBuffer`. If you try to read beyond the end-of-file, the file marker is moved to the end-of-file and you'll get an end-of-file error result code. After reading is completed, `ioActCount` is set to the number of bytes *actually* read in and `ioPosOffset` gives the file marker position.

Result Codes

noErr	no error
eofErr	end-of-file error
extFSErr	external file system
fnOpnErr	file not open error
ioErr	disk I/O error
paramErr	negative ioReqCount
rfNumErr	bad reference number

```
pascal OSErr PBWrite(paramBlock, async)
   ParmBlkPtr paramBlock;
   Boolean async;
```

PBWrite writes ioReqCount bytes from the buffer pointed to by ioBuffer to the file with access path reference number ioRefNum. IoPosMode and ioPosOffset together indicate the position in the file where the data is to be written. After writing, ioActCount is set to the number of bytes *actually* written, ioPosOffset gives the position of the mark.

Determining where writing begins

ioPosMode	**writing begins**
fsAtMark	at file marker, ioPosOffset is ignored
fsFromStart	ioPosOffset bytes from start of file
fsFromLEOF	ioPosOffset bytes from logical end-of-file
fsFromMark	ioPosOffset bytes from marker

Result Codes

noErr	no error
dskFulErr	disk full error
fLckdErr	file locked error
fnOpnErr	file not open error
ioErr	disk I/O error
paramErr	negative ioReqCount
posErr	position beyond end-of-file
rfNumErr	bad reference number
vLckedErr	software volume lock
wPrErr	hardware volume lock
wrpermErr	no permission to write

```
pascal OSErr PBGetFPos(paramBlock, async)
   ParmBlkPtr paramBlock;
   Boolean async;
```

PBGetFPos sets ioPosOffset to the position of the file marker for the file with access path reference number ioRefNum. IoReqCount, ioActCount, and ioPosMode are set to zero.

Result Codes

noErr	no error
extFSErr	external file system
fnOpnErr	file not open error
ioErr	disk I/O error
rfNumErr	bad reference number

```
pascal OSErr PBSetFPos(paramBlock, async)
   ParmBlkPtr paramBlock;
   Boolean async;
```

`PBSetFPos` sets the position of the file marker for the file with access path reference number `ioRefNum`. `IoPosMode` and `ioPosOffset` together determine the positioning of the file marker. An error will result if you try to set the mark beyond the logical end-of-file.

Positioning the File Marker

ioPosMode	file marker position
fsAtMark	remains the same, ioPosOffset is ignored
fsFromStart	ioPosOffset bytes from start of file
fsFromLEOF	ioPosOffset bytes from logical end-of-file
fsFromMark	ioPosOffset bytes from marker

Result Codes

noErr	no error
eofErr	end-of-file error
extFSErr	external file system
fnOpnErr	file not open error
ioErr	disk I/O error
posErr	position error (before start)
rfNumErr	bad reference number

```
pascal OSErr PBGetEOF(paramBlock, async)
   ParmBlkPtr paramBlock;
   Boolean async;
```

`PBGetEOF` gets the logical end-of-file for the file indicated by `ioRefNum`, and returns this value in `ioMisc`.

Result Codes

noErr	no error
extFSErr	external file system
fnOpnErr	file not open error
ioErr	disk I/O error
rfNumErr	bad reference number

```
pascal OSErr PBSetEOF(paramBlock, async)
   ParmBlkPtr paramBlock;
   Boolean async;
```

`PBSetEOF` uses the value in `ioMisc` to set the logical end-of-file for the open file with access path reference number `ioRefNum`. If the logical end-of-file is beyond the physical end-of-file, the next free block is added to the file, and the physical end-of-file is set to the byte just after this block. If there in not enough room on the volume, no change is made and an error is returned. Using `ioMisc = 0` frees all the space on the volume used by the file.

Result Codes

`noErr`	no error
`dskFulErr`	disk full error
`extFSErr`	external file system
`fLckdErr`	file locked error
`fnOpnErr`	file not open error
`ioErr`	disk I/O error
`rfNumErr`	bad reference number
`vLckdErr`	software volume lock
`wPrErr`	hardware volume lock
`wrpermErr`	write permission error

```
pascal OSErr PBAllocate(paramBlock, async)
   ParmBlkPtr paramBlock;
   Boolean async;
```

`PBAllocate` adds `ioReqCount` bytes to the file with access path reference number `ioRefNum`. If `ioReqCount` is not a multiple of the block allocation size, the next highest multiple (to `ioReqCount`) of the block allocation size is added to the file. If there are not enough bytes available on the volume, then whatever space is available is allocated to the file and `PBAllocate` returns a disk full error. `IoActCount` returns the number of bytes *actually* allocated. The physical end-of-file is set one byte beyond the last byte allocated.

Result Codes

`noErr`	no error
`dskFulErr`	disk full error
`fLckdErr`	file locked error
`fnOpnErr`	file not open error
`ioErr`	disk I/O error
`rfNumErr`	bad reference number
`vLckdErr`	software volume lock
`wPrErr`	hardware volume lock
`wrpermErr`	write permission error

```
pascal OSErr PBFlushFile(paramBlock, async)
   ParmBlkPtr paramBlock;
   Boolean async;
```

`PBFlushFile` writes the contents of the access path `ioRefNum`'s buffer to the proper volume and updates the file directory. Although the *file* is flushed, not all information on the volume is correct until the volume is flushed.

Result Codes

`noErr`	no error
`extFSErr`	external file system error
`fnfErr`	file not found error
`fnOpnErr`	file not open error
`ioErr`	disk I/O error
`nsvErr`	no such volume error
`rfNumErr`	bad reference number

```
pascal OSErr PBClose(paramBlock, async)
   ParmBlkPtr paramBlock;
   Boolean async;
```

`PBClose` writes the contents of access path `ioRefNum`'s buffer to its associated file and frees the memory used by the access path. Note that not all information on the volume is correct until the volume is flushed.

Result Codes

`noErr`	no error
`extFSErr`	external file system error
`fnfErr`	file not found error
`fnOpnErr`	file not open error
`ioErr`	disk I/O error
`nsvErr`	no such volume error
`rfNumErr`	bad reference number

Changing Information About Files

```
pascal OSErr PBGetFInfo(paramBlock, async)
   ParmBlkPtr paramBlock;
   Boolean async;
```

`PBGetFInfo` gets Finder information for a file. The File Manager uses `ioFDirIndex` to determine the file. If `ioFDirIndex` is positive, the File Manager returns information about the file with `ioFDirIndex` sequence number on volume `ioVRefNum`. For non-positive `ioFDirIndex`, the File Manager returns information about the file on volume ioFVRefNum with file name and version number specified by ioNamePtr and ioFVersNum. IoNamePtr returns the file's name (unless ioNamePtr is NULL) and ioFRefNum is set to the reference number of the first-found access path for the file.

Result Codes

noErr	no error
bdNamErr	bad name error
extFSErr	external file system error
fnfErr	file not found error
ioErr	disk I/O error
nsvErr	no such volume error
paramErr	no default volume

```
pascal OSErr PBSetFInfo(paramBlock, async)
   ParmBlkPtr paramBlock;
   Boolean async;
```

PBSetFInfo sets the Finder information for the file with name ioNamePtr and version number ioVersNum on volume ioVRefNum. The Finder information includes the file's type, creator, and modification date, among other things.

Result Codes

noErr	no error
bdNamErr	bad name error
extFSErr	external file system error
fLckdErr	file locked error
fnfErr	file not found error
ioErr	disk I/O error
nsvErr	no such volume error
vLckdErr	software volume lock
wPrErr	hardware volume lock

```
pascal OSErr PBSetFLock(paramBlock, async)
   ParmBlkPtr paramBlock;
   Boolean async;
```

PBSetFLock locks the file on volume ioVRefNum with file name and version number given by ioNamePtr and ioVersNum. The lock does not affect the existing access paths.

Result Codes

`noErr`	no error
`extFSErr`	external file system error
`fnfErr`	file not found error
`ioErr`	disk I/O error
`nsvErr`	no such volume error
`vLckdErr`	software volume lock
`wPrErr`	hardware volume lock

```
pascal OSErr PBRstFLock(paramBlock, async)
   ParmBlkPtr paramBlock;
   Boolean async;
```

`PBRstFLock` unlocks the file on volume `ioVRefNum` with file name and version number given by `ioNamePtr` and `ioVersNum`. Unlocking will not affect access paths already in use.

Result Codes

`noErr`	no error
`extFSErr`	external file system error
`fnfErr`	file not found error
`ioErr`	disk I/O error
`nsvErr`	no such volume error
`vLckdErr`	software volume lock
`wPrErr`	hardware volume lock

```
pascal OSErr PBSetFVers(paramBlock, async)
   ParmBlkPtr paramBlock;
   Boolean async;
```

`PBSetFVers` changes the version number for a file on the volume with volume reference number `ioVRefNum`. The file's name and current version number are given by `ioNamePtr` and `ioVersNum`. The new version number is given by `ioMisc`. This change does not affect any access paths currently in use for the file.

The Resource Manager and Segment Loader will not operate on a file unless its version number is zero.

Result Codes

`noErr`	no error
`bdNamErr`	bad name error
`dupFNErr`	duplicate file error
`extFSErr`	external file system error
`fLckdErr`	file locked error
`fnfErr`	file not found error
`ioErr`	disk I/O error
`nsvErr`	no such volume error
`paramErr`	no default volume
`vLckdErr`	software volume lock
`wPrErr`	hardware volume lock

```
pascal OSErr PBRename(paramBlock, async)
   ParmBlkPtr paramBlock;
   Boolean async;
```

`PBRename` changes the name of a file or a volume. If `ioNamePtr` points to a file name and `ioVersNum` is it's version number, then `PBRename` changes the file name to the name pointed to by `ioMisc`. If `ioNamePtr` points to the name of a volume or `ioVRefNum` is the reference number of a volume, the volume's name is changed to the name pointed to by `ioMisc`. Renaming will not affect existing access paths.

Result Codes

`noErr`	no error
`bdNamErr`	bad name error
`dirFulErr`	directory full error
`dupFNErr`	duplicate file name error
`extFSErr`	external file system
`fLckedErr`	file locked error
`fnfErr`	file not found error
`fsRnErr`	file system renaming error
`ioErr`	disk I/O error
`nsvErr`	no such volume error
`paramErr`	no default volume
`vLckedErr`	software volume lock
`wPrErr`	hardware volume lock

```
pascal OSErr PBDelete(paramBlock, async)
   ParmBlkPtr paramBlock;
   Boolean async;
```

`PBDelete` removes the file with name given by `ioNamePtr` and version number `ioVersNum` from the `ioVRefNum` volume. `PBDelete` removes both forks of the file.

Result Codes

`noErr`	no error
`bdNamErr`	bad name error
`extFSErr`	external file system
`fBsyErr`	file busy error
`fLckedErr`	file locked error
`fnfErr`	file not found error
`ioErr`	disk I/O error
`nsvErr`	no such volume error
`vLckedErr`	software volume lock
`wPrErr`	hardware volume lock

Font Manager

The Font Manager provides tools for getting information about typefaces and managing font resources. The Font Manager is seldom called directly — other Toolbox Managers use fonts and provide interface routines for selecting fonts.

Constants

```
/* Font Numbers */
#define systemFont   0
#define applFont     1
#define newYork      2
#define geneva       3
#define monaco       4
#define venice       5
#define london       6
#define athens       7
#define sanFran      8
#define toronto      9

/* Font Types */
#define propFont  0x9000
#define fixedFont 0xB000
#define fontWid   0xACB0
```

Data Structures

```
typedef struct
{  int family;
   int size;
   char face;
   char needBits;
   int device;
   Point numer;
   Point denom;
} FMInput;

typedef struct
{  int errNum;
   Handle fontHandle;
   Byte bold;
   Byte italic;
   Byte ulOffset;
   Byte ulShadow;
   Byte ulThick;
   Byte shadow;
   SignedByte extra;
   Byte ascent;
   Byte descent;
   Byte widMax;
   SignedByte leading;
   Byte unused;
   Point numer;
   Point denom;
} FMOutput, *FMOutPtr;

typedef struct
{  int fontType;
   int firstChar;
   int lastChar;
   int widMax;
   int kernMax;
   int nDescent;
   int fRectMax;
   int chHeight;
   int owTLoc;
   int ascent;
   int descent;
   int leading;
   int rowWords;
} FontRec;
```

Functions

Initializing the Font Manager

```
pascal void InitFonts()
```

`InitFonts` gets the Font Manager ready for use. It also reads the system font into memory if it's not already there. You must call `InitFonts` once before calling any Toolbox routine that uses the Font Manager.

Getting Font Information

```
pascal void GetFontName(fontNum, theName)
   int fontNum;
   Str255 theName;
```

GetFontName sets theName equal to the name of the font with font number fontNum. TheName will be an empty string if there is no font having the given font number.

```
pascal void GetFNum(fontName, theNum)
   Str255 fontName;
   int *theNum;
```

GetFNum sets theNum equal to the font number of the font with name fontName. If there is no font with the given font name, theNum is set to zero.

```
pascal Boolean RealFont(fontNum, size)
   int fontNum, size;
```

RealFont returns TRUE if the font with font number fontNum is available in the font size size. RealFont returns FALSE otherwise. RealFont looks through all open resource files.

Keeping Fonts in Memory

```
pascal void SetFontLock(lockFlag)
   Boolean lockFlag;
```

SetFontLock makes the most current font either purgeable or unpurgeable. If lockFlag is TRUE, the font is made unpurgeable. If lockFlag is FALSE, the font is made purgeable.

Advanced Routine

```
pascal FMOutPtr SwapFont(inRec)
   FMInput *inRec;
```

SwapFont returns information about a version of a font which is specified by inRec. The information is returned via a Font Manager output record, which is pointed to by SwapFont's return value. The information SwapFont makes available is used by QuickDraw routines.

Printing Manager

The Printing Manager enables applications to use QuickDraw for plotting output on a printer. The Printing Manager defines the interface to all printing devices. The interface consists of functions that start and end printing jobs and tell the printer that a page is beginning or has ended. The bulk of the Macintosh printing interface is actually QuickDraw. Once a printing job is begun, QuickDraw can be used for printing in much the same way it is used to draw on the screen.

Constants

```
#define IMemFullErr  -108
#define noErr        0

#define bDraftLoop   0
#define bSpoolLoop   1
#define bUser1Loop   2
#define bUser2Loop   3

#define iPrBitsCtl   4
#define lScreenBits  0
#define lPaintBits   1
#define iPrIOCtl     5
#define iPrEvtCtl    6
#define iPrEvtAll    0x0002fffd
#define iPrEvtTop    0x0001fffd
#define iPrDevCtl    7
#define lPrReset     0x00010000
#define lPrPageEnd   0x00020000
#define lprLineFeed  0x00030000
#define iFMgrCtl     8

#define iPFMaxPgs    128
#define iPrPgFract   120
```

```
#define iPrAbort     128
#define iPrRelease   2
#define lPfType      'PFIL'
#define lPfSig       'PSYS'

#define sPrDrvr      ".Print"
#define iPrDrvrRef   -3
#define lPrintType   'PREC'
#define iPrintDef    0
#define iPrintLst    1
#define iPrintDrvr   2
#define iMyPrDrvr    0xe000
#define iPStrRFil    0xe000
#define iPStrPFil    0xe001
#define iPrStlDlg    0xe000
#define PrJobDlg     0xe001

#define feedCut      0
#define feedFanFold  1
#define feedMechCut  2
#define feedOther    3

#define scanTB    0
#define scanBT    1
#define scanLR    2
#define scanRL    3
```

Data Structures

```
typedef char TStr80[81]
typedef TsStr80 *TPstr80;
typedef Rect TPRect;

typedef struct
{  GrafPort gPort;
   QDProcs gProcs;
} TPrPort, *TPPrPort;

typedef union
{  GrafPtr pGPort;
   TPPrPort pPrPort;
} TPPort;

typedef struct
{  int iDev;
   int iVRes;
   int iHRes;
   Rect rPage;
} TprInfo;
```

```
typedef unsigned char TFeed;
typedef int TWord;

typedef struct
{  TWord wDev;
   int iPageV;
   int iPageH;
   SignedByte bPort;
   TFeed feed;
} TPrStl;

typedef struct
{  int iFstPage;
   int iLstPage;
   int iCopies;
   SignedByte bJDocLoop;
   char fFromUsr;
   ProcPtr pIdleProc;
   TPStr80 pFileName;
   int iFileVol;
   SignedByte bFileVers;
   SignedByte bJobX;
} TPrJob;

typedef unsigned char TScan;

typedef struct
{  int iRowBytes;
   int iBandV;
   int iBandH;
   int iDevBytes;
   int iBands;
   SignedByte bPatScale;
   SignedByte bUlThick;
   SignedByte bUlOffset;
   SignedByte bUlShadow;
   TScan scan;
   SignedByte bXInfoX;
} TPrXInfo;

typedef struct
{  int iPrVersion;
   TPrInfo prInfo;
   Rect rPaper;
   TPrStl prStl;
   TPrInfo prInfoPT;
   TPrXinfo prXInfo;
   TPrJob prJob;
   int printX[19];
} TPrint, *TPPrint, **THPrint;
```

```
typedef struct
{  int iTotPages;
   int iCurPage;
   int iTotCopies;
   int iCurCopy;
   int iTotBands;
   int iCurBand;
   char fPgDirty;
   char fImaging;
   THPrint hPrint;
   TPPrPort pPrPort;
   PicHandle hPic;
} TPrStatus;
```

Functions

Initialization and Termination

```
pascal void PrOpen()
```

PrOpen readies the Printing Manager by opening the Printer Driver and the printer resource file. If PrOpen cannot open both of these, PrOpen opens neither and PrError returns an error code.

```
pascal void PrClose()
```

PrClose shuts down the Printing Manager. The printer resource file is closed. Memory used by printer resource file and the Printing Manager is released. PrClose does not close the Printer Driver, PrDrvrClose can be called to do that.

Print Records and Dialogs

```
pascal void PrintDefault(hPrint)
   THPrint hPrint;
```

PrintDefault puts the default print settings into the appropriate fields of hPrint's print record. PrintDefault obtains the default values from the printer resource file.

```
pascal Boolean PrValidate(hPrint)
   THPrint hPrint;
```

PrValidate makes sure that the fields of hPrint's print record are compatible with the current version of the Printing Manager and the installed printer. If the print record is not valid, it is adjusted according to the default values in the printer resource file and PrValidate returns

TRUE. If PrValidate makes no adjustments, it returns FALSE.

PrValidate also makes whatever changes are needed so that hPrint's print record has the current style and job settings. These changes do *not* affect PrValidate's return value.

```
pascal Boolean PrStlDialog(hPrint)
   THPrint hPrint;
```

PrStlDialog activates the style dialog. HPrint's contents are used as the initial settings for the dialog items. If the user cancels the dialog, the print record remains as it was and PrStlDialog returns FALSE. If the user clicks the OK button, hPrint's print record is changed to reflect the user's style selections, and PrStlDialog returns TRUE.

If the print style is stored with the document, the document should be updated when PrStlDialog returns TRUE.

```
pascal Boolean PrJobDialog(hPrint)
   THPrint hPrint;
```

PrJobDialog activates the print job dialog. The printer resource file gives the initial settings for the dialog items. If the user cancels the dialog, the print record remains as it was and PrJobDialog returns FALSE. If the user clicks the OK button, hPrint's print record and the printer resource file are changed to reflect the user's selections, PrValidate is called, and PrJobDialog returns TRUE.

```
pascal void PrJobMerge(hPrintSrc, hPrintDst)
   THPrint hPrintSrc, hPrintDst;
```

PrJobMerge copies print job information from the prJob field of hPrintSrc to the prJob field of hPrintDst. Other fields in hPrintDst, such as printer information and paper rectangle, are updated using information in prJob.

Draft Printing and Spooling

```
pascal TPPrPort PrOpenDoc(hPrint, pPrPort, pIOBuf)
   THPrint hPrint;
   TPPrPort pPrPort;
   Ptr pIOBuf;
```

PrOpenDoc initializes a printing port and returns a pointer to the port. The printing port becomes the current port.

Hprint is a handle to the print record associated with this port. The bJDocLoop field in the print record indicates whether this is to be draft printing or spooling. If spooling is called for, the spool file's name, version, and volume reference number are obtained from hPrint's job subrecord.

PPrPort is a pointer to the printing port. If pPrPort is NULL, PrOpenDoc allocates a printing port. PIOBuf is a pointer to the i/o buffer. When pIOBuf is NULL, the volume buffer is used as the i/o buffer.

Each PrOpenDoc call must be balanced by a call to PrCloseDoc.

```
pascal void PrOpenPage(pPrPort, pPageFrame)
   TPPrPort pPrPort;
   TPRect pPageFrame;
```

PrOpenPage starts a new page in pPrPort's print document. The printing port is reinitialized.

For spool printing, pPageFrame points to the rectangle used as QuickDraw's picture frame for the page. When the page is actually being printed, the rectangle is scaled to match the page rectangle given in the printer information subrecord. If you don't want scaling to occur, use pPageFrame = NULL, and QuickDraw will use the page rectangle for the picture frame.

Each PrOpenPage call should be balanced with a call to PrClosePage.

```
pascal void PrClosePage(pPrPort)
   TPPrPort pPrPort;
```

PrClosePage closes the open printing page in printing port pPrPort. For spool printing, the QuickDraw picture of the page is closed. For draft printing, a form feed is printed and the user is alerted if a new page needs to be inserted.

```
pascal void PrCloseDoc(pPrPort)
   TPPrPort pPrPort;
```

PrCloseDoc finishes printing (or spooling) the document using pPrPort. For draft printing, a form feed is printed and the printer is reset. For spooling, the spool file is closed if everything went okay. If spooling was unsuccessful the spool file is deleted.

If PrOpenDoc allocated pPrPort, PrCloseDoc will dispose of the printing port.

Spool Printing

```
pascal void PrPicFile(hPrint, pPrPort, pIOBuf, pDevBuf,
 prStatus)
   THPrint hPrint;
   TPPrPort pPrPort;
   Ptr pIOBuf, pDevBuf;
   TPrStatus *prStatus;
```

PrPicFile prints a spooled document. PrPicFile should be called after PrCloseDoc to print the spooled document.

HPrint is the printing record of the spooled document. For spool files, the file's name, volume reference number, and version number are obtained in hPrint's job subrecord.

PPrPort points to the printing grafPort. If pPrPort is NULL, PrPicFile allocates a printing port on the heap. Use pIOBuf to specify an i/o buffer for reading the spool file. If pIOBuf is NULL, the volume buffer is used. PDevBuf points to a device-dependent buffer. If pDevBuf is NULL, PrPicFile will allocate a buffer. PrPicFile updates prStatus as PrPicFile prints the file.

Handling Errors

```
pascal int PrError()
```

PrError returns the error code resulting from the last call to a Printing Manager function. PrError should be called after each Printing Manager call.

```
pascal void PrSetError(iErr)
   int iErr;
```

PrSetError sets the global variable PrintErr to iErr. PrintErr is used by the Printing Manager. Setting PrintErr to iPrAbort will cancel a print job already in progress.

Low-Level Driver Access

```
pascal void PrDrvrOpen()
```

PrDrvrOpen opens the Printer Driver and reads it into memory if it's not already there.

```
pascal void PrDrvrClose()
```

PrDrvrClose closes the Printer Driver, and releases any memory it occupied.

```
pascal void PrCtlCall(iWhichCtl, lparml, lparm2, lparm3)
   int iWhichCtl;
   long lparml, lparm2, lparm3;
```

PrCtlCall calls the current Printer Driver's control routine. IWhichCtl can be one of the following operations: bit map printing, text streaming, or printer control.

Use iWhichCtl = iPrBitsCtl for bit map printing. For bit map printing, lParml is a pointer to the QuickDraw bitmap to be printed and lParm2 is a pointer to the rectangle to be printed. LParm2 should be in the printing grafPort's coordinates. LParm3 determines the type of printing: square dots or the printer's default. Use the constant lPaintBits to indicate square dots (maybe slower, but truer to the screen) or the constant lScreenBits to indicate the printer's native dots (faster but maybe distorted). Always use lPaintBits on the LaserWriter.

For text streaming, use iWhichCtl = iPrIOCtl. Text streaming sends a stream of text directly to the printer — without using QuickDraw. LParml points to the start of the text to print and the low-order word of lParm2 contains the number of characters to print. The high-order word of lParm2 must be zero. LParm3 should be zero. The text can contain control or escape sequences for setting the printing style. Consult your printer manual for details.

Use iWhichCtl = iPrDevCtl for printer control operations. LParml specifies the operation. LParm2 and lParm3 should always be zero. The following operations can be preformed: reset the printer, carriage return and page advance, and end of page. To reset the printer the high-order word of lParml should be 0x0001. Set the low-order word to the number of copies to print. For carriage return and page advance, the high-order word of lParml should be 0x0003 and the low-order word should be the number of dots to advance the page. Set the low-order word to 0xFFFF to indicate a standard 1/6 inch page advance. To indicate the end of a page, set the high-order word of lParml to 0x0002.

```
pascal Handle PrDrvrDCE()
```

PrDrvrDCE returns a handle to the Printer Driver's DCE (device control entry).

```
pascal int PrDrvrVers()
```

PrDrvrVers returns the version number of the Printer Driver in the system resource file.

Resource Manager

The Resource Manager organizes Macintosh resource files. The Resource Manager is seldom called directly, but every Macintosh Toolbox Manager that reads resource information (such as typefaces, icons, text, dialog templates, window templates, control definitions, drivers, desk accessories, etc.) uses the Resource Manager to retrieve that information from the open resource files. Even an application's code is a resource.

The Resource Manager is really a simple database tool. Resources may be found by name or by numeric ID. You might be tempted to use the Resource Manager as a simple database tool in your own applications, but you should avoid doing this. The Resource Manager is too slow for most general purpose database uses.

Constants

```
/* Resource Attributes */
#define resSysRef    0x80
#define resSysHeap   0x40
#define resPurgeable 0x20
#define resLocked    0x10
#define resProtected 0x08
#define resPreload   0x04
#define resChanged   0x02
#define resUser      0x01

/* Resource File Attributes */
#define mapReadOnly  128
#define mapCompact   64
#define mapChanged   32

/* ResError Result Code Constants */
#define noErr       0
#define resNotFound  -192
#define resFnotFound -193
```

```
#define addResFailed -194
#define addRefFailed -195
#define rmvResFailed -196
#define rmvRefFailed -197

#define mapReadOnly  0x80
#define mapCompact   0x40
#define mapChanged   0x20
```

Functions

Initializing the Resource Manager

```
pascal int InitResources()
```

InitResources initializes the Resource Manager, opens the system resource file, and reads in the file's resource map. The return value is the file's reference number. InitResources is called by the system at startup. Your application should *not* call InitResources.

```
pascal void RsrcZoneInit()
```

RsrcZoneInit initializes the resource map read in from the system resource file. RsrcZoneInit is called by the system (*not* your application) when your application starts up. All open resource files, except for the system resource file, are closed. RsrcZoneInit goes through the resource map giving NULL values to handles that point to the application heap (these are easy to find – they all have zero resSysHeap attribute), since the previous application heap is no longer valid.

Opening and Closing Resource Files

```
pascal void CreateResFile(fileName)
   Str255 fileName;
```

CreateResFile creates a resource file with name fileName on the default volume. CreateResFile creates a file with both the resource and data fork. If a file with the given name already exists, a resource fork is created for the file. If the existing file already had a resource fork, CreateResFile does nothing and a duplicate file name error is returned by ResError.

CreateResFile only creates the file. Your application must open the resource file before using it.

```
pascal int OpenResFile(fileName)
   Str255 fileName;
```

OpenResFile opens the resource file with name fileName. The resource map is read in from the file. All resources having a set resPreLoad attribute are also read in. The file becomes the current resource file and a file reference number is returned.

If the file was already open, the file reference number is returned, but the file does *not* become the current resource file. If the file cannot be opened, ResError returns an Operating System result code and OpenResFile returns -1. OpenResFile assumes the file to be opened is on the default volume.

When an application is running, at least two resource files are open: the system resource file and the application's resource file. The system resource file has reference number zero. To find out the reference number of the application resource file, call CurResFile after the application starts up and before any other resource files are opened.

ResError Codes

noErr	no error

```
pascal void CloseResFile(refNum)
   int refNum;
```

CloseResFile closes the resource file with reference number refNum. The following events happen when CloseResFile is called: UpdateResFile is called, ReleaseResource is called for each resource in the file, the memory used by the resource map is released, and the resource file is closed.

If refNum is zero (the system resource file), all open resource files are closed before this one. If refNum is not a reference number for a resource file, then nothing happens and ResError returns an error code.

All open resource files (except the system resource file) are closed when the application is terminated.

ResError Codes

noErr	no error
resFnotFound	can't find resource file

Checking for Errors

```
pascal int ResError()
```

ResError returns the error code resulting from the last Resource Manager routine.

ResError Codes

`noErr`	no error
`resNotFound`	can't find resource
`resFnotFound`	can't find resource file
`addResFailed`	couldn't add resource
`addRefFailed`	couldn't add reference
`rmvResFailed`	couldn't remove resource
`rmvRefFailed`	couldn't remove reference

Setting the Current Resource File

```
pascal int CurResFile()
```

`CurResFile` returns the current resource file's reference number. To get the reference number for the application, call `CurResFile` when the application is started.

When the system resource file is the current resource file, `CurResFile` returns the actual reference number of the system resource file. Your application can use this number or zero when referring to the system resource file.

```
pascal int HomeResFile(theResource)
   Handle theResource;
```

`HomeResFile` returns the file reference number of the resource file containing `theResource`. If an error occurs, for example `theResource` is not a handle to a resource, `HomeResFile` returns `-1`.

ResError Codes

`noErr`	no error
`resNotFound`	resource not found

```
pascal void UseResFile(refNum)
   int refNum;
```

`UseResFile` makes the resource file with reference number `refNum` the current resource file. If `refNum` is zero the system resource file becomes the current resource file.

ResError Codes

`noErr`	no error
`resFnotFound`	resource file not found

```
pascal int CountTypes()
```

CountTypes looks in all the open resource files and returns the total number of resource types that are found.

```
pascal void GetIndType(theType, index)
   ResType *theType;
   int index;
```

GetIndType sets theType equal to the resource type referenced by index. Index should be a number from one to the number returned by CountTypes. If index is not in that range, theType is set to four NULL characters.

Getting and Disposing of Resources

```
pascal void SetResLoad(load)
   Boolean load;
```

SetResLoad sets the global variable ResLoad to load. When ResLoad is TRUE, the routines that return handles to resources automatically read the resource into memory. When ResLoad is FALSE, these routines do not read in the resource and they return a NULL.

TRUE is ResLoad's normal state. If you set ResLoad to FALSE you should restore it to the normal state as soon as possible. Other Toolbox routines rely on the Resource Manager to load resources.

```
pascal int CountResources(theType)
   ResType theType;
```

CountResources looks through all open resource files and returns the total number of resources of type theType that are found.

```
pascal Handle GetIndResource(theType, index)
   ResType theType;
   int index;
```

GetIndResource returns a handle to the indexth resource of type theType. Index should be a number from one to the value returned by CountResources(theType). If index is not in this range, NULL is returned.

If the requested resource cannot be found, NULL is returned. If ResLoad is TRUE, GetIndResource reads the resource into memory. If Resload is FALSE, an empty handle is returned.

```
pascal Handle GetResource(theType, theID)
   ResType theType;
   int theID;
```

GetResource returns the handle to the resource of type theType having resource ID theID. GetResource reads the resource into memory, unless ResLoad is FALSE.

GetResource searches for the resource starting in the current resource file then through all resource files opened before the current resource file. If the resource is not found, NULL is returned.

ResError Codes

noErr	no error
resNotFound	resource not found

```
pascal Handle GetNamedResource(theType, name)
   ResType theType;
   Str255 name;
```

GetNamedResource returns a handle to the resource of type theType having the resource name name. GetNamedResource is the same as GetResource, except it uses a name rather than an id number.

ResError Codes

noErr	no error
resNotFound	resource not found

```
pascal void LoadResource(theResource)
   Handle theResource;
```

LoadResource reads theResource into memory, if necessary. If theResource is already in memory, LoadResource does nothing.

ResError Codes

noErr	no error
resNotFound	resource not found

```
pascal void ReleaseResource(theResource)
   Handle theResource;
```

ReleaseResource frees the memory occupied by theResource's data and the handle to the resource in the resource map becomes NULL. TheResource can no longer be used as a resource handle. If the resource needs to be read in again, a new handle will be allocated.

ReleaseResource should only be called when your application is completely through with a resource.

ResError Codes

noErr	no error
resNotFound	resource not found

```
pascal void DetachResource(theResource)
   Handle theResource;
```

DetachResource removes theResource from the resource map. This has the effect of making the resource manager forget about this resource.

Getting Resource Information

```
pascal int UniqueID(theType)
   ResType theType;
```

UniqueID returns a unique ID number for a resource of type theType. UniqueId looks through all open resource files, and returns an ID that is not used by any existing resource of type theType. The ID will be greater than zero, but it may be in the system resource range (zero to 127). If the ID returned is not greater than 127, UniqueID should be called again.

```
pascal void GetResInfo(theResource, theID, theType, name)
   Handle theResource;
   int *theID;
   ResType *theType;
   Str255 name;
```

GetResInfo returns information about resource theResource. Name is set to the resource's name, theType is set to the resource type and theID is set to the resource's id. If theResource is not a handle to a resource, GetResInfo does nothing.

ResError Codes

noErr	no error
resNotFound	resource not found

```
pascal int GetResAttrs(theResource)
   Handle theResource;
```

GetResAttrs returns the attributes of resource theResource. If theResource is not a handle to a resource, GetResAttrs will do nothing.

ResError Codes

noErr	no error
resNotFound	resource not found

```
pascal long SizeResource(theResource)
   Handle theResource;
```

SizeResource returns the size (in bytes) of resource theResource's data. If theResource is not a handle to a resource, -1 is returned.

ResError Codes

noErr	no error
resNotFound	resource not found

Modifying resources

```
pascal void SetResInfo(theResource, theID, name)
   Handle theResource;
   int theID;
   Str255 name;
```

SetResInfo changes theResource's name and ID number to the those given by name and theID.

SetResInfo makes the changes to the resource map only. To make the changes permanent, call ChangedResource after calling SetResInfo. These changes can become permanent if ChangedResource is called for *any* resource which is in the same resource file as theResource, since ChangedResource causes the entire resource map to be written out when the file is updated. If you do not want these changes to become permanent, you must restore the original values before the resource file is updated.

SetResInfo does nothing if: theResource is not a handle to a resource, theResource is protected, the resource map will become too large to fit into memory, or there is not enough disk space to store the modified resource file. In any of these cases, ResError returns an appropriate error code.

```
pascal void SetResAttrs(theResource, attrs)
   Handle theResource;
   int attrs;
```

SetResAttrs sets theResource's attributes (in the resource map) to the attributes in attrs. If theResource is not a handle to a resource, SetResAttrs does nothing.

Do not use SetResAttrs for setting the resChanged attribute. The resChanged attribute must *only* be changed by ChangedResource. The only attribute to become effective immediately is resProtected. All others become effective next time the resource is read in.

You should follow SetResAttrs with a call to ChangedResource if you want the changes to be permanent. Calling ChangedResource will cause the entire resource map to be written out when the resource file is updated.

ResError Codes

noErr	no error
resNotFound	resource not found

```
pascal void ChangedResource(theResource)
   Handle theResource;
```

ChangedResource checks if there is enough space on the disk to hold the modified resource file. If there is, ChangedResource sets theResource's resChanged attribute in the resource map. If there isn't the enough disk space, the resChanged bit is cleared.

If the resChanged attribute of a resource is TRUE, the Resource Manager writes the resource data to the resource file when WriteResource is called or when the resource file is updated. The entire resource map is written when theResource's resource file is updated.

ChangedResource does nothing when theResource is not a handle to a resource or when there is not enough space on the disk for the modified resource file. When this happens ResError returns an error code.

When changing resource data for purgeable resources, you must be certain that the resource won't be purged while you are changing it. To do this, make the resource unpurgeable (using Memory Manager's HNoPurge routine) while you are operating on it, write it out once it's been changed, then reset it as purgeable (using Memory Manager's HPurge routine).

ResError Codes

noErr	no error
resNotFound	resource not found

```
pascal void AddResource(theData, theType, theID, name)
   Handle theData;
   ResType theType;
   int theID;
   Str255 name;
```

AddResource adds a resource to the current resource file. The file's resChanged attribute becomes TRUE. TheData is a handle to resource data in memory. If theData is an empty handle, zero-length data will be written out for the resource. The type, ID and name of the resource are given by theType, theID and name. Your application is responsible for providing the resource with a unique ID (see UniqueID), as AddResource does not check for this.

AddResource does nothing when theData is a NULL handle or a handle to a resource. When this happens, ResError indicates that adding the resource failed. If there's not enough room for the resource, AddResource does nothing. This can happen if the resource map gets too big to fit in memory or there isn't enough disk space. If this is the case, ResError returns an Operating System result code.

ResError Codes

noErr	no error
addResFailed	resource was not added

```
pascal void RmveResource(theResource)
   Handle theResource;
```

RmveResource removes resource theResource from the current resource file. TheResource's resource reference is removed from the resource map and it's resource data is removed from the resource file when the file is updated.

RmveResource does nothing when theResource is not a handle to a resource in the current resource file or the resProtected attribute is set for theResource.

After successfully removing the resource, call the Memory Manager function DisposHandle to free the memory occupied by the resource data.

ResError Codes

noErr	no error
rmvResFailed	resource was not removed

```
pascal void UpdateResFile(refNum)
   int refNum;
```

UpdateResFile updates a resource file according to the state of the file's resource map. RefNum is the reference number for the resource file.

UpdateResFile does the following:

- The data in the file is made current. Here, resource data is added, changed, or removed from the file according to the resource map. WriteResource is called for each resource whose resChanged attribute is set. If a resource's data is larger than before, the data is written at the end of the file.
- Next the file is compacted: vacancies left by moved or removed resources are closed up.
- If you've added, removed or called ChangedResource successfully, the entire resource map is written out to the resource file in its current form.

UpdateResFile is useful if you want to update a file without closing it. The application needn't call UpdateResFile before closing a file as UpdateResFile is called by CloseResFile.

ResError Codes

noErr	no error
resFnotFound	can't find the resource file

```
pascal void WriteResource(theResource)
   Handle theResource;
```

WriteResource writes out the resource data for resource theResource if it's resChanged attribute is set. After writing out the data, the resChanged attribute is cleared. If the resource has been purged, zero-length data is written out. If the resProtected attribute has been set, or if theResource is not a handle to a resource, WriteResource does nothing.

WriteResource does not check if there is enough space on the disk for the the resource, but ChangedResource does. Be sure that ChangedResource was successful before calling WriteResource.

ResError Codes

noErr	no error
resNotFound	can't find the resource

```
pascal void SetResPurge(install)
   Boolean install;
```

SetResPurge can cause the Memory Manager to check with the Resource Manager before it purges a handle's data. The Resource Manager determines whether or not the handle in question belongs to a resource in the application heap. If it does, `WriteResource` is called if the `resChanged` attribute is set. This occurs if `install` is `TRUE`. `SetResPurge(FALSE)` restores the normal state where the Memory Manager will purge without consulting the Resource Manager.

Advanced Routines

```
pascal int GetResFileAttrs(refNum)
   int refNum;
```

`GetResFileAttrs` returns the attributes of the resource file with reference number `refNum`.

ResError Codes

`noErr`	no error
`resFnotFound`	can't find the resource file

```
pascal void SetResFileAttrs(refNum, attrs)
   int refNum, attrs;
```

`SetResFileAttrs` sets the file attributes of the resource file with reference number `refNum` to `attrs`. You should *not* change the attributes of the system resource file.

ResError Codes

`noErr`	no error
`resFnotFound`	can't find the resource file

Toolbox Utilities

The Toolbox Utilities provide a grab bag of routines: Fixed point arithmetic, which is considerably faster than floating point. String manipulation. Bit-image compression. Bit manipulation. Longword manipulation. Graphics utilities.

Some of the Toolbox Utilities routines, like the bit manipulation routines, are redundant with respect to capabilities C provides. Others, such as the graphics routines, might be better classified among QuickDraw routines.

Data Structures

```
typedef long Fixed;

typedef struct
{  long hiLong;
   long loLong;
} Int64Bit;

typedef Str255 *StringPtr;
typedef Str255 **StringHandle;

typedef struct Cursor *CursPtr;
typedef struct Cursor **CursHandle;

typedef struct Pattern *PatPtr;
typedef struct Pattern **PatHandle;
```

Functions

Fixed-Point Arithmetic

```
pascal Fixed FixRatio(numer, denom)
   int numer, denom;
```

FixRatio does fixed point division. The value returned by FixRatio is the fixed point value of numer/denom. When denom is zero, FixRatio returns 0x7FFFFFFF with the sign bit of numer.

```
pascal Fixed FixMul(a, b)
   Fixed a, b;
```

FixMul does fixed point multiplication. The return value of FixMul is the fixed point value of a*b, computed MOD 65536 and truncated.

```
pascal int FixRound(x)
   Fixed x;
```

FixRound rounds the positive fixed point number x to the nearest integer and returns that integer. If x is halfway between two integers, FixRound will round up.

The rounded values of negative fixed point numbers are equal to : -FixRound(-x).

String Manipulation

```
pascal StringHandle NewString(theString)
   Str255 theString;
```

NewString allocates space for theString in the heap and returns a handle to the space. NewString does not actually put theString in the heap, it just allocates space.

```
pascal void SetString(h, theString)
   StringHandle h;
   Str255 theString;
```

SetString makes the handle h a handle to theString.

```
pascal StringHandle GetString(stringID)
   int stringID;
```

GetString returns a handle to the 'STR ' resource having resource ID stringID. If the string is not already in memory, GetString calls on the Resource Manager to read it in. An empty handle is returned if the string cannot be read.

```
pascal void GetIndString(theString, strListID, index)
   Str255 theString;
   int strListID, index;
```

GetIndString sets theString equal to the indexth string in the string list with ID strListID. If the string list is not in memory, GetIndString calls on the Resource Manager to read it in. Index must be a number from one to the number of strings in the string list. If index is out of range, or if the string list cannot be read in, theString becomes an empty string.

Byte Manipulation

```
pascal long Munger(h, offset, ptr1, len1, ptr2, len2)
   Handle h;
   Ptr ptr1, ptr2;
   long offset, len1, len2;
```

Munger does search and replacement (munging) of byte patterns in a handle. Handle h is the destination handle. Offset is number of the byte in handle h where searching begins. Ptr1 points to the pattern to search for, known as the target. The target's length, in bytes, is given by len1. Ptr2 points to the replacement pattern which is len2 bytes in length. The value returned by Munger is the offset of the byte (in the destination handle) one byte beyond where the replacement occurred. If the target was not found, Munger returns a negative value.

Munger considers it a match if all the bytes from offset to the end of the destination match the beginning of the target.

Sending NULL pointers or zero length patterns to Munger will cause the following:

- If the target pointer (ptr1) is NULL and len1 is positive, len1 bytes at offset in the destination are replaced.
- If the target pointer (ptr1) is NULL and len1 is negative, all bytes in the destination beyond offset are replaced.
- If len1 is zero, the replacement is inserted at offset.
- If the replacement pointer (ptr2) is NULL, no replacement occurs, and Munger returns the byte where the target is found.
- If len2 is zero, the target deleted.

```
pascal void PackBits(srcPtr,dstPtr, srcBytes)
   Ptr *srcPtr, *dstPtr;
   int srcBytes;
```

PackBits compacts data. It does this for srcBytes bytes of data starting at the location pointed to by srcPtr and places the compacted data at the location pointed to by dstPtr. SrcPtr is incremented by srcBytes and dstPtr is incremented by the number of bytes in the compacted area.

Bytes are compacted whenever there are three or more contiguous equal bytes. This condition occurs frequently in QuickDraw images. To compact bit images, call PackBits once for each row in the image. In the worst case, the length of the compacted bytes is one byte longer than the original length. To undo the packing, call UnPackBits.

```
pascal void UnPackBits(srcPtr,dstPtr, dstBytes)
   Ptr *srcPtr, *dstPtr;
   int dstBytes;
```

UnpackBits expands the data that was compacted by PackBits. The compacted data pointed to by srcPtr gets unpacked to the dstBytes number of bytes pointed to by dstPtr. After expanding the data, dstPtr is incremented by dstBytes and srcPtr is incremented by the number of bytes in the expanded area.

Bit Manipulation

```
pascal Boolean BitTst(bytePtr, bitNum)
   Ptr bytePtr;
   long bitNum;
```

BitTst tests whether a given bit is set (1) or clear (0). If the bit is set, BitTst is TRUE. If the bit is clear, BitTst is FALSE. The bit tested is the bit which is offset bitNum bits from high-order bit of the byte pointed to by bytePtr.

```
pascal void BitSet(bytePtr, bitNum)
   Ptr bytePtr;
   long bitNum;
```

BitSet sets the bit which is offset bitNum bits from high-order bit of the byte pointed to by bytePtr.

```
pascal void BitClr(bytePtr, bitNum)
   Ptr bytePtr;
   long bitNum;
```

BitClr clears the bit which is offset bitNum bits from high-order bit of the byte pointed to by bytePtr.

Logical Operations

```
pascal long BitAnd(value1, value2)
   long value1, value2;
```

`BitAnd` returns `(value1 & value2)`.

```
pascal long BitOr(value1, value2)
   long value1, value2;
```

`BitOr` returns `(value1 | value2)`.

```
pascal long BitXor(value1, value2)
   long value1, value2;
```

`BitXor` returns `(value1 ^ value2)`.

```
pascal long BitNot(value)
   long value;
```

`BitNot` returns `(~value)`.

```
pascal long BitShift(value, count)
   long value;
   int count;
```

`BitShift` shifts the bits in `value`. If `count` is positive, `BitShift` returns `(value << count)`. If `count` is negative, `value` is treated as unsigned and `(value >> count)` is returned.

Other Operations on Long Integers

```
pascal int HiWord(x)
   long x;
```

`HiWord` returns the high-order word of `x`.

```
pascal int LoWord(x)
   long x;
```

`LoWord` returns the low-order word of `x`.

```
pascal void LongMul(a, b, dest)
   long a, b;
   Int64Bit *dest;
```

LongMul sets dest equal to a*b.

Graphics Utilities

```
pascal Handle GetIcon(iconID)
   int iconID;
```

GetIcon returns a handle to the 'ICON' resource with ID iconID. If the icon is not in memory, GetIcon calls on the Resource Manager to read it in. If the icon cannot be read in, an empty handle is returned.

```
pascal void PlotIcon(theRect, theIcon)
   Rect *theRect;
   Handle theIcon;
```

PlotIcon draws theIcon in theRect. Since drawing is done in the current grafPort, theRect should be in local coordinates. Drawing is done via CopyBits using srcCopy mode.

```
pascal PatHandle GetPattern(patID)
   int patID;
```

GetPattern returns a handle to the 'PAT ' (pattern) resource with ID patID. If the pattern is not already in memory, GetPattern calls on the Resource Manager to read it in. If the pattern cannot be read in, an empty handle is returned.

```
pascal void GetIndPattern(thePattern, patListID, index)
   Pattern *thePattern;
   int patListID, index;
```

GetIndPattern sets thePattern equal to the indexth pattern in the 'PAT#' (pattern list) resource with ID patListID. Index must be a number from one to the number of patterns in the pattern list. If the pattern list is not in memory, then GetIndPattern calls on the Resource Manager to read it in.

```
pascal CursHandle GetCursor(cursorID)
   int cursorID;
```

GetCursor returns a handle to the 'CURS' (cursor) resource with ID cursorID. If the cursor is not already in memory, GetCursor calls on the Resource Manager to read it in. If the specified cursor cannot be read in, an empty handle is returned.

The system resource file has the following cursors:

```
#define iBeamCursor 1
#define crossCursor 2
#define plusCursor 3
#define watchCursor 4
```

```
pascal void ShieldCursor(shieldRect, offsetPt)
   Rect *shieldRect;
   Point offsetPt;
```

ShieldCursor hides the cursor if it is over rectangle shieldRect. The rectangle can be specified in either global or local coordinates. If using global coordinates, offsetPt should be (0,0). For local coordinates, offsetPt should be the top left corner of the grafPort's boundary rectangle.

ShieldCursor decrements the cursor level. It must be balanced by a call to ShowCursor when you no longer wish to have this "shielding" effect.

```
pascal PicHandle GetPicture(pictureID)
   int pictureID;
```

GetPicture returns a handle to the 'PICT' (picture) resource with ID pictureID. If the picture is not already in memory, GetResource('PICT', pictureID) is called to read it in. If the picture cannot be read in, GetPicture returns an empty handle.

Miscellaneous Utilities

```
pascal long DeltaPoint(ptA, ptB)
   Point ptA, ptB;
```

DeltaPoint subtracts ptA from ptB. It returns a long integer whose high-order word is the difference of the vertical coordinates and whose low-order word is the difference of the horizontal coordinates.

```
pascal Fixed SlopeFromAngle(angle)
   int angle;
```

`SlopeFromAngle` returns the slope (slope is `dh/dv`) of the line which is at the given angle with the y-axis. Angles are measured with zero degrees at 12 o'clock. Positive degrees are measured clockwise, negative degrees are measured counterclockwise. Angles are treated `MOD 180`.

```
pascal int AngleFromSlope(slope)
   Fixed slope;
```

`AngleFromSlope` returns the angle between the y-axis and the line having the given `slope`. As in `SlopeFromAngle`, angles are measured with zero degrees at 12 o'clock. Positive degrees are measured clockwise, negative degrees are measured counterclockwise. Angles are treated `MOD 180`.

Desk Manager

The Desk Manager opens and closes desk accessories. It also routes menu commands, editing commands, and events to open desk accessories. The Desk Manager also provides a routine through which desk accessories may be allotted time for periodic actions.

Constants

```
#define undoCmd   0
#define cutCmd    2
#define copyCmd   3
#define pasteCmd  4
#define clearCmd  5
```

Functions

Opening and Closing Desk Accessories

```
pascal int OpenDeskAcc(theAcc)
   Str255 theAcc;
```

`OpenDeskAcc` opens the desk accessory whose resource name is specified by `theAcc`. If `theAcc` has a window, this window becomes the active window and the display changes accordingly. The Resource Manager is used to read in the desk accessory from the resource file.

If the desk accessory is successfully opened, the return value is the driver reference number. Your application will not need this number, so it can be ignored.

If `theAcc` cannot be opened the return value is undefined. When this happens, the user already knows that the desk accessory cannot be opened and therefore won't be displayed. Again, your application can ignore the return value.

Before calling OpenDeskAcc, save the current grafPort using GetPort. Upon return from OpenDeskAcc restore the grafPort with SetPort.

```
pascal void CloseDeskAcc(refNum)
   int refNum;
```

CloseDeskAcc closes the desk accessory driver reference number refNum. This routine should be used when a system window is active and the user selects close from the file menu. The driver reference number can be found in the windowKind field of the desk accessory's active window.

If the user clicks a desk accessory's goAway box, the Desk Manager automatically calls CloseDeskAcc. Calling CloseDeskAcc is not necessary when an application is terminated. When the application heap is released, the desk accessories (which are in the application heap) are also released.

Handling Events in Desk Accessories

```
pascal void SystemClick(theEvent, theWindow)
   EventRecord *theEvent;
   WindowPtr theWindow;
```

SystemClick should be called after determining that a mouse-down event occurred inside a system window. TheWindow is the window where theEvent occurred. SystemClick first determines which part of the desk accessory the mouse button was pressed in. If theEvent occurred:

- in the content region of an active window, theEvent is passed to the desk accessory which responds appropriately.
- in the content region of an inactive window, theWindow is made the active window.
- in the drag region, the Window Manager function DragWindow is called. DragWindow will drag a gray outline of theWindow across the screen, and then move theWindow when the user is done dragging. If theWindow is inactive, DragWindow will make it the active window.
- in the goAway region, the Window Manager function TrackGoAway is called. TrackGoAway tracks the mouse until the mouse button is released (TrackGoAway takes care of highlighting). If the button is released in the goAway region, the desk accessory will close itself. If the mouse button is released outside this region, nothing happens.

```
pascal Boolean SystemEdit(editCmd)
   int editCmd;
```

SystemEdit should be called after determining that the user has selected one of the five standard editing commands from the edit menu. The parameter editCmd indicates which editing command was chosen. If the edit commands are in the standard arrangement (in ascending order with a gray line between Undo and Cut), then editCmd = menuItem - 1.

SystemEdit returns TRUE if a desk accessory handled the editing. This happens when the active window is owned by a desk accessory. When SystemEdit returns FALSE, it is the application's responsibility to handle the editing.

Performing Periodic Actions

```
pascal void SystemTask()
```

SystemTask allows each open desk accessories to perform whatever predefined periodic action it may have. SystemTask alerts the desk accessory that the action needs to be performed if some specified amount of time has occurred since it was last done.

SystemTask should be called at least every sixtieth of a second (one tick in the Macintosh's time unit). Calling SystemTask once each time through the event loop will usually meet this specification. If you do a lot of processing in the event loop, you should call SystemTask more often.

An example of a desk accessory which has a periodic action is the alarm clock: the displayed time needs to be changed every second.

Advanced Routines

```
pascal Boolean SystemEvent(theEvent)
   EventRecord *theEvent;
```

SystemEvent is called by the Toolbox Event Manager routine GetNextEvent whenever it gets an event. SystemEvent determines whether the system should intercept and handle the event, or whether theEvent should be passed on to the application. When theEvent is an event that should be handled by the system, whatever needs to be done to handle theEvent is done and SystemEvent returns TRUE. If theEvent is an event which should be a handled by the application, SystemEvent returns FALSE.

SystemEvent will immediately return FALSE for null, abort and mouse-down events. Why FALSE for a mouse-down event? Well, in order for SystemEvent to check if it should handle the mouse-down, it would first have to find out if the event occurred in a system window. This process will be repeated when FindWindow is called. So rather than doing the same calculation twice, it is done once— by FindWindow.

If theEvent is a mouse-up or keyboard event, SystemEvent checks if the active window is a desk accessory window capable of handling such an event. If it is, theEvent is passed along to the desk accessory and SystemEvent returns TRUE. If it isn't, SystemEvent returns FALSE and your application should handle theEvent.

If theEvent is an activate or update event, SystemEvent checks if it occurred in a desk accessory's window. If it did and the desk accessory can handle this event (desk accessories should be set up to do this), the desk accessory is given theEvent and SystemEvent is TRUE. If responsibility to deal with theEvent can't be given to the desk accessory, SystemEvent is FALSE.

If theEvent is a disk-inserted event, SystemEvent calls the File Manager routine MountVol. Some low-level processing takes place here, but SystemEvent returns FALSE, allowing your application the opportunity to take further action with the event.

```
pascal void SystemMenu(menuResult)
   long menuResult;
```

SystemMenu is called by the Menu Manager functions MenuSelect and MenuKey when an item from a desk accessory's menu has been chosen. SystemMenu directs the desk accessory to do the action appropriate for the menu selection. MenuResult has the menu ID as its high-order word and the menu item number as its low-order word. This is the same format used in the return value of MenuSelect and MenuKey.

Scrap Manager

The Scrap Manager controls access to the desk scrap. The desk scrap is where "cut" or "copied" information can be held until it is pasted. The desk scrap is so called because it persists across invocations of Macintosh applications. The desk scrap enables the user to paste material from your application into whatever application is run next.

Constants

```
#define noTypeErr -102
```

Data Structures

```
typedef struct
{  long scrapSize;
   Handle scrapHandle;
   int scrapCount;
   int scrapState;
   StringPtr scrapName;
} ScrapStuff, *PScrapStuff;
```

Functions

Getting Scrap Information

```
pascal PScrapStuff InfoScrap()
```

`InfoScrap` returns a ScrapStuff pointer with information about the desk scrap.

Desk Scrap Information

field name	information
`scrapSize`	size (in bytes) of the desk scrap
`scrapHandle`	if the scrap is in memory, this is a handle to it if the scrap is on disk, `scrapHandle` is empty
`scrapCount`	a value that changes each time `ZeroScrap` is called (see `ZeroScrap` for details and use)
`scrapState`	> 0 if desk scrap is in memory, 0 if it's on disk
`scrapName`	the scrap file's name (usually `DeskScrap`)

Keeping Scrap on the Disk

```
pascal long UnloadScrap()
```

`UnloadScrap` writes the desk scrap to the scrap file, if necessary. If the desk scrap is already written out to the scrap file, `UnloadScrap` does nothing. If there are no errors, `UnloadScrap` returns zero. If an error did occur, `UnloadScrap` returns an Operating System error code.

```
pascal long LoadScrap()
```

`LoadScrap` reads the scrap file into the desk scrap, if necessary. If the scrap is already in memory, `LoadScrap` does nothing. If there are no errors, `LoadScrap` returns zero. If an error did occur, `LoadScrap` returns an Operating System error code.

Reading from the Scrap

```
pascal long GetScrap(hDest, theType, offset)
   Handle hDest;
   ResType theType;
   long *offset;
```

`GetScrap` gets data of `theType` from the desk scrap and copies it into memory. `HDest`, a previously allocated handle, becomes a handle to the data. `Offset` returns the location the data was copied from. The location is given as the number of bytes offset from the start of the desk scrap.

If no errors occur, `GetScrap` returns the number of bytes copied. If errors did occur, `GetScrap` returns an Operating System error or `noTypeErr`. `NoTypeErr` occurs when there is no data of `theType` in the desk scrap.

If `hDest` is `NULL`, the data will not be read in — this lets you spy on the desk scrap. You can find out if you have data of `theType` before you allocate a handle for it, or you may just want to find out the size of the data for `theType`. To determine the preferred data type of the application that wrote the scrap, call `GetScrap` with different types: the type returning offset equal to zero is the preferred type. Offset zero indicates this was the first scrap written out.

Writing to the Scrap

```
pascal long ZeroScrap()
```

ZeroScrap clears the desk scrap. The desk scrap must be cleared before it can accept any new scrap from the application or from a desk accessory. An Operating System error code is returned if there is an error, otherwise ZeroScrap returns zero.

ZeroScrap also changes PScrapStuff->scrapCount. By watching for changes to the scrapCount field, your application can monitor changes to the desk scrap.

```
pascal long PutScrap(length, theType, source)
   long length;
   ResType theType;
   Ptr source;
```

PutScrap writes the data pointed to by source to the desk scrap. Length specifies the number of bytes to be written and theType is the data type. If there are no errors, PutScrap returns zero. If errors occur, an Operating System error code is returned.

You *must* clear the desk scrap (by calling ZeroScrap) before your first call to PutScrap.

Segment Loader

The principal job of the Segment Loader is to load the segments of an application on demand. If an application is divided into segments when it is created, the Segment Loader will provide a transparent "overlay" mechanism that can leave unused parts of an application on disk until they are used.

The Segment Loader section of the Toolbox also contains some utility routines that help applications which can handle multiple documents at one time. These routines return information about the documents that were selected when the application was launched. These routines provide roughly the same functionality as the the "argv" argument vector that is conventionally an argument of the "main" routine in a C program.

Constants

```
#define appOpen   0
#define appPrint  1
```

Data Structures

```
typedef struct
{  int vRefNum;
   OSType fType;
   int versNum;
   Str255 fName;
} AppFile;
```

Functions

```
pascal void UnloadSeg(routineAddr)
   Ptr routineAddr;
```

UnloadSeg makes the segment containing the routine pointed to by routineAddr relocatable and purgeable. Your application is responsible for unloading segments. The Segment Loader will load segments as necessary.

```
pascal void CountAppFiles(message, count)
   int *message, *count;
```

CountAppFiles gets information from the Finder for the application. Count is set to the number of documents selected when your application was started, and message will tell you whether the selected documents are to be opened (message = appOpen) or printed (message = appPrint).

```
pascal void GetAppFiles(index, theFile)
   int index;
   AppFile *theFile;
```

GetAppFiles gets information about a document that was selected when your application started up. Use index to specify which document you want information about, where index is between 1 and the count returned by CountAppFiles. The information is returned in theFile: it includes the volume reference number, file type, version number and file name.

```
pascal void ClrAppFiles(index)
   int index;
```

ClrAppFiles indicates to the Finder that your application has processed the file indicated by index.

Call ClrAppFiles after opening or printing the selected document. This insures correct results from CountAppFiles and GetAppFiles.

```
pascal void GetAppParms(apName, apRefNum, apParam)
   Str255 apName;
   int *apRefNum;
   Handle *apParam;
```

GetAppParms gets information about the current application. ApName is the application's name and apRefNum is the reference number of the application's resource file. ApParam is a handle to the Finder information (but you may find that using GetAppFiles is an easier way to access the Finder information).

```
pascal void ExitToShell()
```

ExitToShell releases the application heap, then starts up the Finder. Use ExitToShell to exit from your program.

Index

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