Paul Overaa

Mastering Amiga Assembler

Applicable to all Amigas

The complete desktop tutorial

Write your own programs

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Paul Overaa initially qualified as an analytical chemist and spent two decades working in a field of physical chemistry known as gas-liquid chromatography. It was during this time that he became heavily involved with computerised data reduction techniques and computer programming. Nowadays he considers himself a programmer first and an analytical chemist second.

Paul has previously written books on low-level 6502 and Z80 assembly language programming, on Amiga programming in C, on Amiga systems programming and on both Commodore Amiga and Atari ST program design. He is a proficient C and 68000 assembly language programmer, and a very experienced Amiga programmer whose technical expertise is frequently used by a great many computer magazines including *Amiga Shopper*, *Amiga Format*, *Amiga User International*, *Amiga Computing*, *Program Now*, *Computing*, the *Amiga Buyer's Guide* and *Atari ST User*. In addition to this he provides expertise on MIDI programming for magazines such as *Sound on Sound* and *International Musician*. In the past he has written for many other publications including *ST World*, *Personal Computer World*, *Practical Computing*, *Laboratory Practice*, and the one time highly influential *Transactor Amiga* magazine.

His main passion nowadays is computer programming with his research interests having a strong bias towards the practical use of the Warnier diagram and other language-independent program design techniques.

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Preface

Learning an assembly language is not in itself a difficult task and I'll be the first to admit that there are many books available which have excellent introductory accounts of this subject. But a microprocessor does not work in isolation and in the Amiga the 68000 processor is just a small part of a complex system which involves not only a great many other hardware components but a very complex covering shell of operating system software as well. If you are intent on programming the Amiga using 68000 assembly language then some knowledge of this operating system is needed right from the start and this produces an immediate stumbling block.

Almost all books which deal in depth with programming the 68000 microprocessor do so in an operating system independent way and this makes it very difficult for the would-be 68000 (68K) Amiga programmer to relate what they are learning about to the Amiga environment. On the face of it the solution would be to use general 68000 books to learn about programming the processor and get the Amiga-specific material from books which deal specifically with the Amiga's operating system. Things are not however quite that simple because much of the Amiga's documentation has been

written with the C programmer in mind. Worse than that, much of it has been written for professional programmers who are already system literate.

The bottom line is that in many ways newcomers to assembly language, no matter how enthusiastic they might be, are left high and dry and it is exactly this *information gap* which I have tried to fill with this book. I've attempted to introduce 68000 assembly language specifically from an Amiga orientated viewpoint and my main aim has been to provide you with the necessary footholds to get into low-level Amiga programming as quickly as possible.

The material in this book is essentially self-contained but as you progress you will doubtless follow your own path in terms of what you choose, Amiga-wise, to take an interest in. Regardless of the directions in which you travel you will almost certainly get to a point where more and more reliance has to be placed on the Amiga's official system documentation. I would be less than honest if I told you that some experience with the C language would not be an advantage to you at this stage and my experience is that all programmers, including those whose sole interest was programming at the 68000 microprocessor level, have eventually needed to come to terms with C just in order to cope with the official Amiga documentation. This, from a long term viewpoint, is something which you should clearly keep in mind.

I will not be using, or referring to the C language, for the bulk of this book but there a few occasions, such as the example on mixed code programming, where some knowledge of C is needed. Because of this, and because you may find the material generally useful in your Amiga travels, I have included an appendix which outlines the most important features of the C language.

As far as learning 68000 assembler goes I have worked primarily on a *need to know* basis and have concentrated on those Amiga specific topics that are not found in more general 68000 books and which, in my opinion, have not been properly explained (from the beginner's viewpoint) in existing Amiga specific texts. In order to gain sufficient space to do this I've avoided duplicating what I regard as essentially standard 68000 information. You will not, for instance, find detailed accounts of each and every instruction that the 68000 can execute (such material is readily available from the sources mentioned in the bibliography).

Similarly I have avoided extended discussions of hardware issues because to start assembler programming on the Amiga, and any other machine come to that, all that is needed is a simple conceptual model of the processor and its facilities. Knowledge of how the processor physically communicates with memory and the

outside world, and discussions of what timing signals are used to ensure that such things happen at the right time, are two example areas which do not seem to facilitate the move to low-level programming. These hardware related topics are certainly important to system designers and engineers but for most would-be assembler programmers I've found that discussions of such material only complicates matters.

In short then I've attempted to isolate you the reader from any low-level topic that does not directly contribute to the real task at hand, namely how to go about writing your first 68000 programs. I believe that I can not only show you a simple pathway to achieve this objective but that I'll even be able to make the subject enjoyable and that, believe me, is over half of the battle!

Paul Overaa

1: Fundamental Concepts

The objective of this chapter is to draw your attention to, and explain, a number of general issues related to the writing of assembly language programs. As you probably know, the heart of the conventional microcomputer system is a combined logic/control unit known as a central processing unit or CPU. Most processors have a considerable number of common characteristics including the fact that all have a set of internal registers for storing data and all have some hardware-orientated means of communicating with the outside world. Since the amount of internal storage available on the CPU itself is always limited it must, before it can do any useful work, also be connected to additional memory components that are able to provide a suitable amount of additional CPU-accessible electronic storage. Two basic types of memory chips are in common use:

RAM (random access memory) chips may be both written to and read from and as such are used to provide storage space that may be dynamically changed either prior to or during program execution.

ROM (read only memory) chips can only be read from and are therefore used to hold information blocks that do not change. Once programmed, a ROM chip, whether powered up or not, will keep its contents indefinitely. RAM

chips on the other hand do not hold their data in this way and when the power is removed from the system the contents of all random access memory units will disappear.

On small and medium power computers the processor is usually an integrated circuit known as a microprocessor and this device will have its own *instruction set*, a collection of logic/arithmetic instructions, which can cause the microprocessor to perform various tasks. At the end of the day it is sets of these instructions, stored in memory, which constitute the programs which will be executed by the computer system.

The language that the microprocessor understands is based on binary numbers. Given suitable hardware ie, a processor chip, memory, some input/output facilities, and all the associated electronic support, one way of programming such a system would be to enter suitable binary numbers directly into system memory and then to get the microprocessor to execute the instructions.

This *machine code* programming approach was actually used to create and run programs in the early days of computing. It didn't take long before programmers realised that this sort of programming was a pain because the numbers which related to particular processor instructions didn't have any obvious connection with what the programmer was really trying to do. The solution was to give the instructions meaningful names (or as meaningful as possible) eg ADD, MOVE, SUB and so on. These humanised instruction names were called *mnemonics* because they were a memory aid that helped programmers to remember the purpose of the underlying processor instructions. The next step was to automate the process of converting mnemonics back to the numbers which represented the processor instructions. Programs which did this translation effectively *assembled* the runable program from the mnemonic instructions that the programmer had provided so they were called assemblers. In short, assembly language programming was born!

Over the years microprocessors, assembly language programming concepts, and development software have all become increasingly sophisticated but these assembly languages (and each microprocessor has its own) are always close to the actual machine and its underlying hardware – hence they are called low-level languages. The Amiga, as you'll doubtless already know, uses a microprocessor called the Motorola 68000 and this means that to conveniently program the Amiga at the microprocessor level you need to learn 68000 assembly language.

The High-Level Alternative

The birth of assembly language didn't solve all of the problems that the early programmers faced. To start with, programs written in low-level languages are processor specific so they are not portable, ie not easily made to run on different processors. Another problem is that you have to express what you want to do in terms of the instructions which are available on the processor and this means working primarily with bits and bytes. Any other data structures needed have to be created by the programmer so if, for instance, the problem being solved involved text strings or floating point numbers then it is you, the programmer, who would have to decide how to represent those entities, and do the necessary programming.

High-level languages, such as BASIC and Pascal, attempt to provide a vehicle for expressing algorithms which is more human orientated and powerful. A single statement in a high-level language might correspond to operations which, when expressed in a lower-level language, would need many hundreds of code instructions. At the end of the day however the high-level language interpreter or compiler *must* produce such a series of low-level machine instructions in order that the program can run.

In reality, this low-level/high-level *two tier* classification is rather an over-simplification. Nowadays there exists a wide spectrum of languages each possessing features from both groups. Almost all current assemblers for example allow macros, reusable groups of low-level operations, to be built up and the creation of these types of units allow the programmer to tackle low-level code writing at a significantly higher level than was possible with early assemblers. Having said that, high-level languages clearly have a number of important benefits:

- The structure of the program can be based on, or reflect, the inherent structure of the original problem.
- High-level languages can usually offer a degree of *self-documentation.*
- High-level languages allow meaningful, hardware independent, names to be used both for data and procedures/subroutines.
- The abstraction offered by high-level languages allows for a clearer algorithm representation. Much of the detail which would be present in a lower-level form is hidden by the more powerful language statements.
- High-level languages are easier to learn than low-level languages.
- High-level languages often offer sophisticated debugging facilities.

- High-level programs are often more portable, ie can run on any machine for which the language has been implemented.

The key advantage offered by high-level languages is that they provide a means of expressing the steps of an algorithm at a more *problem/solution* orientated level. If, for example, you wish to open a file, read some data, and then close a file it might be possible to use program statements which represent these file opening, data reading, and file closing operations directly. Three statements which relate closely to the things which need to be done, as opposed to hundreds of assembler instructions which, taken in isolation, will give few obvious clues as to the work being carried out.

As the level of abstraction increases, the programmer becomes less concerned with the hardware on which the program runs and is able to work more and more at a problem-orientated level. Symbolic names take the place of memory addresses, support for different data types means that the language (as opposed to the programmer) can be left to figure out the details about the sizes of objects being used and how/where they should be stored. Similar generalised control abstraction facilities allow loops and decision tests to be used as building blocks, which again makes it easier for the programmer to tackle problems in a *solution orientated*, rather than a hardware orientated, way.

Now if these high-level language characteristics are so good why on earth are people still using assembly language at all? To be honest people have been predicting the demise of the assembly language programmer for years but it simply hasn't happened – in fact interest in assembly language programming actually seems to be on the increase and it turns out that there is far more to the high-level/low-level debate than first meets the eye.

Benefits of the Low-Level Approach

It was once thought that there were only three reasons for using assembly type languages: speed, compactness and the ability to achieve the ultimate control over the system. The benefits are rather more subtle than this because there's no doubt that an understanding of an assembly language gives the programmer an in-depth appreciation of what high-level languages must do to achieve their abstraction magic. It's a similar situation to driving a car. If you don't know roughly how the gears work then you might wonder why you can't pull away in fourth gear without stalling the engine. Plenty of driving will convince you that this is indeed the case, but no matter how much you drive you'll never actually find

out why this is so. Learn a bit about the internal mechanics however and it will become obvious within a very short space of time!

Since the Amiga is a 68000 based machine it's not hard to figure out that *all* Amiga languages must end up generating 68000 code – they have to because otherwise the final programs simply wouldn't be able to run on the Amiga's microprocessor. What then is it that actually makes code written by assembler programmers run faster than the equivalent 68000 code generated by programmers working with high-level languages? The answer is simply that the assembler programmer can make sure that their final code is super-efficient. Here's a typical example.

As you may know, the Amiga has a vast number of pre-written routines available which are organised as a collection of units known as *run-time libraries*. The routines present in these libraries are accessed by a table stored in memory immediately below the base (main reference) address of the library. By using a negative offset, called a LVO (Library Vector Offset), the programmer can specify which routine is to be called. These routines are used by placing the library's base address in one of the 68000 registers (actually register a6), using the LVO as a displacement value, and performing something called an indirect subroutine call. These terms may not mean much at the moment but the important point to grasp is that the necessary data needs to be held in the microprocessor's internal registers before the subroutine call is made.

Now let's consider what happens with a conventional C compiler when a high-level function call is used to execute the same library routine. The compiler starts by pushing function call parameters onto the *stack*, an area in memory which the microprocessor uses to store items on a *last-in-first-out* basis. Now, when you are calling an Amiga library function, it turns out that this is a total waste of effort because, at the end of the day and as indicated above, the Amiga run-time libraries expect the parameters to be present in the 68000 processor registers and not on the microprocessor stack. The bottom line is that before the real library function call can occur, the parameters, so carefully placed on the stack by the compiler generated code, have to be immediately copied back into suitable processor registers.

The code stubs which do this are part of the amiga.lib library and this, plus the fact that the LVO values are also needed, is the reason why C programmers usually link their code with the amiga.lib linker library in the first place. The resultant C code therefore ends up doing a lot of unnecessary work and this of course slows the

program down. By placing library call parameters directly into the appropriate 68000 registers the assembly language programmer can eliminate such inefficiencies very easily indeed.

Now to be completely fair, at least as far as the above example goes, I ought to point out that some compilers (eg Lattice/SAS C) do now support register based parameter passing and can therefore also now eliminate these amiga.lib subroutine time penalties. Being equally fair as far as the assembler programmer is concerned I should mention that while register based parameter passing in C is a recently added facility such advantages have always been available to the 68000 assembler programmer!

The underlying general point I'm trying to make is this: all high-level languages have to make compromises with the code they generate and because of this there will always be many occasions where the assembly language programmer can cut corners and eliminate inefficiencies. This is the reason why the assembly language programmer will almost always be able to produce program code that runs faster than code generated by a compiler.

Assembly language then has a lot going for it. High-level language topics that programmers often find difficult to understand, such as bit-manipulation operations and the use of indirection and pointers, have natural and easy to recognise counterparts in assembly language. The overall result, believe it or not, is that knowing something about your machine at this low level of programming will not only help you get a gut feeling for what computing is all about but it can even help you to write more effective high-level code. For more information see the Appendix *Mastering Amiga Guides.*

Creating an Assembly Language Program

The first step in writing an assembly language program is to use an editor program to prepare a source code file. This file will simply be an ASCII text file which contains the program instructions that you've written and you will of course be able to list and print the contents of such a file just as you would a letter or any other piece of stored text. Most commercial assemblers come with their own editor programs but, if you prefer, it is also possible to use an alternative editor or wordprocessor program. The only proviso with the latter option is that it must be possible to stop the wordprocessor from inserting additional control characters because these characters would, as likely as not, cause the assembler program to come to a grinding halt as it tries unsuccessfully to interpret them.

Once a source file is available, the next step is to get the assembler program to convert it to the appropriate 68000 instructions. On the Amiga the assembler will in many cases first have to be used to create a standardised intermediate form known as an object code file. This is not a runable program as such and there are three possible reasons for this. Firstly, although the object file will include the translated 68000 instruction-related material, the code will not itself be in the right format to be loaded by AmigaDOS. Secondly, the program will not contain an all-important piece of Amiga specific front-end code known as the startup code which is needed if the program is to run from the Workbench. Thirdly, the file may still contain references to unresolved (unknown) items, such as linker library routines or variables that have been specified as being present in other object code modules.

A third stage, known as *linking*, attempts to fill in the gaps created by these unresolved references. The Amiga linker, called Blink, is able to combine the startup code and the code you have written (plus any other specified object code modules or library code), to produce a program file that may then be loaded and run under the Amiga's operating system. Having said all that I'm afraid that I must now point out that nowadays many assemblers can produce a variety of different output file formats. HiSoft's *Devpac* assembler for instance, providing it is presented with a suitable source code file, can generate directly executable code without an explicit linking stage!

Libraries on the Amiga cause a few headaches for the beginner primarily because the term is used in a number of different ways. During the example of high-level language inefficiencies I spoke of the Amiga's run-time libraries which are collections of shared routines that, by virtue of the Amiga's operating system, can be made available to all programs which need them during the times that they are actually running.

The libraries I am talking about in the context of the above linker discussion are rather different. Linker libraries are sets of pre-written system or utility routines which will be tagged onto the code you write during the linking stage. If you use a linker library function within your program the linker, providing you correctly specify the name of the library which holds the routine, will automatically find and include the right piece of code in the finished program. I'll be saying much more about the various Amiga library schemes later in the book.

On occasion things may not go well and you may find that as the assembler attempts to translate your source file it reports any number of errors. Whatever the cause (syntax errors, illegal instructions etc) these faults will have to be corrected and this may

mean that in the early days you'll frequently pass through the *edit<->assemble* cycle quite a few times before you succeed in creating a program that assembles successfully. Even having got through that stage of the proceedings you may then find that the linker reports additional errors. Mis-spelling library routine names or not specifying the correct location of library files are commonly seen linker errors. These errors must also be found and eliminated before a runable version of the program can be created.

As you doubtless already know there is no guarantee, even once a program is up and running, that it is free from errors. In fact assembly language programmers, unless they are very careful, are likely to spend far more time looking for bugs than their high-level language counterparts. Many assembly language programmers frequently use a piece of software called a debugger, which is a system tool that is able to execute a program on a step-by-step basis, in order to help them to trace program execution and identify faults. Whilst I certainly agree that debuggers can be useful on occasion I am not in favour of their use as a general fault-finding tool.

Number Systems

One thing you are going to need to get used to as you enter the world of assembly language is the use of additional numbering systems. Since this primarily involves binary and hexadecimal numbers some words on these two number schemes are in order.

In the decimal number system ten different symbols (the digits 0-9 inclusive) are used to represent numbers. Each digit in a number is ten times more significant than the digit to its right, and ten times less significant than the digit to its left. This *ten times* relationship that exists between the digits of all decimal numbers is obviously a fundamental part of the decimal numbering system. If, for example, we consider the number 375 and write a full description of what each digit means, we can see that it is just a convenient way of expressing this sum:

$$(3 \times 100) + (7 \times 10) + 5$$

Going one better than this and, bearing in mind that any number raised to the power zero is unity, you can express each effective digit term as a product of one digit and a power of 10 like this:

$$3 \times 10^2 + 7 \times 10^1 + 5 \times 10^0$$

For decimal numbers 10 is known as the *radix*, or base, of the numbering system but many other bases are possible. Computers use binary, ie base 2, numbers which consist of strings of 0s and 1s

and again, if you think of a binary number in terms of its explicit *radix = 2* representation, it's easy to see the relationship between the binary and decimal number systems:

1 0 1 1 binary =

$$1 \times 2^3 + 0 \times 2^2 + 1 \times 2^1 + 1 \times 2^0$$

$$8 + 0 + 2 + 1 = 11 \text{ decimal}$$

By writing out what the binary number means in full it becomes quite easy to see that 1011 binary is the decimal number eleven!

Computers use binary numbers internally because the two digits 0 and 1 relate directly to the possible states of bits within the memory hardware of most computer systems. Binary numbers are then intimately involved with a great many computing applications but, since they are not that easy for us humans to work with (because long strings of 0s and 1s are easily mis-interpreted) a related radix scheme called hexadecimal is often used as an alternative.

Hexadecimal numbers use a radix of 16 and the sixteen symbols used are the digits 0-9 plus the letters A-F. Each column in a base 16 number therefore represents some power of the base. For example the decimal number 16 itself is written as 10 hex, because:

10 hex = $1 \times 16^1 + 0 \times 16^0$

$$16 + 0 = 16 \text{ decimal}$$

Similarly 1F hex would be:

1F hex = $1 \times 16^1 + 15 \times 16^0$

$$16 + 15 = 31 \text{ decimal}$$

The fact that the bases of the binary and hexadecimal numbering systems are power related (2 to the power of 4 equals 16) produces a special, and very useful, relationship between these two numbering systems – it allows one hexadecimal digit to represent *four* binary digits. Best of all the *binary<–> hex* conversion process is very easy to understand once you've learnt the table in Figure 1.1.

Binary	*Hex*
0000	0
0001	1
0010	2
0011	3
0100	4
0101	5
0110	6
0111	7
1000	8
1001	9
1010	A
1011	B
1100	C
1101	D
1110	E
1111	F

Figure 1.1. Table for binary to hex conversion and vice versa.

To convert a hexadecimal number into binary form you just replace each hexadecimal digit with its group of four binary digits. To convert a binary number to its hex form you peel off (from right to left) groups of four bits and replace them with the corresponding hex digit!

So to convert CF hex to the binary equivalent you'd replace each of the two hexadecimal symbols with the binary equivalents like this:

```
CF hex =        C         F

              1100      1111          = 11001111 binary
```

To go the other way you take groups of four bits from the binary number and replace then with the corresponding hex digits. The binary number 1111000010101010, for example, could be translated to hexadecimal form as follows:

```
1111000010101010 = 1111 0000 1010 1010

                     F    0    A    A   = F0AA hex
```

Using (and converting between) binary, hex and decimal number systems is not that difficult but it does take practice. Familiarity with hex and binary number forms is also essential for understanding how the bitwise logical operations, provided by both microprocessor instructions and high-level languages, work. Logical

AND and OR instructions for instance, which I'll assume you know about from languages such as BASIC, perform operations based on the two truth tables in Figure 1.2.

X	Y	X AND Y	
0	0	0	
1	0	0	**Logical AND Operation**
0	1	0	
1	1	1	

X	Y	X OR Y	
0	0	0	
1	0	1	**Logical OR Operation**
0	1	1	
1	1	1	

Figure 1.2. Logical AND Operation (top) and Logical OR Operation (bottom).

Being able to picture in your mind what these tables mean is a big advantage. If you AND two operands together then only the bit positions where both operands have a bit set to 1 will produce a 1 in the result. With the OR operation you'll get a 1 in the result when either (or both) of the bits in that position in the corresponding operands are set to 1.

The bit pattern for F0 hex for instance is 11110000 so ANDing any value with F0 hex will force the lower four bits of the result to zero – the value F0 hex is called a mask because it *masks out* certain bit positions. The OR operation is equally useful because it can force bit positions to take particular values.

Last Words

The instruction sets of most processors, such as the 68000 used in the Amiga, are quite limited and there is nothing inherently complex about their operations. Each instruction carries out some elementary task, perhaps adding two values together or copying the contents of one memory location to another.

Despite this underlying simplicity there's no doubt that tackling 68000 assembly language is not a task to be undertaken lightly. Problems will arise when you try to work out how to combine hundreds and thousands of assembly language instructions into a program which does a particular job. It is a task which is error

prone and, by its very nature, time consuming. The benefits? Firstly you'll be able to make your programs run at the ultimate speed. Secondly, you will develop a gut feeling for what computing is all about at the *nuts and bolts* level.

Assembly language programming on the Amiga adds another dimension – the complexity of the operating system itself. Before you can comfortably write assembler code to do a particular job it's necessary to know enough about the operating system and its library code system call arrangements, to work out what your assembler code should be doing. Learning about these Amiga facilities alone is a massive challenge simply because there is so much to understand. There is no easy road! You've just got to sit down and work at it.

Don't forget incidentally that it is often possible to combine both high-level and low-level approaches in the so called *mixed code* approach. Here the bulk of the code is written as normal using a high-level language, then any routines which are particularly critical are added as assembler patches. This gives the programmer the best of both worlds – essentially high-level development coupled with the absolute speed and control in the program sections where it counts. I'll look, in some detail, at an example of this type of coding towards the end of the book.

2: The 68000 Chip and its Assembly Language

The main central processing unit (CPU) of the Amiga is a device known as the Motorola 68000 or Motorola 68K chip. It has actually been available for over a decade but in those early days its use was restricted to fairly high cost systems. The 68000 has now been superseded by more recently developed CPUs, including later offerings from Motorola that now form part of the Motorola 680x0 family. Despite its age however the basic 68000 is still an extremely capable chip as its use in the Amiga should show.

During the previous chapter I mentioned that to write assembly language programs all that one needs is a simple conceptual model of the processor. There is no need to understand the hardware, the electronic connection schemes or how all the various integrated circuits are built and used.

What is important is that you get an understanding of the general internal characteristics of the 68000 such as what sort of data it can store internally, the sizes of the data it can work with, any restrictions that are imposed by the architecture (overall logical design) of the chip and so on. This purpose of this chapter therefore to build a type of conceptual picture of the 68000 microprocessor, discuss the features which are relevant to the writing of assembly language programs,

and then introduce you to the actual operations that the processor can perform. Since most computer users are exposed to the ideas of bits, bytes and memory right from the time they start taking their first steps with BASIC I will assume that these terms are familiar. External memory, whether it be RAM or ROM can, as you therefore doubtless know, be best thought of as a large array of individually addressable storage slots which may be identified by a *memory address.* Obviously there is no point having memory connected to the system if the microprocessor has no means of accessing it and, as you'll see from the following description, the 68000 does indeed provide the appropriate mechanisms.

A Schematic 68000 Model

The 68000's internal registers are split into two basic groups, address registers and data registers, and registers of each group are numbered from 0 to 7. Data registers are therefore labelled as d0, d1, d2...d7 (or D1, D2... etc), with the corresponding address registers labelled as a0 or A0 and so forth. Address register a7 has a special purpose in that it serves as the microprocessor's stack register and is set up to point to an area of memory that can be used to store information on a last-in-first-out basis (LIFO). Because of 68000 architecture restrictions the stack has to be located at an even-numbered memory address. There are in fact two different 68000 stack pointers and this stems from the fact that the processor can operate in two modes – user mode and supervisor mode. Since it is convenient for each mode to have its own stack the 68000 has been designed so that register a7 behaves like two separate registers and stores both a user mode stack pointer and a supervisor mode stack pointer. Mode related issues are transparent for the purposes of the programming which we shall be involved with in this book.

Each 68000 register can hold a four byte (32-bit) number and amongst its other facilities the processor is able to move such numbers between its internal registers, between a register and a memory location (and vice versa). The 68000 can also move external data held in memory from one location to another.

One of the most distinctive features of the 68000 is the flexibility of its registers. Although they can hold 32-bit (long word) values the processor can, for many operations, use the address registers to work with 16-bit values (words) and the data registers can in fact work with either 32-bit values, 16-bit or 8 bits. Similarly there are few restrictions on what you can, or cannot, use the contents of such registers for. If, for instance, you wish to copy the contents of a data register into an address register the 68000 lets you do it. Having said that, it is usually better to use address registers for

storing and working with memory addresses and data registers for data orientated operations because each of the groups are better suited to their design-chosen purposes. When working with instructions that may involve byte, word or long word values it is often necessary for the assembly language programmer to identify the size that should be assigned to a given value. As you'll see later the 68000 conventions are based on placing .b, .w or .l after the instructions. The 68000, because of its internal architecture, does however have a limitation on the address values that it uses when accessing word or long word addresses because the address must be even (word aligned). Assemblers take care of much of the word-alignment problems automatically and if, for example, you set aside space for a long word variable, the assembler will usually ensure that it gets allocated an even address.

The 68000 also contains a 32-bit program counter which is a register used by the microprocessor to determine the address of the next instruction to be executed. Under normal conditions the program counter is automatically incremented as instructions are read and acted upon, hence instructions contained in memory are executed in sequence, ie one after another. An important part of microprocessor programming however revolves around a number of instructions which can alter the contents of the program counter and the result of doing this has far reaching implications. By changing the program counter address it is possible to cause the microprocessor to get its next instruction from anywhere in memory (as opposed to getting the instruction next in sequence in memory), the result of which is that the execution of the program can *jump* from one part of the program to another.

The fact that these jumps can be made conditional on the state of various processor flags means of course that the processor can make *intelligent* flow control decisions based on the data with which it is working. A program might for instance compare two numbers and, on the basis of the result, execute (or perhaps not execute) a particular set of instructions.

The 68000's Status Register

Another important 68000 register is the status register which is actually divided into two eight bit registers known as the system byte and the user byte. The system byte is only accessible in supervisor mode and contains a number of system related bitfields, such as interrupt masks, which we will not be concerned with.

The user byte on the other hand is vitally important because it contains flag bits whose values are set and cleared according to the results of particular instructions. Five flags are available and these provide single bit true/false type detection of the processor

conditions known as carry (C), overflow (V), zero (Z), negative (N), and extend (X). The carry bit holds the carry from the most significant bit produced by bit shifting or arithmetic operations. Like many processors the 68000 inverts the carry bit after subtraction and so with subtraction the carry flag actually behaves as a *borrow* flag. The zero flag is set high (ie set to 1) when an operation produces a zero result. If, for example, the result of adding two numbers together produced a zero then the 68000's zero flag would be set to 1. The negative bit, sometimes called the sign bit, always takes the value of the most significant bit of the result. It can be used to good effect when working with operands that are in a form known as *signed two's complement* but is also frequently used just as a *most significant bit* indicator. The 68000's overflow and extend flags are also primarily used for arithmetic applications. Not all instructions, incidentally, affect all flags as you'll see when we start looking at typical instructions.

Addressing Modes

One of the most powerful features of the 68000 instruction set is the rich variety of addressing modes that are available. Most processor instructions work on a piece of data (called the operand) and this data has to be stored somewhere. In short, many instructions will use some real or implied source address, do something, and then transfer the result to its destination address. The processor's addressing modes enable these source and destination addresses to be specified. With the 68000 there are eleven basic addressing schemes and, for completeness, here are the names:

1. Inherent
2. Register
3. Immediate
4. Absolute
5. Address register indirect
6. Address register indirect with displacement
7. Address register indirect with postincrement
8. Address register indirect with predecrement
9. Address register indirect with index and displacement
10. Program counter relative with displacement
11. Program counter relative with index and displacement

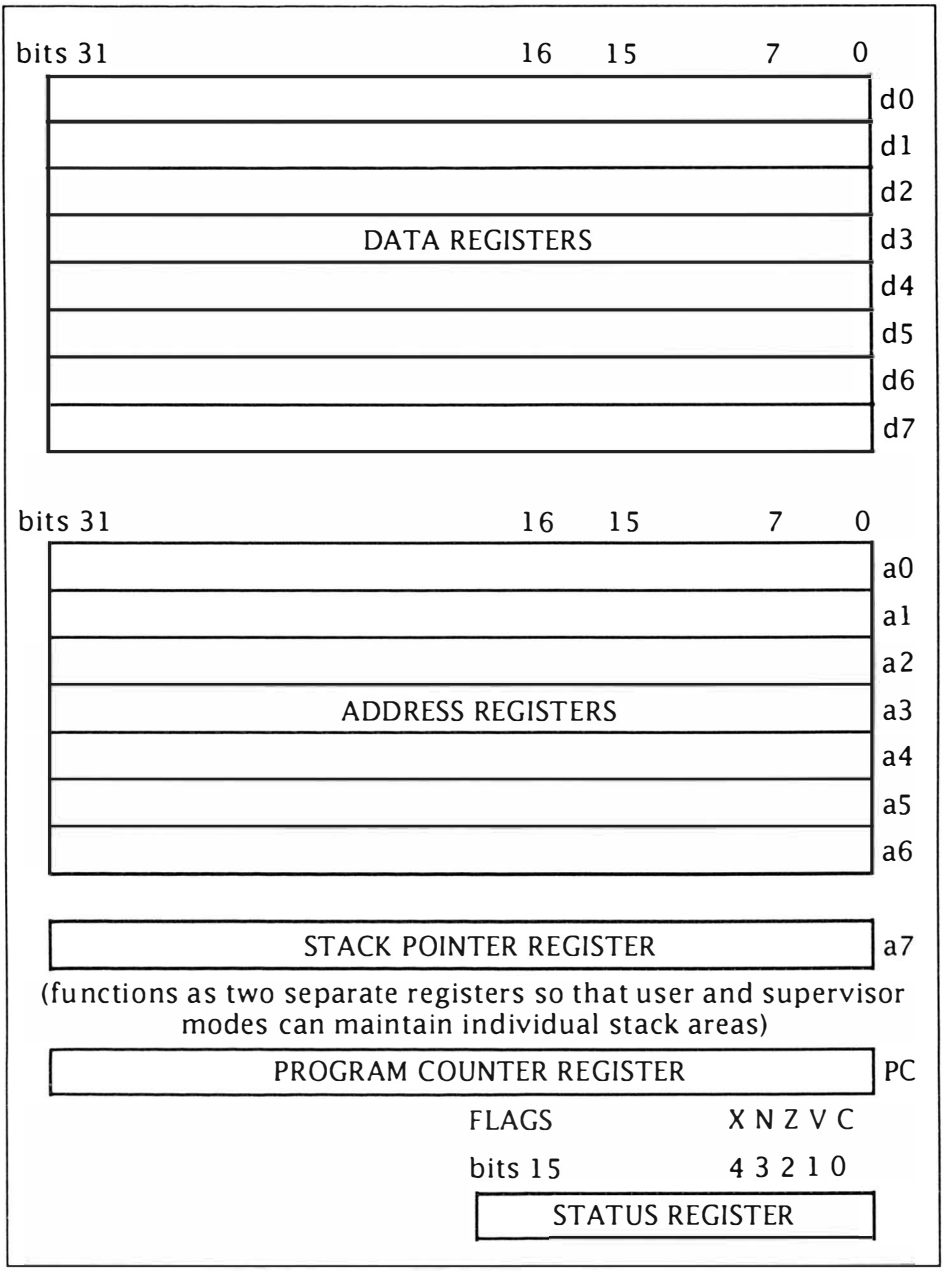


Figure 2.1. Schematic model of the Motorola 68000 microprocessor.

Inherent addressing means that the instruction itself implies the location of the operand. Register addressing implies that the operand resides in one of the 68000's internal registers. Absolute addressing means that the *address* of the operand is located just after the instruction in memory whereas immediate addressing implies that the operand itself is located just after the instruction in memory.

Indirect addressing is a very powerful concept and on the 68000 a variant called register indirect addressing is used. In short an address register is used to specify the *address* of the operand. In addition to these straightforward addressing modes it is possible to specify displacements, to auto-increment or auto-decrement an address by 1, 2, or 4 bytes (handy for stepping through lists of 1, 2 and 4 byte data items) and to write program counter relative code, which is necessary when writing truly relocatable code. It's not advisable to explain all of these addressing modes at the present time and such descriptions are left to later chapters where various addressing schemes can be explained within the context of some real programs.

68000 Instruction Classes

The 68000 instruction set is large and almost all sensible addressing modes can be used with any instruction. As was the case with the 68000's addressing modes it is not a useful exercise, either now or later, to list and discuss each instruction. Such discussions, if made, would in fact fill a complete book by themselves. It is obviously necessary however to have some understanding of the general types of things the 68000 can do before we start looking at actual programs so here is a very brief overview of the type of operations supported.

Data Movement

The 68000 has a large number of instructions which allow the transfer of data to and from memory and/or the 68000 microprocessor's internal registers. For example, the instruction:

```
move.b d0, d1
```

transfers the lower eight bits of data from register d0 to register d1. This is an example of register addressing.

On the other hand:

```
move.l #0, d1
```

places a zero value in register d1. The hash # sign indicates an operand source addressing mode known as *immediate* addressing. In terms of the final 68000 instruction this means that the operand (in this case a 32-bit zero value) is stored immediately after the move.l instruction code.

Data can also be moved to memory locations so to move the full 32-bit contents of register d0 to a memory location which has been given the symbolic name _DOSBase you would use this instruction:

```
move.l d0, _DOSBase
```

Arithmetic and Logic Instructions

The 68000 supports a standard set of logic and arithmetic operations which allow it to perform addition, subtraction, multiplication and addition. In addition to this it also supports all of the common logic operations (AND, OR, XOR etc.) As an example, the instruction:

```
add.l d0, d1
```

adds the full (32-bit) contents of data register d0 to the contents of register d1.

Flow Control Facilities

Without flow control instructions a processor would only be able to execute program instructions sequentially. The ability to execute different parts of a program under different input/data conditions is fundamental to the nature of computing so the 68000, like all other processors, provides a number of useful mechanisms.

The 68000 provides both conditional and unconditional branch/jump type instructions for transferring control from one part of a program to another. One such instruction is called beq (Branch on EQual to zero) and this is a flow control branch which is only taken *if* the 68000's zero flag is set. To use this instruction to conditionally branch to a symbolic address called EXIT one would write:

```
beq EXIT
```

Unconditional branch/jump instructions are also available and I'm always reminded when I discuss this particular area about BASIC's Goto instruction. This got the blame for helping programmers to produce tangled web, spaghetti type, programs which no one could understand, debug or alter. Goto is now defunct within the world of high-level languages, discredited and largely unused. Any competent programmer however will tell you that gotos *can* be used properly and can result in tidy well structured programs. The

difficulty is of course that it is only too easy to use the goto statement in an undisciplined way, and it's that which leads to program structure problems.

Why have I mentioned the goto at this time? It's because it has a strong connection with the branch and jump instructions of the 68000 processor. Programming at low-level then has all the disadvantages, yet none of the advantages, of the primitive high-level language facilities which have long since been superseded by forms which encourage the programmer to produce, or at least facilitate the production of, tidier programs. When you program using 68000 assembly language, or any other assembly language come to that, you'll find no such encouragement. To a large extent any structure and tidiness in the code will have to come from you the programmer.

Subroutine orientated branch and jump instructions are also available on the 68000 and these automatically store a *return* address on the stack. After a subroutine call has been executed this return address is used to transfer control back to the main part of the program.

Other Instructions

Instructions are provided which allow the 68000 to test, set, and clear individual bits and to rotate and shift operands. There are powerful address calculation instructions, automated loop instructions, and even instructions which allow data areas to be allocated within stack space as subroutine calls are made. A variety of instructions are also available for comparing particular operand values, which set the appropriate status register flags.

Assemblers

This section discusses the functions performed by assemblers, starting with features that are common to all assemblers and then considering some of the capabilities of more sophisticated packages.

An assembly language program consists of a number of statements. Some statements will correspond directly to 68000 instructions, others will be assembler-orientated directives known as pseudo-operations or pseudo-ops. Program lines may contain as many as four fields – a label, a mnemonic (which represents an instruction op-code), an operand or address field (which, if present, will be the data that the instruction acts on), and a comment. Here are some typical assembly code lines to illustrate the format. Don't worry about what the instructions are doing, it's the general layout of the program lines that is important, not the details:

```
*
; an example assembly language code fragment
*
OpenLib     move.l     library_name,a1          get library name
            move.l     _IntuitionBase, d0       get library base value
            rts
  ^          ^             ^           ^            ^
Labels     Mnemonics          Operands          Comments field
```

Comments

Comments are optional and do not need to be present. They are added for the same reasons that REM statements are added to BASIC programs, to provide in-line documentation, lines to separate routines etc. Assemblers vary in how they delimit comments but usually lines which begin with an asterisk will be treated as a whole line comment, any characters after a semicolon will similarly be ignored, and any text after the operands field will, providing it is separated by one or more spaces, usually also be treated as a comment.

Labels

Labels similarly do not have to be used but, if they are used, they normally have to be placed at the start of the line (some assemblers are quite fussy about field placement). Many 68000 assemblers adopt a convention which allows white space to signify the end of the label (as in the above example) but also allow the label to start at a position other than the first character of the line providing it is terminated with a colon (:).

Each byte of each instruction or data item in an assembler program has, by virtue of its position in the program, an address by which it can be identified. Internally the assembler keeps track of this numerical position information by using a *location counter*. Referring to places within a program using such numbers is awkward because it means the programmer has to remember the lengths of each instruction, so labels can make life a lot easier. It does of course also lead to far more readable code. In the above fragment the programmer can use *OpenLib* rather than having to work with some relatively meaningless numeric value.

Labels can also appear in the operand fields and this, as the EXIT label in the following fragment illustrates, is commonly used to specify a location to jump or branch to:

```
OpenLib     move.l    library_name,a1       get library name
            move.l    -IntuitionBase,d0     get library base value
            beq       EXIT                  test result for success
            CALLSYS   CloseLibrary,_AbsExecBase
 EXIT       rts                             logical end of program
```

Programmers use labels to identify space set aside for variables and static program data, the starts of both the program and particular routines, entry and exits points, jump/branch positions etc. Given the purpose of labels in an assembly language program it should be obvious that it is best to use labels that are meaningful, as OpenLib, EXIT, and library_name in the above example should show. Labels like X12ZB or ICYR2Y4ME are, of course, less than useful.

Label Conventions

The conventions which assemblers expect do vary, sometimes considerably. Many assemblers for instance will place restrictions on the lengths of labels and on the characters which may be used within them. The leading character must often be a letter and usually only a few non-alphanumeric characters are allowed. Many assemblers will allow long labels, others may not, and some may allow their use but truncate them without warning. Modern day assemblers now provide local label support and Devpac for instance adopts a convention whereby a label beginning with a period (or optionally an underline) will be attached to the last non-local label:

```
OpenLib     move.l    library_name,a1       get library name
            move.l    IntuitionBase, d0     get library base value
            beq       .EXIT                 test result for success
            CALLSYS   CloseLibrary,_AbsExecBase
.EXIT       rts                              logical end of program
```

Devpac, to provide compatibility with other 68000 assemblers, also allows strings of digits terminated with a $ sign to identify local labels. Irrespective of the conventions the benefits are the same – it is possible to re-use commonly required labels without the risk of name clashes.

With older assemblers if, for instance, you had three routines similar to the above fragment within the same program it was necessary to use say EXIT1, EXIT2, EXIT3 or some other name convention to avoid causing *duplicate label* errors. Obviously an assembler, since it has to equate each label to a specific address, cannot allow the same label to be defined twice within a program.

Assembler Directives

These are the *pseudo-ops* mentioned earlier and are used to define symbols, designate areas of memory for data storage, place fixed values in memory and so on. Directives also exist for more mundane operations such as controlling the listing and error reporting facilities of the assembler. Once again, conventions are going to vary from assembler to assembler but the detailed specifics will of course be fully documented in your assembler manuals.

Having said that, a few pseudo-ops do need to be dealt with because they will be used extensively within the book.

The EQU Equate Directive

This allows the programmer to define a label with a specific numerical value. For instance:

```
NULL    EQU     0
TRUE    EQU     1
FALSE   EQU     0
SPACE   EQU     32
```

Most assemblers will allow you to define one label in terms of another or in terms of a numeric expression:

```
OFFSET EQU      10
STRUCT EQU      4+OFFSET
```

None of these EQU type definitions cause the assembler to create any code. All that happens is that the definition supplied gets noted internally and from that point on the programmer is free to use the label wherever they would otherwise have needed to use the appropriate numerical value. Other advantages, in terms of program maintenance, also exist, because if you alter a label at the front of a program that new definition is then automatically updated wherever the label has been used. C programmers use the #define C preprocessor facility in much the same way.

Storage Allocation Directives

All assemblers recognise a set of directives which allow you to reserve specified amounts of memory and initialise locations, or sets of locations, to particular values. It is usually possible to specify bytes, words or long word allocations by appending .b, .w, or .l to a directive. A ds (define storage) directive will, when written as ds.l, allocate space for a number of four-byte (long word) values. So to reserve four bytes of uninitialised space for a variable called _IntuitionBase we could use:

```
_IntuitionBase    ds.l    1
```

Directives will also be available for placing constant values in memory. The following statement uses dc.b, the byte form of a *define constants* directive, to store the numerical equivalents of the characters *intuition.library* plus a terminal NULL (zero) character in a set of memory locations whose start address has been labelled as intuition_name:

```
intuition_namedc.b 'intuition.library',NULL
```

Note: *all* microprocessor data is represented by numbers and so to develop text-orientated programs it has been necessary to devise codes whereby each character is represented by a number. Several schemes have been developed but the one used more than any other is called the American Standard Code for Information Interchange (ASCII). You'll find the details in Appendix C.

Operands and Addresses

Most assemblers assume that all numbers are decimal numbers unless otherwise stated but can accept binary, octal, and hexadecimal numbers if suitably identified. The $ sign, for instance, is frequently used to specify hexadecimal numbers. Modern assemblers offer great flexibility in terms of the complexity of the numeric expressions they accept and many provide multiplication, division, addition, subtraction, logical operations, use of parenthesis etc. Assemblers which support the generation of floating point coprocessor code will also provide provisions for the use of floating point constants.

ASCII character constants, as illustrated in the previous section's dc.b directive example, are also allowed with quotes or double quotes being used to delimit the start and the end of the set of characters.

Macro Assembly

You frequently find that particular sequences of instructions crop up again and again. Macro assemblers, such as Devpac, allow you to assign names to such instruction sequences and when the name is encountered the assembler automatically expands it to produce the original set of instructions. Nowadays this facility is not restricted to predefined, absolutely fixed, instruction sequences – macros can be used which contain parameter placeholder markers. When the macro is used the parameters provided for that particular instance are inserted into the code that is generated. Macros allow assembly language programming to be done at a significantly higher level than was previously possible and they are in fact an essential part of Amiga assembly language programming owing to the fact that a great many pre-defined macros have been made available to the programmer in the system header files. You'll find many examples of macros being used in later chapters.

Conditional Assembly

Most assemblers provide directives which allow specified parts of a program to be assembled, or not assembled, depending on specified conditions. For instance the single standard start-up code source file provided by Commodore includes changeable constant declarations which allow the automatic generation of a number of different start-up module versions. Programmers often include debugging code in their programs but conditionally remove the relevant sections of code in the released versions of their programs.

A Commercial Package

Assembler programs, as we've already seen, are not used in isolation. An editor is needed to create the program, and a linker plus any number of other program support tools will also be needed. On the Amiga it's also necessary to have the system header files available. So, whilst all assembler packages will have some common ground, there are likely to be significant differences in terms of the overall environment offered to the programmer. This applies both in terms of the conventions used and in the overall environment integration (which affects the ease of use). To illustrate the features that a modern Amiga assembler environment will offer I've chosen to look at what I consider to be the best assembly language programming environment available on the Amiga at the current time, HiSoft's Devpac 3.

Devpac

HiSoft's 68000 Devpac Amiga assembler package has been around for quite a few years and during that time a large user-base has formed. Most Devpac users will tell you that the package is popular for two main reasons. Firstly, it is a robust program which does the job that it is supposed to do. Secondly, it has proved to be a stable, well supported, product. If you are a serious user, and most Amiga assembly language programmers are, then those qualities are obviously important.

The latest version of Devpac, called Devpac 3, has a number of advantages over earlier versions. The editor has been greatly enhanced and it now offers multiple file editing with full mouse-controlled cut & paste facilities, enhanced menu selection and a new *Workbench 2 style look*, even when running under Workbench 1.3. Especially useful editor features include the ability to open individually scrollable multiple windows on the same file, bookmark set and locate facilities, a macro recording facility for memorising complex keypress sequences, and powerful assembler/debugger integration options.

The assembler supports the 68000-68040, 68332, 68881/2 and the 68851 memory management unit (MMU) chips. It can produce S-records (an output form used by EPROM programmers), can generate and process pre-assembled include files and can create more source-code tracking debugging info. The Devpac debugger has a flexible, user-configurable, multi-window arrangement and can handle multiple files.

Since the Devpac environment has proven to be so popular (there are around ten thousand Devpac users) I will try and explain the purpose, and the benefits, of some of the Devpac facilities. The main HiSoft tools are the editor, assembler, and the debugger.

The Devpac Editor

The Devpac editor, and its menu system, has been well planned and makes extensive use of Workbench 2 style requesters and gadgets. You'll find action gadgets and buttons, check-box gadgets, radio buttons and gadgets that cycle through various options as they are selected. File operations now use the ARP (or the ASL in the case of the Workbench 2) requester so all file operations have become a lot easier. One of the big changes with the latest editor is that it now lets you work with multiple files and even allows you to open more than one window in the same file. This is handy for doing multiple copy and paste operations between different areas because you do not have to keep moving back and forth between the source and destination sections.

An Edit menu provides clipboard cut/copy/paste facilities and with Devpac 3 these can now be done by proper mouse-controlled marking, ie by holding the left mouse button down and wiping the mouse over the area of text or program-code you wish to mark for copying. Being able to view, and copy sections between, different windows of different projects is a major plus for the new editor. The editor also includes a Search menu which offers easy to use requester-based *find* and *find & replace* facilities, and a bookmark scheme which allows you to use up to ten place-markers within a project. A macro facility which lets the editor learn useful sequences of keystrokes has also been provided. These editor macros are nothing to do with the 68000 orientated code macros discussed earlier in this chapter.

A Settings menu allows you to set the editor and assembler controls and define the usual types of global settings for tab size, end-of-line behaviour, auto indenting, automatic back-up creation and so on. Window arrangement is controllable by a menu which allows the view arrangements of the various project windows to be altered

(stacked, diagonally offset etc.) Most editor settings can be saved to disk and when the editor has been asked to create project icons, things like bookmark settings can also be stored with the project.

The assembler options themselves are grouped into three separate requesters which are called up by selecting one of three items on the assembler settings sub-menu. A control requester provides control over basic assembler operation, source and destination file paths, listing control etc. The Options requester gives access to the large number of more technical assembler settings (identifying processor, coprocessor and MMU types, ensuring PC-relative code, producing local label underscoring and so on). The third requester provides a range of assembler optimisation settings.

As with earlier Devpac editors the Devpac 3 version provides automatic location of errors in the source after assembly via find error, previous error and next error menu options. Create the source code using the editor and select *assemble* from the program menu. Edit/assemble until the assembly process is error free and you'll then be able to run the code directly from the editor's program menu. In short it is possible to create, assemble, debug, run and save your code without ever leaving the Devpac environment!

Devpac 3, as you may have gathered, has more options than space permits me to talk about – you are, for instance, also able to make the assembler and/or debugger resident, control font usage, set the editor's printing parameters and make projects read only, so that you don't inadvertently alter a file that you've opened to use just as a clipboard source document. Many options have Amiga-key menu shortcuts or Shift, Ctrl or Alt keyboard sequences so experienced users can bypass the sometimes time-consuming menu operations if they so choose.

The Devpac Assembler

Devpac's assembler is called GenAm and it is a fast full-spec offering which supports parameter driven macros and which can be used both from the editor menu or as a stand-alone program. GenAm has all the *bells and whistles* expected of a modern day assembler – it provides comprehensive expression handling and supports *, /, +, -, =, bitwise and/or/xor/not, left and right shifting and the usual inequality operators. Like many assemblers it allows decimal, hex, octal, binary and character constants but also offers floating point constants for 68881/2 coprocessor applications. Devpac allows the use of local labels and, by default, all label names are significant to 127 characters.

As far as assembler control is concerned GenAm has all the usual options. If for instance you want to suppress warnings, ignoring multiple-file includes, eliminate symbol-table and macro listing and create a runable (executable) end file, then GenAm will let you do it. At one time I would have said that support for the floating point co-processors etc, was not going to be that useful to the average user, but times are changing and with some of the excellent new accelerator boards which are being offered to Amiga users this new Devpac is ideal for ray-tracers and anyone else who wants to try their hand at programming their 68881/2 chips directly.

One very handy feature of the new Devpac offering is that it supports the use of imported symbol tables, ie include files that have previously been read into the assembler and pre-assembled to create a file containing all the relevant definitions. In fact when searching for an include file GenAm looks first for a file of the same name but with a .gs extension. If such a file is found GenAm will assume that it is a pre-assembled equivalent and will use it in preference to the file originally specified. The benefit of using such pre-treated files is faster assembly times and Devpac's symbol table generation option can be used to good effect with the Amiga system headers themselves.

The assembler can generate both executable code and linkable code, plus the Motorola standard S-records format mentioned earlier. It also includes a number of options for providing debug data in its output files. SYMBOL hunks (as defined by the AmigaDOS binary file format), LINE debug hunks (recognisable by Lattice/SAS's CodeProbe), and compressed HCLN chunks are all supported.

The purpose of including such data is that it enables the debugger to make the original source-code labels visible reference points in the disassembled code. Because the final code size is increased one normally only includes debugging info during the program development stages. By reassembling with the debug options turned off the excess data can be eliminated in the final version of the program.

GenAm has far more facilities than we can possibly mention but it is worth pointing out that some are especially useful to the Amiga programmer. Multiple hunks (including chip and fast) are fully supported and there's an INCBIN directive for including binary files, which is useful for reading in sprite data and general screen graphics.

The Devpac Debugger

Programs written in assembly language are particularly error prone and even slight coding errors can spell disaster. This being so, all commercial assembler packages provide some type of debugging facilities. With Devpac the debugger is called MonAm.

MonAm is a low-level debugger able to step through a program displaying code instructions, 68000 register contents, processor status, and memory contents in hex or ASCII form as it does so. If you have included debug info in your program the MonAm can use that to display your original program labels. The debugger can also be used to look at compiler written code and, if the package that produced the code included line number debug data, it is even possible to view the original source code! MonAm is very powerful and one major feature is this ability to use symbols taken from the original program.

Four window types are defined to provide views of processor details (register contents, flag values etc), 68000 mnemonic disassembly, memory contents hex or ASCII, and source code. The disassembler (a program which reads an executable program and tries to generate the original assembly language instructions) recognises all 68000 family processor instructions, including the 68040, maths coprocessor and MMU instructions. MonAm windows can now be locked to allow interactive monitoring of complex data structures and any number of source files may be loaded into each window along with any associated line number debugging info. Multi-module programs can therefore be single-stepped line by line from your original source files.

Two powerful operators are provided which convert a program address into a source-code line number and locate any part of the program from its position in the source. Like the Devpac assembler, the MonAm debugger program can also run as a stand alone program but most users access it directly from the menus of the Devpac editor program.

Other Components

As well as the editor, assembler and debugger the Devpac 3 package includes Blink, the Amiga's defacto standard linker, a program called SRSpilt which is an S-record splitter utility and a utility called FD2LVO which converts Commodore FD files into include files containing direct library vector offset data (LVO values). You also get the all important Commodore assembly language include files, the standard run-time and link libraries (plus extra maths and IFF parse libraries) and some example programs to get you started.

Make it Easy!

This book is in no way restricted to Devpac users but it must be said that if you have yet to get an assembler package Devpac 3 is worthy of serious consideration. It provides some superb facilities and newcomers will get an assembler environment which will help make learning about, and using, assembly language just about as easy as it ever could be!

In the last two chapters I've covered some general concepts, introduced the 68000 to you and looked at issues related to the writing of assembly language programs. Now it's time to put some of these pieces together and start looking at the writing of some simple, but nevertheless, real assembly language programs.

3: Solving Simple Problems

One of the easiest ways to come to terms with 68000 assembly language programming is to look at some programs and so this is exactly what we shall be doing in this chapter. Before making a start however a few words of warning are in order, just in case you are expecting to dive straight into the world of Amiga graphics and multitasking.

The plain truth of the matter is that to explain the purposes of a large number of the 68000 instructions we need to start with very simple examples which steer well clear of Amiga operating system issues. Unfortunately such simple programs will, by definition, tend not to do much – in fact the programs that we'll deal with in this chapter will not even have any visible output when they are run.

From a newcomer's viewpoint this is unfortunate. On the face of it the prospect of spending time examining programs that add two numbers together, or copy a few bytes from one set of memory locations to another is hardly likely to instill a burning desire to learn about the 68000.

Nevertheless this chapter is very necessary because it illustrates the use of a number of *very* important 68000 instructions. Be patient – these examples have been

deliberately chosen so as to illustrate the operations that you'll be expected to know about once we get into proper Amiga 68000 programming. There are a few points to bear in mind:

- Whilst reading this chapter you may find it useful to occasionally refer to Chapter 17 which lists a selection of commonly used instructions, details of the 68000 processor's addressing modes, and various other details.
- All the examples discussed in this chapter are CLI/Shell based programs and should not be run from the Workbench.
- Users who have access to an Amiga 68000 monitor/debugger program (such as Devpac's MonAm) will find it useful to enter and run many of the examples in single-step mode. Even though the program may have no visible output it will still be possible to see how the various instructions affect the state of the processor's registers and flags.

Data Transfer

Data movement on the 68000 can be achieved with move instructions. A number of variants exist but the basic format is:

```
move.<size> source, destination
```

If the object size is not specified then a word size (16 bit) is assumed.

To move the contents of a location which has been given the symbolic name X to the lowest 8 bits of register d0 we would write:

```
move.b X, d0        copy byte X to lowest 8 bits of d0
```

Similarly, to move the lowest 8 bits of register d0 to a location which has been labelled Y we could write:

```
move.b d0, Y        copy lowest 8 bits of d0 to Y
```

One way of initialising the above X and Y variables would be to use the byte form of the *define constant* and *define storage* pseudo-ops (dc.b and ds.b), like this:

```
X dc.b 10     allocate one byte and initialise it to 10

Y ds.b 1      allocate one byte but do NOT initialise it
```

If we put these fragments together we can build a program which will copy the pre-initialised 1 byte value held in location X to location Y:

```
* Example CH3-1.s
START   move.b X, d0       copy byte X to lowest 8 bits of d0
        move.b d0, Y       copy lowest 8 bits of d0 to Y
        rts
X       dc.b 10      allocate one byte and initialise it to 10
Y       ds.b 1       allocate one byte but do NOT initialise it
```

The program starts with X holding the value 10 and Y being undefined. After it has been run, byte X will still contain the value 10 but byte Y will also contain 10.

Any of the data registers d0-d7 could have been used for this program and d0 was an arbitrary choice.

Nowadays most assemblers initialise ds.x statements to zeros but from the point of view of consistent documentation it is best to assume that such initialisation is not done. If you really want to initialise byte Y to zero, choose the dc.b 0 pseudo-op.

The rts (return from subroutine) instruction at the end of the code is used to return control back to the Amiga's operating system. Don't worry about understanding what it does – such issues will be discussed in detail in the next chapter. Strictly speaking even these simple programs should terminate with register d0 set to zero, achieved by using a move.l #0, d0 (or a clr.l 0,d0) instruction just before the rts, but for simplicity this Amiga-orientated operation has not been included in these, otherwise general, discussions.There is in fact a much easier way to achieve the above copy operation because the 68000 allows you to transfer data directly from one memory location to another, like this:

```
    move.b X, Y          copy byte X to byte Y
```

This means that it's possible to eliminate the use of d0 as a temporary storage register in the above program and write this simpler version:

```
* Example CH3-2.s
START   move.b X, Ycopy byte X to byte Y
        rts
X       dc.b 10      allocate one byte and initialise it to 10
Y       ds.b 1       allocate one byte but do NOT initialise it
```

When move is used to copy a piece of data the instruction, providing the destination is not an address register, generally affects the flags in the user-byte 68000 status register. These flags are variously called the user-byte flags, condition codes, or just the status byte flags (this book will use the latter term). With move

instructions the Zero (Z) and Negative (N) flags will be set to an appropriate state whilst the Overflow (V) and Carry (C) flags will be cleared.

Now that you've seen how to move 8 bit values you'll be pleased to know that you can move word (16 bit) and long word (32 bit) values just as easily. The following version performs a word (two byte) copy:

```
* Example CH3-3.s
START   move.w X, Ycopy word X to word Y
        rts
X       dc.w 10     allocate two bytes and initialise to 10
Y       ds.w 1      allocate two bytes but do NOT initialise
```

Since instructions assume a word size by default it is not necessary to include the .w size indicator on the move instruction. Example CH3-3.s could therefore just as easily have been written as follows:

```
* Example CH3-4.s
START   move X, Y       copy word X to word Y
        rts
X       dc.w 10         allocate word and initialise to 10
Y       ds.w 1          allocate word but do NOT initialise
```

Since two bytes are needed to store a word value, and since each byte has an individual address, you might be wondering what address the assembler assigns to the word variables. On the 68000 Amiga system words are stored in memory as shown in Figure 3.1.

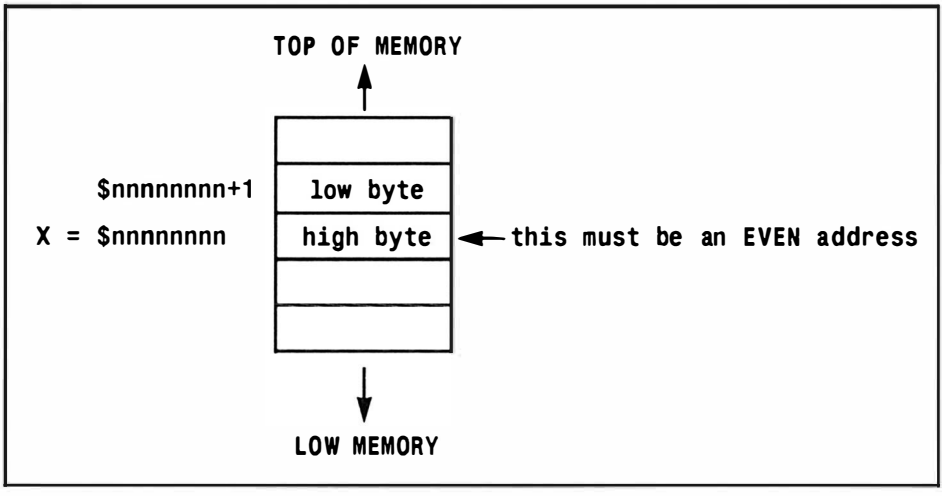


Figure 3.1. 68000 storage of words in memory.

Without looking at the following solution, try to change program Example CH3-4.s to produce a long word version. Here's the result you should have obtained:

```
* Example CH3-5.s
START move.l X, Y   copy long word X to long word Y
      rts
X     dc.l 10       allocate one long word and initialise to 10
Y     ds.l 1        allocate one long word but do NOT initialise
```

Four bytes are needed to store a long word value and on the 68000 these items are again stored in a particular order. Just as a word can be expressed in terms of an upper and lower byte so we can consider a long word as containing an upper and lower word like this:

```
          32 bits          16 bits      16 bits
<long word value> = <upper word> <lower word>
```

The 68000 stores the word components of long words in the same way as it stores the byte components of ordinary (16 bit) words, ie it stores the bytes of the most significant word first, so the net result is that long words are stored in memory (Figure 3.2).

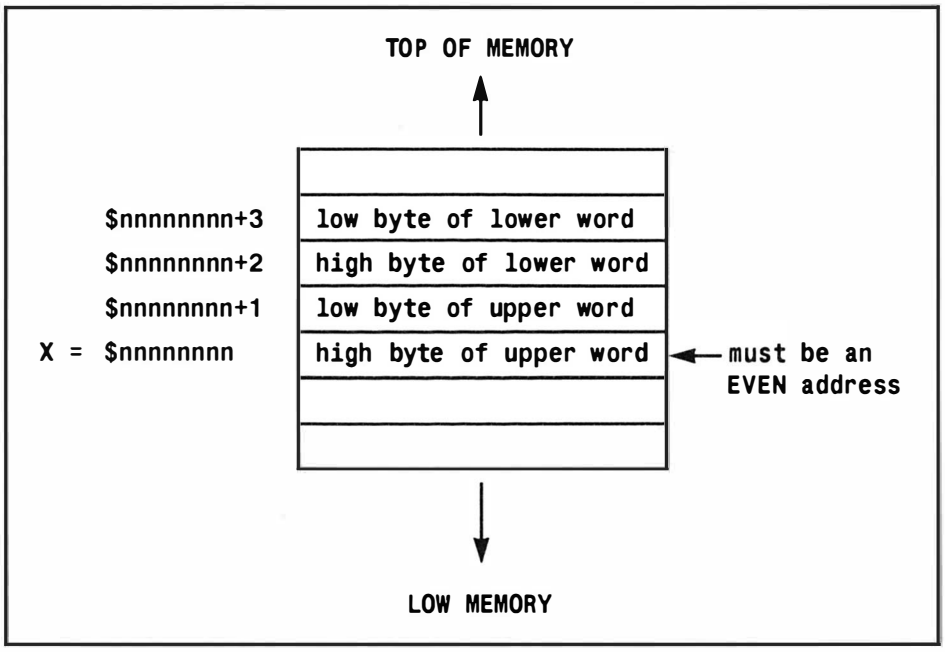


Figure 3.2. 68000 storage of long words in memory.

In transferring data from one set of locations to another, Example CH3-5.s was using absolute addressing. Remember that the X and Y labels used in the move.l X, Y instruction represent numerical addresses.

Another way of writing the programs that we've just been looking at would be to reserve uninitialised memory space for both the X and Y variables and then explicitly initialise the X variable when the program is run. The following example uses an additional immediate addressing move instruction to load variable X with the value decimal 10. By convention immediate addressing on the 68000 is signified by placing a hash (#) sign in front of the operand:

```
* Example CH3-6.s
START  move.l #10, X  initialize long word X to 10
       move.l X, Y    copy long word X to long word Y
       rts
X      ds.l 1    allocate one long word but do NOT initialise
Y      ds.l 1    allocate one long word but do NOT initialise
```

Data Transfer Using Address Registers

You will see from the instruction code summaries provided in Chapter 17 that the move instruction is unable to transfer data *to* an address register. In actual fact a specialised form of the move instruction, called movea (move address) is available for this purpose and a number of differences which exist between move and movea need to be discussed.

Firstly, like most direct address register instructions, movea can only operate on word or long word values. Secondly, movea does *not* affect any of the processor's flags. This, for address-orientated operations is actually a convenience not a limitation. Lastly, movea sign-extends any word values it is working with. This means that the uppermost bit (bit 15 of the word) will be propagated throughout the upper 16 bits of the address register. Sign extension was introduced on the 680x0 series to allow a form of absolute addressing based on word addressing to be used (as opposed to a full long word address) and you can find additional details in Chapter 17.

Although it is not a good idea to use address registers for such purposes we could write a word (16 bit) version of our original Example CH3-1.s data copying program like this:

```
* Example CH3-7.s
START movea.w X, a0    copy X to lowest 16 bits of a0
      move.w a0, Y     copy lowest 16 bits of a0 to Y
      rts
X     dc.w 10  allocate one word and initialise it to 10
Y     ds.w 1   allocate one word but do NOT initialise it
```

As it happens most 68000 assemblers *do* allow you to use the move mnemonic when specifying an address register so program Example CH3-7.s actually could have been written as:

```
* Example CH3-8.s
START move.w X, a0     copy X to lowest 16 bits of a0
      move.w a0, Y     copy lowest 16 bits of a0 to Y
      rts
X     dc.w 10  allocate one word and initialise it to 10
Y     ds.w 1   allocate one word but do NOT initialise it
```

The difference however is that in the case of this last example the assembler will automatically insert a movea instruction for loading register a0 and this means that unlike data register loading operations the address register loading operation will *not* affect the processor's status flags. More subtle differences can also occur as this example clearly shows:

```
* Example CH3-9.s
START move.w X, a0       copy X to lowest 16 bits of a0
      move.w a0, Y       copy lowest 16 bits of a0 to Y
      rts
X     dc.w $FFFF  allocate one word and initialise to FFFF hex
Y     ds.w 1      allocate one word but do NOT initialise it
```

Here we are using a word data value which includes a 1 in the uppermost position (FFFF hex = 1111 1111 1111 1111). Because the first instruction is really a movea, and because the sign bit (bit 15) of the word $FFFF is set high then the value that movea transfers to register a0 is FFFFFFFF hex, and not FFFF hex. Since the program only copies the lower 16 bits of the register back to location Y this doesn't affect the result in this case *but* the instruction has of course affected the upper 16 bits of the a0 register in a way that the related data register version of the program would not do.

Most 68000 coders soon get used to the flag and sign extension implications of address register usage, use the move mnemonic for both data and address orientated instructions, and let their assemblers decide on the correct object code instruction.

Complementing a Value

Complementing a number means turning all the 1s present in the number to 0 and turning all the 0s present to 1. If, for example, register d0 contained the value:

```
d0 = 0000 0000 0000 0000 0000 0000 0000 0000 binary
ie    0    0    0    0    0    0    0    0  hex
```

then the complemented value would be:

```
d0 = 1111 1111 1111 1111 1111 1111 1111 1111 binary
ie    F    F    F    F    F    F    F    F  hex
```

You should work out for yourself that if d0 = 1F01 hex then after a long word (32 bit) complement operation d0 will contain E0FE hex (write out each hex digit in the binary form as above, invert all the bits, and then translate the answer back to hexadecimal form).

The 68000 instruction which performs this operation is called NOT and like many other instructions it exists in byte, word and long word forms. Here's a short program which uses immediate addressing to load d0 with the byte value 0F hex, inverts it, and then stores the result in a location whose symbolic name (ie its label) is RESULT:

```
* Example CH3-10.s
START   move.b #$F, d0     initialise low 8 bits of d0 to F
                           hex
        not.b d0             invert lower 8 bits
        move.b d0, RESULT    copy inverted d0 to RESULT
        rts
RESULT  ds.b 1          allocate one byte but do NOT initialise
```

As was the case with the earlier examples, the 68000 allows us to eliminate the use of a temporary storage register by using the not.b instruction directly on a memory location:

```
* Example CH3-11.s
START   move.b #$F, RESULT  store value directly in RESULT
        not.b RESULT        invert value
        rts
RESULT  ds.b 1          allocate one byte but do NOT initialise
```

In the above example the not.b instruction is using absolute addressing (with example CH3-10.s the register addressing form was used).

Addition

The 68000's basic addition instruction uses this syntax:

```
add<.size> source, destination
```

where the result of the *source + destination* addition gets placed in the destination register (in common with a great many 68000 instructions that work with two operands).

So far the instructions we have looked at have allowed source and destination operands to be either in registers or memory. Not all 68000 instructions are that flexible and in fact the *add* instruction only allows one of its operands to be in memory. You may add the contents of a register to a memory location, or do the reverse (add the contents of a memory location to a register). What you cannot do however is add the contents of one memory location directly to the contents of another.

The limitation means that for this instruction we need to use a temporary register much as we did with our early data copying examples. Here is an example which loads register d0 with a number contained in NUMBER1 and then adds that number to the contents of the memory locations represented by the label NUMBER2:

```
* Example CH3-12.s
START    move.l NUMBER1, d0    load 1st number into register d0
         add.l d0, NUMBER2     add contents of d0 to value in
                               NUMBER2
         rts
NUMBER1  dc.l 3                set initial value to 3
NUMBER2  dc.l 4                set initial value to 4
```

After program Example CH3-12.s has been run, the variable NUMBER2 contains the value 7.

Up until now I've mentioned byte, word and long word forms of variables but have not said anything about when the various forms should be used. As far as data items are concerned the unwritten rule for the assembler programmer is the same as for the programmer working in any other language, namely *conserve as much memory as possible*, ie don't waste it by allocating unnecessary space.

Have a look at the internal contents of the two four byte numbers used in the previous example:

	byte 3	byte 2	byte 1	byte 0	
NUMBER1	00000000	00000000	00000000	00000011	decimal 3
NUMBER2 before	00000000	00000000	00000000	00000100	decimal 4
NUMBER2 after	00000000	00000000	00000000	00000111	decimal 7

Both numbers *and* the final result fit comfortably into an eight bit byte so in all honesty we did not need to use long word size variables, bytes would have done. Here then is an improved version:

```
* Example CH3-13.s
START   move.b NUMBER1, d0  load 1st number into register d0
        add.b d0, NUMBER2   add contents of d0 to value in NUMBER2
        rts
NUMBER1 dc.b 3              set initial value to 3
NUMBER2 dc.b 4              set initial value to 4
```

Only two bytes of variable storage space are needed instead of eight in the previous example, and the byte-orientated forms of the instructions execute more quickly as well. Programmers would therefore say that this new version of the program was *more memory efficient*, or just *more efficient* than the previous one.

Putting Some Pieces Together

Now let's try something a little more complicated. We'll set up some space for a long word variable called NUMBER1, initialise it using immediate addressing to some arbitrary value (I've used 1FFFFF hex), increment it by 1, complement the result, and then store it in a variable called RESULT. Here's one program that does the job:

```
* Example CH3-14.s
START   move.l  #$1FFFFF, NUMBER1  initialise number
        move.l  #1, d0             load d0 with value 1
        add.l   NUMBER1, d0        increment d0 copy of NUMBER1
        not.l   d0                 complement result
        move.l  d0, RESULT
        rts
NUMBER1 ds.l    1                  space for number
RESULT  ds.l    1                  space for result
```

Depending on what was actually required there are many ways that a program similar to the above could have been written. It might, for instance, have been appropriate to place the original value directly in the locations assigned for the result, and do the addition and complement operations on the result locations like this:

```
* Example CH3-15.s
START   move.l   #$1FFFFF, RESULT    initialise number
        addi.l   #1, RESULT          increment value
        not.l    RESULT              complement result
        rts
RESULT  ds.l     1                   space for result
```

In the above example a special form of the add instruction, addi, is being used. This allows an immediately addressed source operand (in this case 1) to be added directly to the destination operand. If you take a sneak preview of the add addressing mode details in Chapter 17 you'll find that the normal add instruction couldn't have been used in Example CH3-15.s anyway because to use immediate addressing the destination would need to be a data register. However, as is the case with a number of instructions, most 68000 assemblers do let you write statements such as:

```
    add.l   #1, RESULT     increment value
```

and then automatically translate the instruction to:

```
    addi.l  #1, RESULT     increment value
```

so program Example CH3-15.s could, after all, be written as follows:

```
* Example CH3-16.s
START   move.l   #$1FFFFF, RESULT    initialise number
        add.l    #1, RESULT          increment value
        not.l    RESULT              complement result
        rts
RESULT  ds.l     1                   space for result
```

Quick Instructions

For immediate operands within limited ranges the 68000 offers a number of *quick* instructions. Instead of using real immediate addressing, where the operand is placed immediately after the op-code in memory, these instructions have a data value buried into the instruction op-code itself. The moveq instruction for instance

uses a data register as the destination and allows 16 bit operands to be specified (it does however sign extend the data to long word size).

To load register d2 with the value 3 for instance we could write:

```
moveq #3, d2  load d2 with value 3
```

Add and subtract quick instructions also exist and these allow immediate data in the range 1-8 to be specified.

To increment by 4 the contents of a memory location whose address has the symbolic name RESULT we might, using absolute addressing, write:

```
addq #4, RESULT
```

If we choose to load the address of RESULT into register a1 we could instead use the 68000's indirect addressing scheme to specify the destination address:

```
move.l #RESULT,a1     load a1 with address of RESULT
addq #4,(a1)          add 4 to the contents of the byte
                      'pointed to' by register a1
```

where the destination operand's (An) notation is the 68000 assembly language form for specifying an indirect address.

Another method of loading register a1 with the address of the RESULT variable is to use the more specialised Load Effective Address, lea, instruction and if this is done with the above fragment the code ends up looking like this:

```
lea RESULT, a1        load a1 with address of RESULT
addq #4, (a1)         add 4 to the contents of the byte
                      'pointed to' by register a1
```

The earlier loading of the address of the RESULT operand into a1 using an immediate addressing move instruction served us well enough but in general the lea instruction is a far more flexible alternative. Much more use will be made of the lea instruction later in the book.

Going Loopy

Program loops enable a programmer to create a *repetitive subset* of instructions, ie a set of instructions that can be repeated a specified number of times. Most loops have up to four identifiable sections:

- An initialisation section which sets up, ie initialises, any variables.

- A processing section, usually called the *main body* of the loop, which does the real work.
- A control section which decides whether or not further iterations (passes through the loop) are required.
- A terminal section which carries out any post-loop processing that may be needed.

There are in fact two types of repetitive loops in common use. With post-test repetition, the control test comes *after* the main body of the loop. With pre-test repetition the control test comes *before* the main processing section.

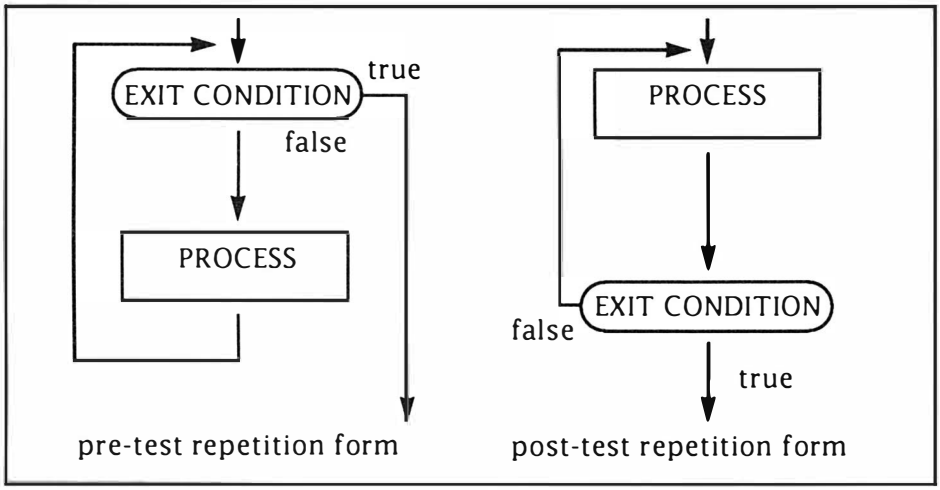


Figure 3.3. Flowcharts of pre-test and post-test loop arrangements.

The difference between these two forms, namely the location of the control test, has an important practical implication. The main body of a post-test style loop will *always* be executed at least once but if the conditional test used with a pre-test loop is satisfied immediately then the body fragment will *never* be executed. By way of comparison, BASIC's WHILE/WEND loops are pre-test forms, but BASIC's DO/WHILE loops are post-test. Despite the fact that many debates have occurred concerning the merits of the two schemes, in practice both have their uses.

Post-test repetition, as far as the assembly language programmer is concerned, does tend to produce shorter code. The following fragment uses register d0 as a loop counter (initialised to 10). With each pass through the loop the value in d0 is decreased by 1 and following this decrement operation the control portion of the loop uses a *branch on not equal to zero*, bne, instruction to either branch, or not branch to the specified location. This instruction is one of a number of flow control facilities provided by the 68000

and it looks to see if the processor's zero flag has been set. *If it has not*, the specified branch is taken and the net result is that the loop code is executed until such time as d0 becomes zero (ie the loop is executed ten times):

```
        moveq #10, d0     initialise d0 as a counter
LOOP    do something      unwritten main body
        subq  #1, d0      decrease counter
        bne   LOOP        repeat loop if count not zero
        .
        .
        .
```

To write this loop in pre-test form requires that we both invert the sense of the exit condition test and add an extra instruction, an *unconditional branch* (bra) which always forces control back up to the top of the loop:

```
          moveq #10, d0     initialise d0 as a counter
LOOP      beq LOOP_END
          do something      unwritten main body
          subq #1, d0       decrease counter
          bra LOOP
LOOP_END  subsequent code
          .
          .
          .
```

The *branch on some condition* instructions, collectively written as bcc (where cc represents the testable condition) are an example of relative addressing. The object code created for these instructions does not include an absolute address to branch to – instead a displacement from the current value of the program counter is provided. This is the computer world's equivalent of someone knocking on your door and asking where one of your neighbours live. You, instead of saying "they live at number 66" (an absolute address), reply by pointing the caller in the right direction saying "they live six doors further down the road". What you've done is give a *displacement* which could have been positive (eg six doors further up the street) or negative. Relative addressing therefore specifies an address by providing the difference between the current address held in the 68000's program counter and the address you wish to reach. A great many testable conditions are

available for conditional branch instructions. Most will be covered (in context) during the course of the book but Chapter 17 provides summaries of the allowable options, should you care to review them.

String Conversion

In this section I want to write a program a little more involved than previous examples have been. It concerns the translation of text strings from one form to another. One way to represent a text string in memory is to store a *count* of the number of characters followed by the characters themselves. In an assembly language program such static (permanent) strings can be set up using dc.b directives like this:

```
TEXT   dc.b    5,"APPLE"
```

and in memory this would lead to the situation shown in Figure 3.4 below.

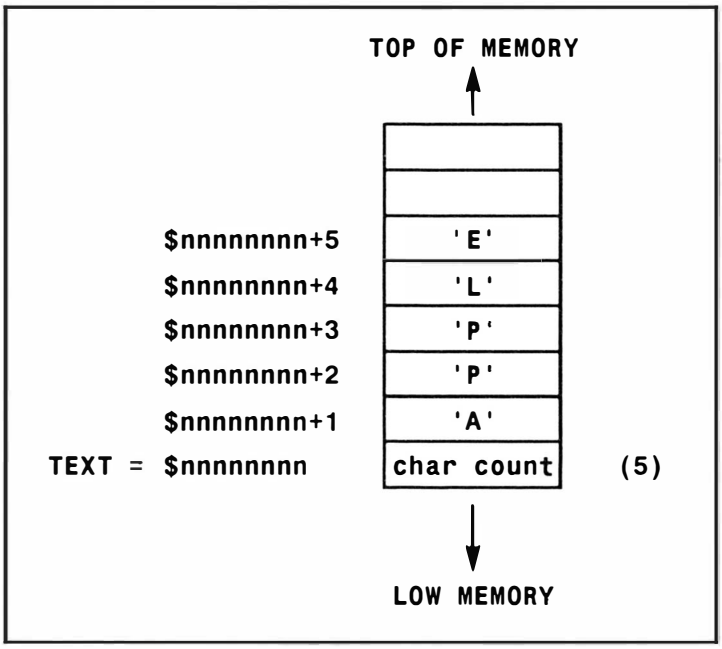


Figure 3.4. One way of representing a string in memory.

Another convention which is also in use, and equally popular, is to use a special symbol to mark the end of the string. The C language stores strings in this way and instead of a count being used, a NULL (zero) value is placed at the end of the string. The assembly language programmer can do a similar thing like this:

```
TEXT   dc.b    "APPLE",0
```

and this would result in the string being stored in memory as per Figure 3.5.

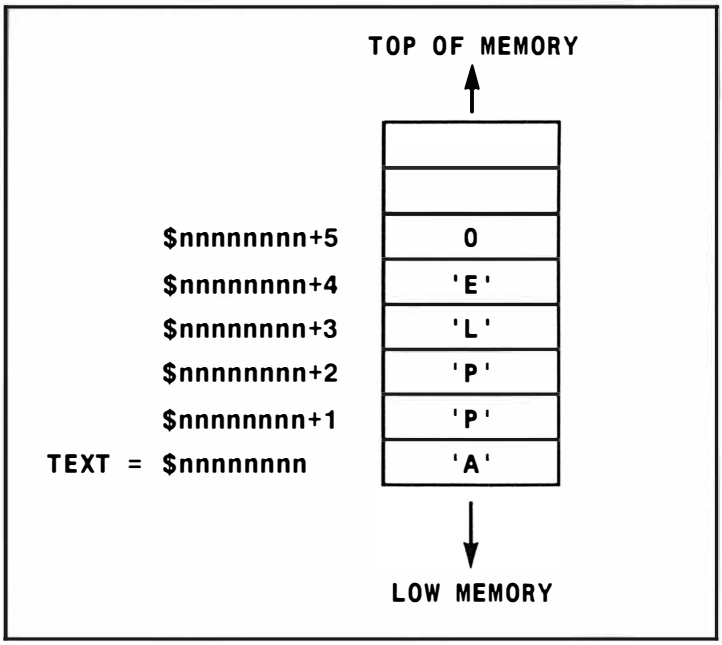


Figure 3.5. The C style way of representing a string in memory.

Now let us suppose that a string has been declared in a program using the former <count><characters> convention and that we want to write a routine which will convert that string to the alternative form whilst copying it to some alternative locations.

By loading register a0 with the address of the first byte of the original string the count can be loaded into register d0 using the indirect addressing scheme mentioned earlier:

```
lea       TEXT, a0          put address of string in a0
move.b    (a0), d0          copy count to register d0
```

At this point we know how many characters are in the string – it's given by the value now in register d0.

In light of the fact that we are going to copy the string , and so will need to reserve some space to store it, let's further assume then that another declaration has been made in our program:

```
COPY  ds.b    6             reserved for copy of string
```

and that we shall load the address of this *buffer* area into register a1 using another lea instruction like this:

```
          lea     COPY, a1    address of copy buffer in a1
```

The position we've now reached in our preliminary planning is that we have a0 pointing to the start of the source *string* (its count byte) and a1 pointing to the destination area and we have this much of the framework of a suitable program:

```
        lea     TEXT, a0        put address of string in a0
        move.b  (a0), d0        copy count to register d0
        lea     COPY, a1        address of copy buffer in a1
        copy and convert the string
        rts
TEXT    dc.b    5,"APPLE"
COPY    ds.b    6
```

Bearing in mind that the first byte of the source string should *not* be copied, because it is not part of the text string itself, it's not too hard to see that if we increment the address in a0 by 1 then that register will then be pointing to (ie contain the address of) the first real character of the source string. By using an addq.l instruction to increment the source pointer and by including a few appropriate notes about what we are trying to do our *program framework* grows into this form:

```
        lea     TEXT, a0        put address of string in a0
        move.b  (a0), d0        copy count to register d0
        addq.l  #1, a0          skip to first real character
        lea     COPY, a1        address of copy buffer in a1
        copy d0 characters of
        the text string from
        source to destination
        insert a terminal NULL
        character at end of string
        rts
TEXT    dc.b    5,"APPLE"
COPY    ds.b    6
```

The loop itself is surprisingly easy to code. Firstly, we use indirect addressing to copy the character. Remember the first line of the following fragment is saying copy the contents of the byte *WHOSE ADDRESS IS IN REGISTER A0 TO THE LOCATION WHOSE ADDRESS IS IN REGISTER A1*. Secondly, we increment both the source and the destination pointers (ie registers a0 and a1) by 1. Thirdly, we subtract 1 from the count value held in d0.

When the value in d0 reaches zero we'll have copied all of the characters in the string and this means that we create our loop using the *branch on not zero* type conditional branch instruction mentioned earlier:

```
LOOP  move.b   (a0), (a1)    copy character
      addq.1   #1, a0        move to next source character
      addq.l   #1, a1        move to next destination byte
      subq.b   d0            decrease character counter
      bne      LOOP          loop until d0 is zero
```

Now when we add these instructions into our existing framework things start to look up:

```
      lea      TEXT, a0      put address of string in a0
      move.b   (a0), d0      copy count to register d0
      addq.l   #1, a0        skip to first real character
      lea      COPY, a1      address of copy buffer in a1
LOOP  move.b   (a0), (a1)    copy character
      addq.1   #1, a0        move to next source character
      addq.l   #1, a1        move to next destination byte
      subq.b   #1, d0        decrease character counter
      bne      LOOP          loop until d0 is zero
      insert a terminal
      NULL character at
      end of string
      rts
TEXT  dc.b     5,"APPLE"
COPY  ds.b     6
```

All that remains is for us to store a terminal NULL (zero) value at the end of the destination string, which corresponds to the *terminal processing* section of the control loop mentioned in the general loop discussions. Since the loop will have already incremented the a1 pointer this is easily done with:

```
      move.b #0,   (a1)        add terminal NULL
```

and by adding this instruction we get a complete program:

```
* Example CH3-17.s
      lea       TEXT, a0      put address of string in a0
      move.b    (a0), d0      copy count to register d0
      addq.l    #1, a0        skip to first real character
      lea       COPY, a1      address of copy buffer in a1
LOOP  move.b    (a0), (a1)    copy character
      addq.1    #1, a0        move to next source character
      addq.l    #1, a1        move to next destination byte
      subq.b    #1, d0        decrease character counter
      bne       LOOP          loop until d0 is zero
      move.b    #0, (a1)      add terminal NULL
      rts
TEXT  dc.b      5,"APPLE"
COPY  ds.b      6
```

These types of loop-orientated conversion and copying operations are used in all manner of applications and so it's not surprising that the 68000 offers some special facilities for writing such loops efficiently.

To start with, the processor includes special indirect addressing modes which allow the pointer increment operations to be done automatically. They are called address register indirect with *post*-increment, and address register indirect with *pre*-decrement. In the first case the increment operation is done after the address is used and in the second case the decrement occurs before the address is used. The reason why this arrangement was chosen will become obvious after the next chapter but for now accept it as 68000 magic.

Both autoincrement and autodecrement modes can adjust an address by 1, 2, or 4 depending on whether bytes, words, or long words are being handled. In the case of the example I've been developing bytes are being transferred and the increment needed is of course 1.

The 68000 programmer specifies the indirect autoincrement mode by placing a plus sign *after* the usual indirect reference, for example:

```
move.b    (a0)+, d0      copy count and increment pointer
```

If, incidentally, we were interested in using the auto predecrement mode we'd use this type of syntax:

```
move.b    -(a0), d0      decrement pointer and copy count
```

In the main body of the loop outlined in Example CH3-17.s both source and destination pointers (registers a0 and a1) need to be incremented and with our newly discovered addressing mode this becomes simplicity itself:

```
LOOP    move.b    (a0)+, (a1)+      copy character and increment
                                    pointers
```

If we put these instructions in place the result is as follows:

```
* Example CH3-18.s
        lea       TEXT, a0          put address of string in a0
        move.b    (a0)+, d0         copy count and increment pointer
        lea       COPY, a1          address of copy buffer in a1
LOOP    move.b    (a0)+, (a1)+      copy character and increment
                                    pointers
        subq.b    d0                decrease character counter
        bne       LOOP              loop until d0 is zero
        move.b    #0, (a1)          add terminal NULL
        rts
TEXT    dc.b      5,"APPLE"
COPY    ds.b      6
```

Not only is the program shorter but the execution time will have been reduced because the autoincrement instructions run faster than the corresponding groups of move and addq instructions.

There is however another refinement that can be made because the 68000 has more special instructions which allow the control part of such loops to be written more efficiently. It is called, in its various forms, a *Test Condition – Decrement and Branch* instruction and is given the general mnemonic dbcc, where cc represents a particular testable condition.

The instruction itself expects a data register to be used as a loop counter together with a conditional branch type label, which internally is stored as a relative address. For example:

```
dbcc d0, LOOP   (cc is a testable condition eg dbeq, dbne etc)
```

The dbcc instruction tests both the status flags and a data register but there are differences between loops written using dbcc and those written with conventional conditional branching which stem from the way that dbcc works. If the condition being tested is satisfied then control passes to the instruction which follows the dbcc. If the condition is not satisfied then the low word (the lower

16 bits) of the data register is decreased by 1 and only if the result does *not* equal -1 is the specified branch taken. In other cases the instruction after the dbcc instruction will be executed.

From the above description you'll see that this instruction has two ways of exiting. Firstly, there can be the normal loop counter based exit. Secondly, there can be a premature exit caused by the specified condition becoming true. The other point that is important to understand is that the conditional part of the test actually works in the completely opposite way to the bcc type conditional branch instructions, because the branch is *not* taken if the condition is satisfied.

For the current example we are only interested in the loop counter part of the instruction so a dbra (which represents branch always) instruction will be used like this:

```
LOOP  move.b    (a0)+, (a1)+    copy character and increment
                                pointers
      dbra d0, LOOP             decrease and branch on zero
```

Because the loop exits when d0 equals -1 we need to subtract 1 from the character count originally loaded into d0. If these changes are made we end up with this final version of a program which does the string conversion:

```
* Example CH3-19.s
      lea       TEXT, a0      put address of string in a0
      move.b    (a0)+, d0     copy count and increment pointer
      sub.b     #1, d0        reduce count by 1 for dbra
      lea       COPY, a1      address of copy buffer in a1
LOOP  move.b    (a0)+, (a1)+  copy character and increment
                                pointers
      dbra      d0, LOOP      loop until d0 is -1
      move.b    #0, (a1)      add terminal NULL
      rts
TEXT  dc.b      5,"APPLE"
COPY  ds.b      6
```

The net result of running program Example CH3-19.s is that, by the time the program finishes, the COPY buffer will hold a copy of the original "APPLE" string in null terminated form.

This latest use of indirect addressing with automated increment coupled with the powerful dbra loop control instruction should begin to show something of the 68000's power, especially as far as

the various addressing schemes go. Example CH3-19.s, for simplicity, has used a static string definition but it's not too hard to imagine writing a routine that would be able to take *any* string in <count><characters> form and convert it to <characters><NULL> form. All that needs to be done is to find some way of writing the routine in a generally useful way and working out how the source and destination string addresses can be passed to the routine.

One solution would be to simply specify that before the routine is used the source and destination addresses should be in a0 and a1 respectively, perhaps adding a note to this effect at the start of the routine:

```
* Example CH3-20.s
; address of source string should be in a0
; address of destination string should be in a1
      move.b   (a0)+, d0       copy count and increment
                               pointer
      sub.b    #1, d0          reduce count by 1 for dbra
LOOP  move.b   (a0)+, (a1)+    copy character and increment
                               pointers
      dbra     d0, LOOP        loop until d0 is -1
      move.b   #0, (a1)        add terminal NULL
      rts
```

This piece of code could be used whenever a string had to be converted and the 68000, like most processors, provides a mechanism for allowing the re-use of code in this fashion. The code fragments themselves are even given a special name – subroutines – and, because they are so important, they get a chapter all to themselves.

4: Subroutines and Parameter Passing

There are frequent cases in programming where the same sequence of instructions is needed in more than one place in a program. Instead of duplicating those instructions (which is wasteful of memory) it has been found useful to provide microprocessors with special instructions that allow a section of code to be re-used. These code sections are themselves mini-programs written to do well-defined jobs and, since they represent routines which may be called by other parts of a program, they are called subroutines!

The 68000 provides two basic methods for transferring control to a subroutine. Firstly there is a jump-to-subroutine instruction, whose mnemonic is jsr, and this causes an unconditional jump to a specified memory address. This instruction behaves just like the unconditional jump (jmp) instruction, but in addition to placing the specified jump address into the program counter it also saves a return address.

By placing a return-from-subroutine instruction (rts) at the end of a subroutine this address can be placed into the program counter and the net result is this: the processor having jumped to, and executed, a piece of suitably written subroutine code, will return to the instruction immediately following the original subroutine call. In

schematic form this arrangement can be described as in Figure 4.1 below.

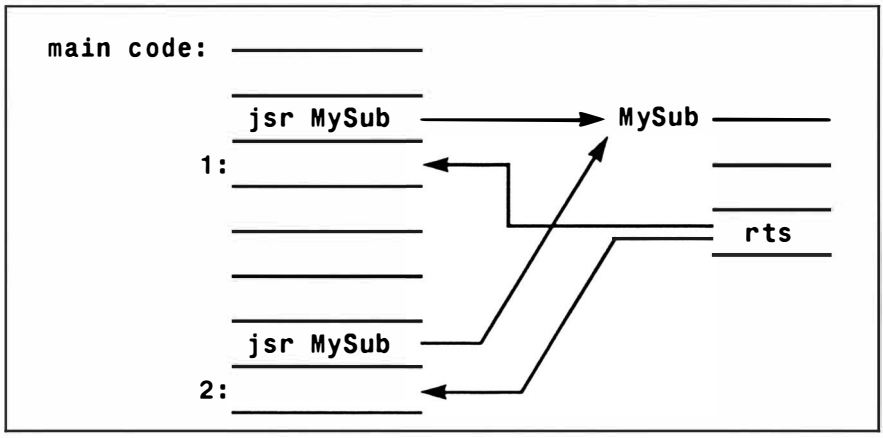


Figure 4.1. Control flow during subroutine calls.

This subroutine call instruction sequence requires the processor to make a note of the address of the instruction which is to be executed once the subroutine has completed its job and this address is conventionally called the return address. Since subroutines may themselves call other subroutines in the course of their work, some mechanism is needed so that these return addresses may be stored and retrieved in an orderly fashion.

Using a Stack

The most common way of providing such a facility is to use a data structure known as a stack which allows items to be stored on a Last-In-First-Out basis. Some microprocessors have hardware-defined fixed stack areas but on the 68000 processor stacks may be implemented anywhere in memory and all that is needed is a contiguous block, ie a block of unbroken, adjacent, memory locations. Register a7 is used to hold the address of the top of the stack, and we usually talk of register a7 as pointing to the top of the stack. Prior to a new subroutine call, the stack will look like Figure 4.2.

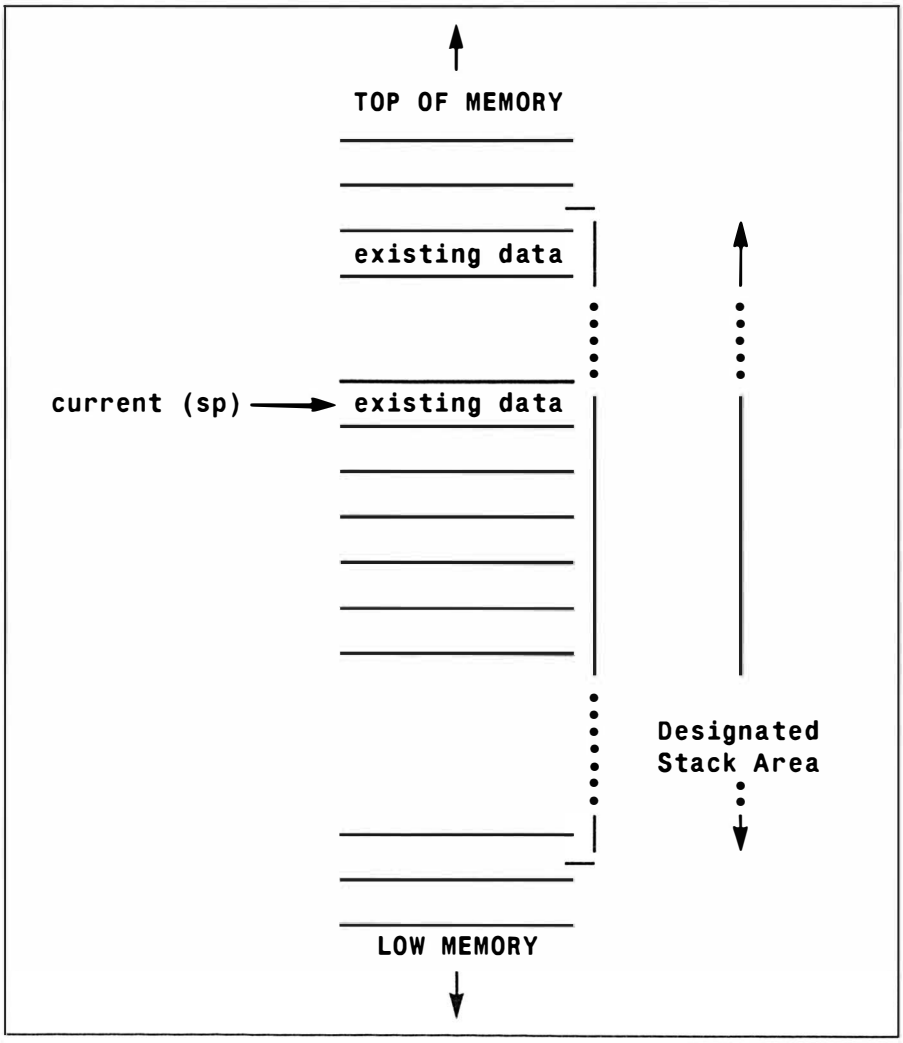


Figure 4.2. Stack condition prior to a new subroutine call.

Before control is passed to a subroutine the processor calculates the address of the next instruction (ie the one which would have been executed if the subroutine call jump was not going to be made). As mentioned above, this address is placed on the 68000's stack so that as the jsr instruction passes control to the subroutine this is the state of the stack (Figure 4.3) overleaf.

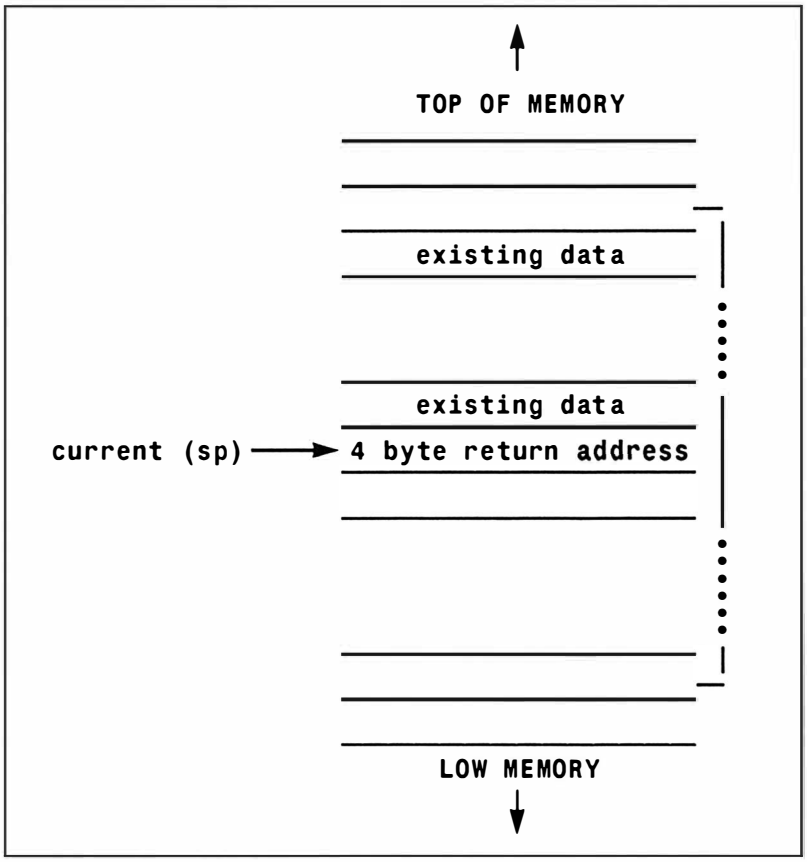


Figure 4.3. Stack after a new subroutine call.

68000 stacks then grow *downwards* in memory and since the stack pointer always points to the last data item added to the stack this means that before adding new items you must first decrease the stack pointer by a number equivalent to the byte-size of the object being stored – that way it properly points to the locations to be used next. The jsr instruction therefore decreases the stack pointer by four, stores the return address, and then places the specified jump location into the processor's program counter. Note that it is common, when placing data items onto the stack, to talk of *pushing* data onto the stack.

The main body of the subroutine will execute just like any other piece of code but the last instruction of the subroutine will be a rts, return-from-subroutine, instruction. This causes the address at the top of the stack to be retrieved *(popped* or *pulled* are commonly used terms for this operation) and placed in the 68000's program counter. The result is simple. The processor jumps to the newly specified address and this of course is the *return address* specified during the original subroutine call.

A further instruction, called branch-to-subroutine (mnemonic bsr), provides a relative addressing form of the subroutine call mechanism. In this case either an 8 or 16 bit displacement can be provided.

We briefly mentioned in Chapter Two that the 68000 supports the use of separate *supervisor* and user *stacks*, which allows system software running in supervisor mode to maintain its own stack area. For the programs discussed in this book, whenever we talk about the 68000 stack we are referring to the user-mode stack!

Push and Pull

There's a point concerning the *pushing* and *pulling* of data from the stack that is worth clarifying. When data is placed on the stack it is, like all other 68000 data movement operations, a *copy* of the data that is written into the stack area. Similarly when data is *pulled* from the stack it is a *copy* of the stack data that is retrieved. If, by way of example, we could *see* the state of the stack just after the subroutine being discussed earlier executed its rts instruction, Figure 4.4 illustrates what we would find.

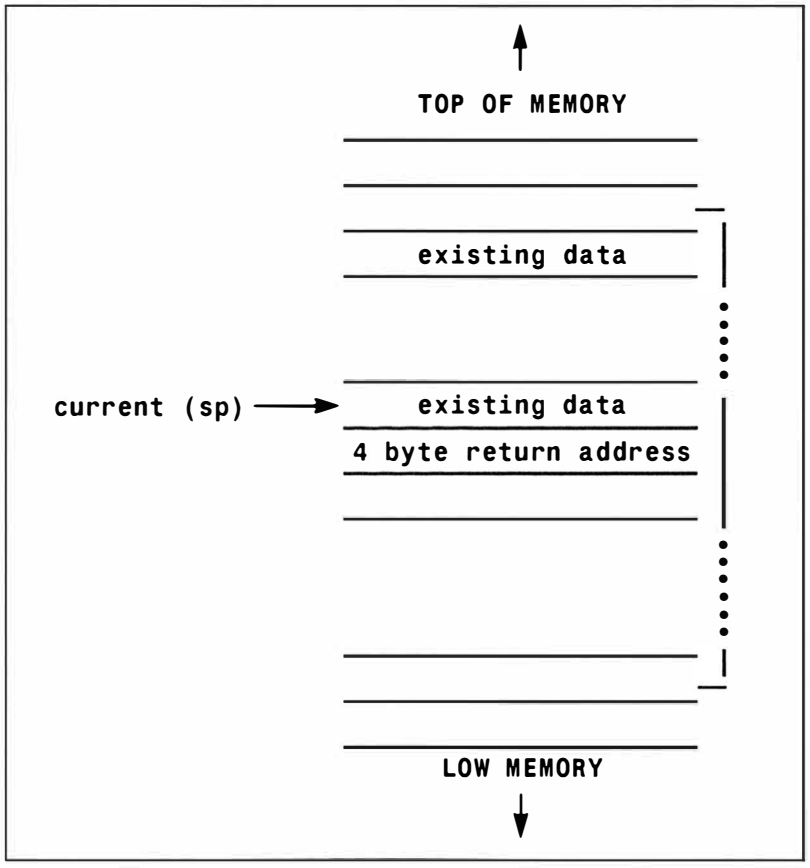


Figure 4.4. Stack after the subroutine has executed a rts instruction.

Although a copy of the return address has been placed in the program counter and the stack pointer adjusted, the return address originally placed on the stack is still there. What of course happens is that the next time a subroutine call is made those locations get over-written with the new address!

Parameter Passing

The programs and code fragments that we've been looking at in the previous chapter are simple examples and not exactly typical of the code you'll find in *real* programs. Most proper programs will need to perform a variety of tasks and many of these, because they either need to be done many times or because they concern jobs which are common to numerous programs, will be written as subroutines.

Apart from the fact that subroutines can save memory space there are other benefits. A subroutine that has been written to be generally useful will, after suitable preliminary testing, be able to be used by programmers secure in the knowledge that it is *safe,* ie the subroutine does what it is supposed to and is error free. In fact maximising the *utility value* of such routines is a good design objective because the more generally useful a piece of code is, the more the programmer will find uses for it. Similarly, maximising the use of either system supplied or self-written subroutines makes program development quicker and this re-use of tested code also reduces the chances of bugs. In fact you can almost guarantee that any bugs that do occur in your program will come from the code that you've written and not from the library subroutines being used.

Most of the subroutines that you'll code in your own programs will use absolute or relative addressing simply because you will know the address of the routine at assembly time. You should be aware however that it is possible to devise extremely sophisticated subroutine access mechanisms using other 68000 addressing modes. I briefly mention the possibility of hash-access and table access calls in Chapter Five and the Amiga's multitasking Exec Kernel uses a dynamic library system built around loadable libraries of subroutines that are accessed indirectly. The Exec library system is in fact so important that I've devoted a whole chapter to it (see Chapter 10)!

You will incidentally see both the terms *function* and *subroutine* in much Amiga literature. In fact all of the library subroutines are called functions and this stems mainly from the fact that the C language (upon which the Amiga and its documentation is very dependent) calls *all* subroutine-like procedures, functions! In other non-C areas of computing one normally reserves the term *function*

for a subroutine that acts on some data and returns a single result. A subroutine which takes the address of a text string and returns its length would be called a function, a subroutine which sorted a set of words into alphabetical order would not! Because you will find that almost all Amiga documentation will be using the term function you'll find that, outside of this chapter, I will be doing the same when discussing Amiga system routines.

In order to be really useful, subroutines must be written so that they are general. There is, for instance, little point in writing a subroutine that prints the message *Please enter a number*! It would however be quite useful to create a subroutine that could print *any* text message specified by the main program. This brings us to one of the most interesting areas of subroutine use. Namely, how such information can be provided to the subroutine and how any results might be passed back. Data items that are to be passed to a subroutine are called *parameters* and the act of arranging to transfer these parameters to the subroutine is called *parameter passing.*

There are two basic ways in which data can be passed to a subroutine:

- Parameters may be placed in the 68000's registers.
- Parameters can be stored in memory

Register-Based Parameter Passing

This first option is both simple and fast. Since pointers to larger objects, such as strings and other blocks of data, can be passed, ie the subroutine can be passed the address of the object rather than the object itself, there is little you cannot do. Similarly the subroutine may return any results, or a pointer to those results, directly in a register.

Memory-Based Parameter Passing

The advantage of this option, despite the fact that it is usually slower, is that it offers more flexibility. Parameters can, for example, if they are known at assembly time, be placed in memory immediately after the subroutine call. For example:

```
                .
                .
                jsr     SomeRoutine
orig_rts        dc.l    #data_item1
                dc.l    #data_item2
                .
```

```
                .
                .
                dc.l    #data_itemN
needed_rts      remaining instructions
                .
                .
```

In this case the return address placed on the stack by the processor would be wrong – the 68000 wouldn't realise that the numbers immediately following the jsr call were data rather than a valid 68000 instruction. In short the return address would need to be altered by the subroutine itself, by adding to the return address an amount equal to the number of bytes of parameters. Other approaches include the passing of a pointer to a parameter block in a similar fashion. An often simpler method is to use global variables, defined and labelled locations that can be read from any routine anywhere in the program.

None of these solutions provide sufficient generality to have found widespread favour but the next, stack-orientated, approach I want to discuss has. Although the 68000 stack was introduced during the discussions of subroutines and return addresses it is now time to point out that the 68000's stack can be used for the storage of other data, namely bytes, words and long words. As usual, word and long word, data *must* be word-aligned and the 68000 stack pointer register does in fact take a special precaution to ensure this word alignment – it word-aligns *all* data, even single byte values. When byte data is pushed onto the stack it is stored in the high-order byte of a 16 bit word.

Stack-based parameter passing can be done by several means. The 68000's move instruction can, for example, be used in conjunction with indirect addressing with auto decrement to push a value onto the stack like this:

```
        .
        .
        .
        move.w      tab_size,-(sp)    push tab size parameter
        jsr ExpandTab                 expand to spaces
        .
        .
        .
        end of program
```

What must be remembered of course is that, after you have pushed the parameter onto the stack, the jsr instruction will have subsequently pushed a return address so the stack will be looking something like Figure 4.5.

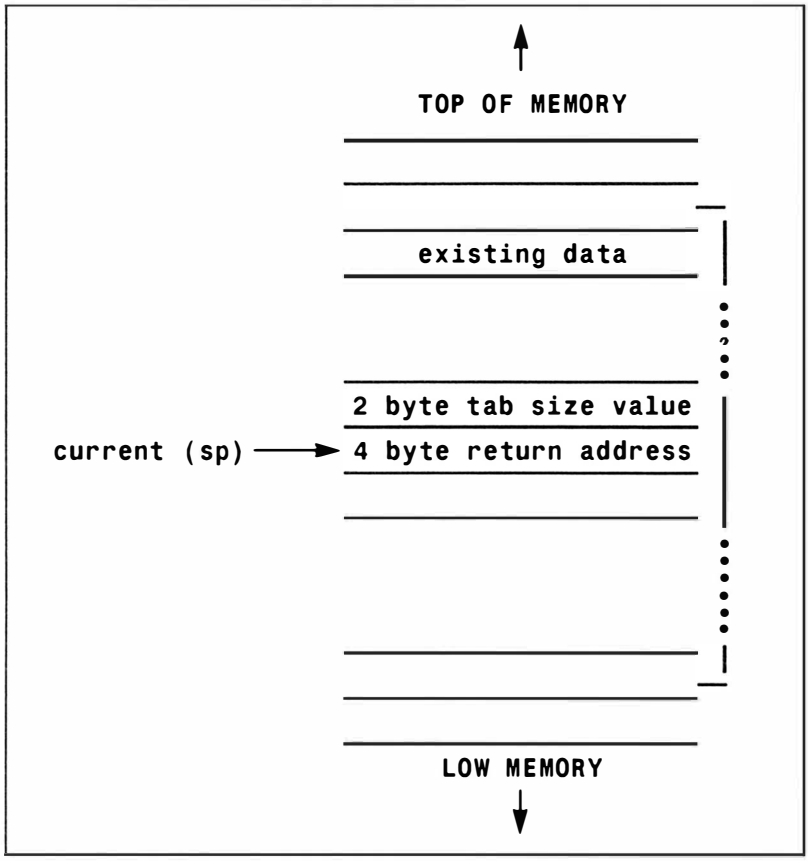


Figure 4.5. The pushed parameter after *the subroutine call has been made.*

This means that the subroutine needs to look not just at the top of the stack but actually into it in order to see the parameter. Since the return address is four bytes long we have to use a displacement of 4 as this example shows:

```
ExpandTab   move.w   4(sp),d0   retrieve tab size in d0
            .
            .
            .
            rest of code        do something
            .
            .
```

```
        .
        rts
```

The above fragment copies into d0 the two bytes of data immediately above the return address. The situation once the subroutine has returned is that the stack pointer will, at least in the case of the current example, be left pointing to the parameter that we placed on the stack. This cannot be left because it will destroy the integrity of the stack as far as any items which have been placed on the stack earlier are concerned. The parameter is not needed and so there is little point in executing a move (sp)+,d0 type pull instruction. Instead the simplest idea is to numerically adjust the stack pointer so that the item is effectively ignored:

```
    .
    .
    .
    move.w    tab_size,-(sp)      push tab size parameter
    jsr       ExpandTab           expand to spaces
    addq.l    #2,sp               clean-up stack
    .
    .
    .
    end of program
```

The Amiga's amiga.lib linker library routines use this type of mechanism and I'll be looking at some real Amiga examples of this technique in Chapter 12.

Other stack-orientated instructions are available, including a very useful one called *push-effective-address,* which can both calculate an address using any of the 68000's addressing schemes and push it onto the stack for you. An example which shows the use of this instruction is given in Chapter 12.

Register Preservation Using Movem

Normally it is advisable to create subroutines which do not alter the contents of any temporary registers that they may use, ie those that will not be used to return a result. The best way to do this is to preserve those registers by pushing their contents onto the stack, restoring them just before the subroutine returns.

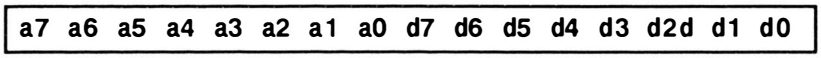
One way of doing this is to push/pull the contents of each register singly using instructions such as:

```
move.l a6, -(sp)        preserve a6 on stack
move.l a5, -(sp)        preserve a5 on stack
move.l a4, -(sp)        preserve a4 on stack
do something
move.l    (sp)+,a4      restore contents of a4
move.l    (sp)+,a5      restore contents of a5
move.l    (sp)+,a6      restore contents of a6
```

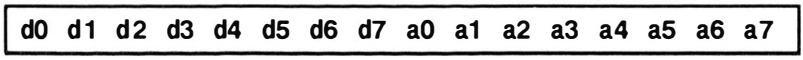
but in actual fact a special *multiple move* instruction exists, called movem, which allows this transfer to be done more efficiently when two or more registers are involved.

Movem actually exists in two forms. The instruction used when transferring registers *to* memory is called, not unsurprisingly, Move-Multiple-Registers-To-Memory (mnemonic movem). It can use all of the absolute and indirect addressing modes *except* the autoincrement mode. This is a deliberate restriction because it forces the programmer not to use to autoincrement when placing data on the stack (that approach would cause stacks to grow upwards in memory which would contradict the 68000 stack conventions).

Its useful to look at how this instruction is designed internally. The first word contains bit patterns which identify the instruction, the transfer size, and the effective destination specification. The second word is a 16-bit mask which has been assigned to represent registers either in this fashion:

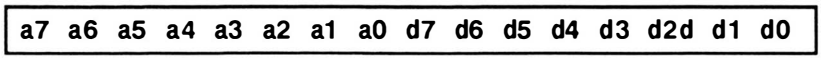


or, if the automatic predecrement addressing mode has been specified, like this:



Registers are moved in the order bit 0, bit 1, bit 2 etc, of the mask and so the order is d0, d1, d2 etc for the normal mask and a7, a6, a5 etc, for the reversed mask (assuming that is that the appropriate mask bits for those registers have been set to 1).

The equivalent Move-Multiple-Registers-From-Memory, movem, instruction does not use this mask reversal. In fact it always uses the bit mask arrangement described first, ie:



and instead it allows the autoincrement addressing mode but does not allow the predecrement form.

When multiple data items are placed onto the stack the order in which they are removed is important. Because the stack works on a Last-In-First-Out arrangement items must be removed in the reverse order to that used to originally put them on the stack. If for instance you store registers d0, d1 and a1 (in that order) then to re-instate the registers you must first pull a1, then d1 and finally d0. The effect of the mask reversal scheme when using the predecrement form of the movem instruction is that this ordering reversal occurs automatically and the program doesn't have to explicitly worry about it (the assembler generates the appropriate mask).

The easiest way to describe the use of the instruction is to show you some examples. To save on the stack the full 32 bit contents of registers d0 through d7 and a0 through a3 for example we would write:

```
movem.l   d0-d7/a0-a3,   -(sp)
```

To restore the registers (ie pull them back off the stack) we'd use:

```
move.l    (sp)+, d0-d7/a0-a3
```

Similarly to preserve register d0 and registers a2-a5 we use this instruction:

```
move.l    d0/a2-a5,      -(sp)
```

and to restore the contents:

```
move.l    (sp)+, d0/a2-a5
```

These instructions have a number of uses but as far as their use in subroutines is concerned you'll mainly see them used on entry and just before exiting (ie just before the rts instruction) like this:

```
SomeSubroutine  movem.l    d0-d4/a0-a3, -(sp)    preserve registers
                <main body of subroutine code>   do something!
                move.l     (sp)+, d0-d4/a0-a3    restore registers
                rts                              return
```

When registers are preserved like this, routines which are expecting parameters to be passed on the stack need to allow for the fact that more items have been pushed onto the stack *after* the return address. In the above example nine 32 bit registers are preserved (d0, d1, d2, d3, d4, a0,a1, a2, and a3) so a further 36 bytes have been placed on the stack. If we go back to the stack-based ExpandTab parameter passing example mentioned earlier and add

the above register preservation code, the offset now needed to access the tab size variable would be (9 x 4) + 4, ie 40, and the code would then be based on this type of framework:

```
ExpandTab  movem.l  d0-d4/a0-a3, -(sp)
preserve registers
           move.w   40(sp),d0          retrieve tab size
in d0
           .
           .
           .
           rest of code                do something
           .
           .
           .
           move.l   (sp)+, d0-d4/a0-a3
restore registers
           rts
```

Link/Unlk Instruction

More sophisticated subroutine arrangements are possible and one scheme used by many 68000 based high-level language compilers (including C) is not only able to eliminate the need for the *altered displacements* illustrated in the previous example but provides a number of other benefits.

The idea is that as soon as a subroutine is entered we immediately preserve the contents of an address register on the stack and then copy the stack pointer into it. This then establishes that register as a fixed *frame pointer* which can be used to access any parameters lying above the frame pointer and return address. Having done that, it is then possible to decrease the real stack pointer (ie register a7) by some chosen value such that this amount of space is then available as *temporary workspace* on the stack. After this has been done the subroutine can do all its usual register preservation operations and data subsequently placed on the stack will be stored *after* (ie below) the temporary *hole* that we've created in the stack. If, for example, a5 was being used as the frame pointer register we'd end up with the situation shown in Figure 4.6 overleaf.

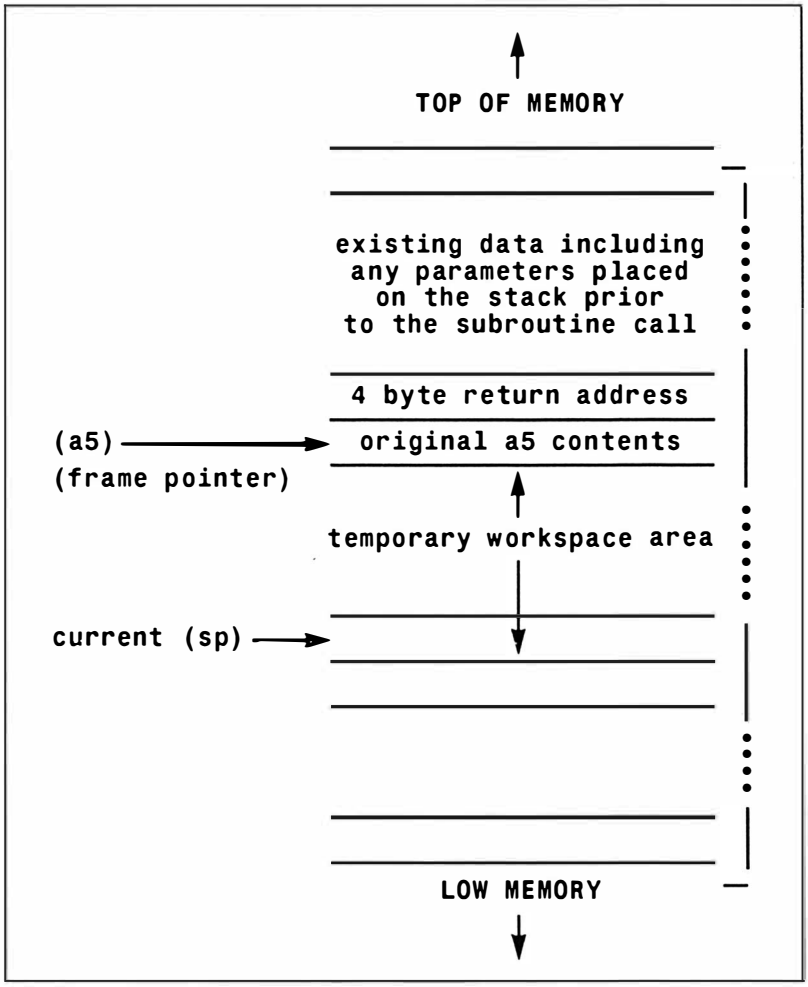


Figure 4.6. A more sophisticated stack-usage scheme.

The situation in Figure 4.6 is then that after the frame pointer has been set up (a5) + 8, in other words the contents of register a5 plus an 8 byte displacement (remember that the return address and the frame pointer are both stored on the stack at this time), identifies the start of the parameters (if any) that are present on the stack. Another benefit of this arrangement is that by using negative displacements it becomes possible to access the temporary stack workspace, which was created when we made a hole in the stack by decreasing the stack pointer. In a high-level language it is just these kinds of negative displacements that are used to create local variables, which exist only during the execution lifetime of the routine in question.

Best of all though is the fact that the real stack pointer is set to the low end of our temporary workspace so, even when any number of new items are pushed onto the stack, the frame pointer remains valid.

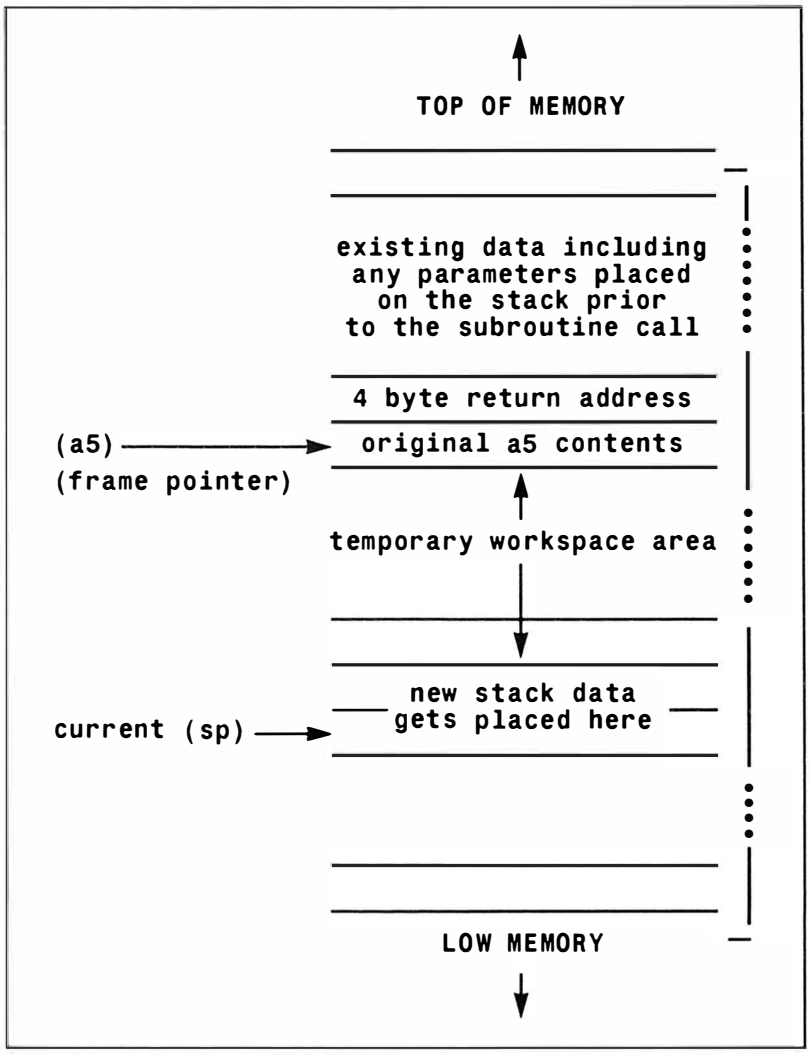


Figure 4.7. Creating a safe hole for temporary variables.

At the end of the subroutine any additional items placed on the stack by the routine are removed and then the stack pointer is advanced past the work area, by loading it with the contents of the frame pointer. The original frame pointer register contents are then pulled off the stack and placed in the register used as a frame pointer, so re-instating it to its original value, and a normal

subroutine rts is performed. This latter instruction, as usual, removes the return address placed on the stack by the jsr (or bsr) instruction.

OK, there are some difficult things to grasp with this approach but the general outline and power of the technique should be apparent. What you might like to know however is that the 68000 provides two instructions which allow this complex set of operations to be done automatically. The instructions are called link and unlink (mnemonic is unlk) and they are used like this:

```
MySub   link a5, -32            create 32 byte work area
        movem.l d0-d7/a0-a2, -(sp)   preserve some registers
        |main body of the     |      providing it is not
        |subroutine will use   |      destroyed by the sub
        |(a5) displacements    |      routine itself a5
        |to access parameters  |      remains valid no matter
        |and local workspace   |      what happens to the
                                      stack pointer

        movem.l (sp)+, d0-d7/a0-a2   restore registers
        unlk a5
        rts
```

The link/unlk instructions can dynamically allocate up to 32768 bytes of stack workspace, and as you'll see from the example the workspace displacement size needs to be given as a *negative* number, because the stack is growing downwards.

I will not be using these more advanced schemes for the examples in this book but it is useful to know that they exist. You will, for instance when using a debugger (such as Devpac's MonAm) to disassemble compiler generated code, often see link/unlk instructions being used in this way.

Styles and Subroutines

There are characteristics of some subroutines which, although they will not be particularly important or relevant to the assembler newcomer, are worth briefly mentioning since the terms do crop up in the Amiga official documentation from time to time.

Truly relocatable routines are routines that may be placed anywhere in memory. They are created by using relative addressing instructions so that absolute memory references are avoided. You might think that, because of the way the Amiga loads its programs and data into any convenient spare memory that is available, that all Amiga programs would need to be relocatable. This isn't true

because the Amiga uses a piece of program loading software called a *relocating loader* which is able to take a program containing absolute address references and *modify* them (ie add a loader calculated offset) so that the program runs properly at the chosen location.

Re-entrant routines are routines that may be interrupted, called by the routine which did the interrupting, and still produce the right results. This allows interrupt system code to make use of available system routines.

Recursive subroutines are routines which are able to call themselves during the course of their operations. Subroutines which preserve their registers and use only those registers and the stack for storing data will be capable of being used recursively. Needless to say they will also be re-entrant!

Subroutines on the Amiga are very important and, as mentioned earlier, the Amiga's run-time and link-time function libraries contain a great many pre-written subroutines for you to use. It is no exaggeration to say that upwards of 80% of the assembly language code that the average Amiga assembler programmer will write will be library related and consist of calling pre-written functions to do particular jobs. To a large extent your coding efforts will just revolve around making sure that your program performs the necessary library routines in the right order and with the right types of integrity checks.

In many ways the use of pre-written routines can be alikened to using a piece of hardware like a photocopier. If you use a photocopier to make a duplicate of something you go to the machine, place the document you wish to copy inside, press a button, and then just wait for the device to do its job. As likely as not you'll do all this without knowing any real details about what goes on inside. In a sense the copier is acting almost like a magic *black box*. You know what input is required (the document to be copied), what must be done to start the copying process, and you know that some results will come back, ie you'll get a copy of the input document.

This information hiding, black box, design concept is a very powerful way of protecting a user from unnecessary complexity. For the programmer, the pre-written subroutine unit provides exactly the same type of *complexity hiding* capabilities and, on the Amiga at least, constitute essential program building blocks to be used in the same way as the electrical engineer might use IC chips (integrated circuits pre-designed to do a particular job) to build an electronic circuit.

There is one general point about this pathway which is important. Although the user of the function doesn't need to know how the subroutine works, they do need to know what it does, what information must be supplied, and the significance of the results produced. this means that the user *must* have suitable documentation for the system routines. This of course is one of the reasons that books such as the RKM *Includes & Autodocs* manual, which lists function usage descriptions for all of the Amiga's library functions, are so important.

5: Program Design Issues

This book is not about program design but there is no doubt that programming a machine as complex as the Amiga is almost impossible unless you adopt some kind of forward planning. That for most people means taking more than a passing interest in the techniques used for program design. I'm not going to review the many tools which are available but I am going to provide some examples of a method that I have found to be of immense value with all kinds of programming, including 68000 assembler.

It's based on a logic design tool called the Warnier diagram and, before looking in detail at the ideas involved, I want to make the following point. The methods I am about to discuss aim to obtain solutions to problems that are completely independent of both the computers and the languages which might eventually be used to implement the chosen design. These latter factors may well affect the final coding stages, but they should not usually influence the overall layout of the design.

So, what is a Warnier diagram? Essentially it is a set of *curly brackets*, that define both particular groups of operations and the order in which they should be performed. The easiest way to

show you about these diagrams is to take some examples and I'll start by taking one which will let me explain some important diagram conventions.

Imagine we wish to produce a report, consisting of details held on a computer file on disk. The Warnier diagram of the basic problem is shown in Figure 5.1.

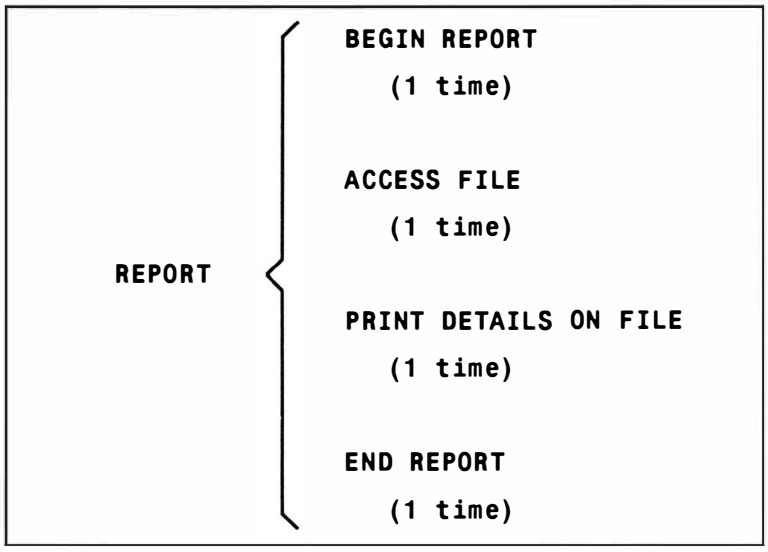


Figure 5.1. Essential characteristics of the simple report generator.

The bracket is read from top to bottom and describes a procedure or group of operations that has, arbitrarily, been called REPORT. The numbers which you see written underneath the various statements identify how many times the item is to be performed and, with just those two conventions, our first diagram is already illustrating some of the essential features of the problem.

Do we know anything more about the problem? Can we think of any information that could be relevant? Well, we know that *computer files need to be opened before reading and closed once the read operation is complete.* These details could therefore also be added to the diagram. To enable us to explain some further conventions used with Warnier diagrams let us first add a minor complication to the problem. Let us suppose that the user wishes to access a file of his (or her) own choosing and to obtain a printed report of the details on the file. The specified file may not exist, and, if this is the case, the user should be informed. These changed or altered requirements can be represented by a more detailed Warnier diagram.

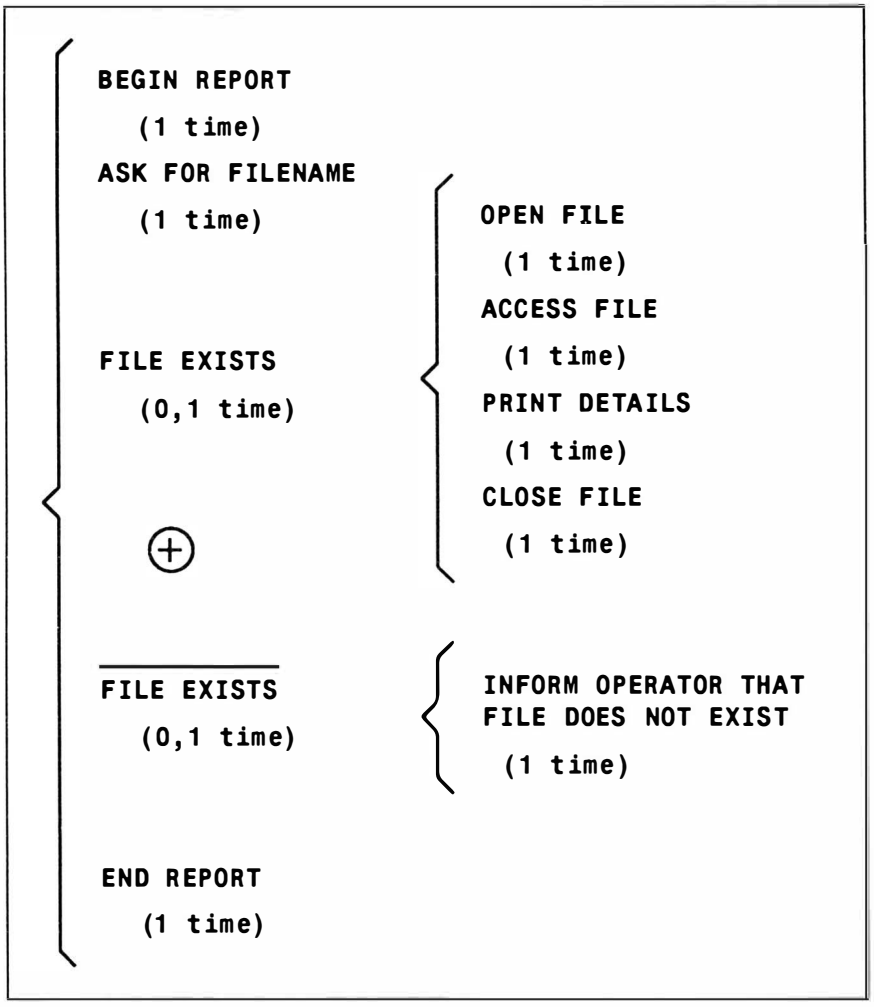


Figure 5.2. Some new restrictions added to Figure 5.1.

Figure 5.2 shows, in Warnier diagram form, the requirements of the problem as it is at the moment. We are using the convention that the logical opposite of a statement is written by placing a bar over it.

$\overline{\text{FILE EXISTS}}$ means FILE DOES NOT EXIST

We are also using a ⊕ sign to separate mutually exclusive operations (sets of operations which will not occur together). In the present example the file will either exist or it will not exist, so only one of these two operations would be performed at any one time and (0,1 time) is written underneath the statements involved. At other times the operations shown within a bracket may need to be repeated and in these cases an expression such as (1 ,N times) would be used.

The conventions used so far are in fact the only ones you will need for the majority of problems that you are likely to encounter. Here they are collected together for convenience:

- Brackets are used to define sets of operations.
- Brackets are read, and performed, downwards within any one *level*. The item at the top of the bracket is performed first, the item at the bottom performed last.
- The logical opposite of a statement can be written as the original statement with a bar drawn over it.
- Brackets written to the right of a statement indicate the operations to be performed *if* that statement is performed.
- Underneath each item or statement we indicate the number of times the operations should be performed.
- Mutually exclusive statements are written separated by a ⊕ sign.

Using these conventions we can express in English exactly what Figure 5.2 tells us: we are dealing with a certain procedure, called REPORT that starts by asking for the name of a file. If the file exists then it is opened, accessed, the details printed, and then the file is closed. If it does not exist then the operator is informed of the fact. Remember that if the file does exist then it is the group of actions (subset) shown to the right of the label FILE EXISTS that are performed.

To appreciate the elegance and speed with which these diagrams can accommodate changing requirements let us place some further restrictions on this problem. Within this hypothetical computer system are files containing sensitive data, perhaps personnel data, wages or medical records. Such data must be protected from unauthorised access and users are therefore issued with access code numbers, so that examination of sensitive files is restricted to those users with the proper authority. If unauthorised attempts to access this data are made the computer should record the fact, perhaps by making an entry into a special *security* file.

Let us first consider the new constraints in isolation. We need to check whether the file specified by the user is a restricted file, if it is we must ask for the user's code number. If the code is correct then we allow access, if not we write a *security record* indicating an attempted illegal access.

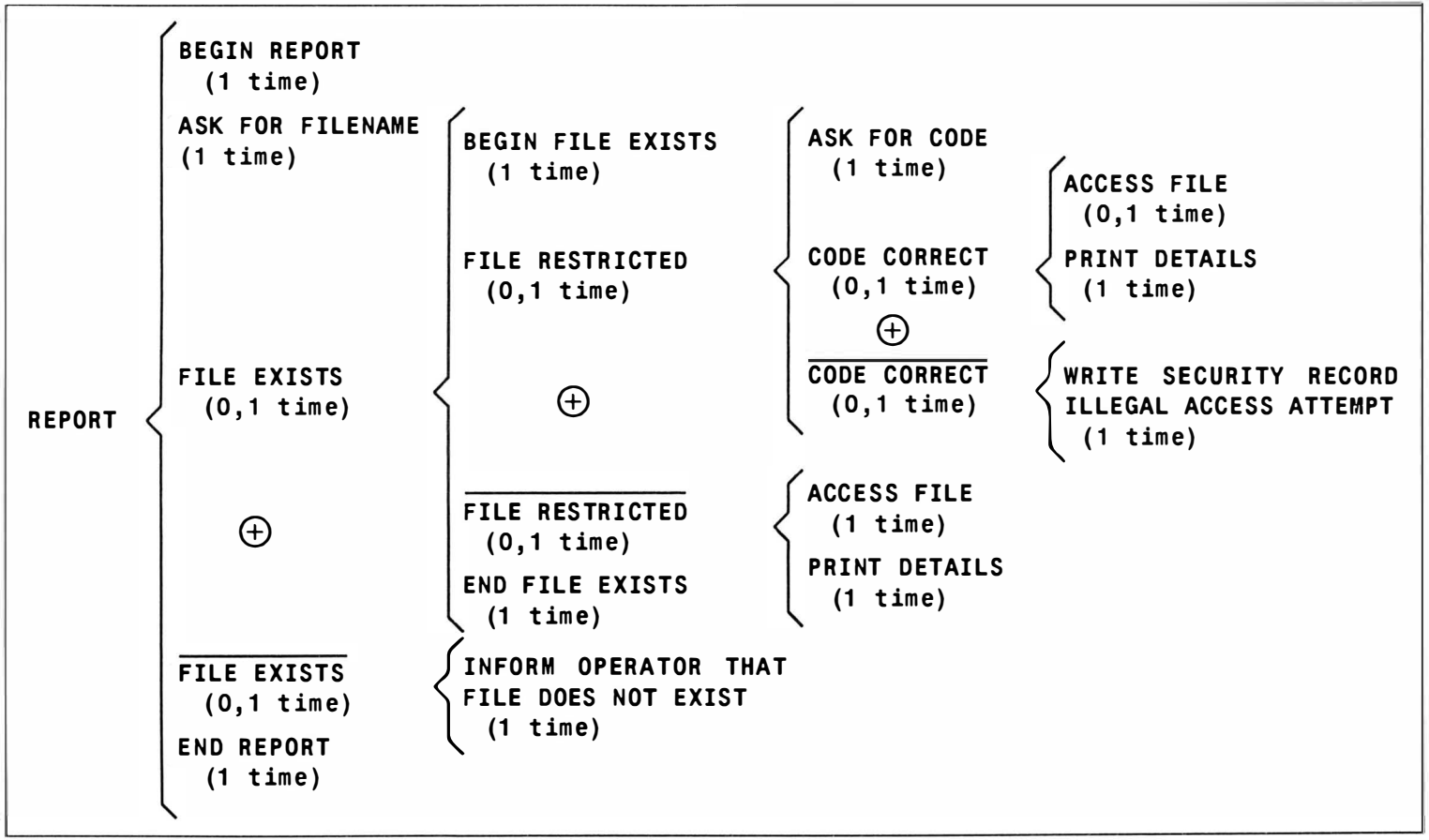


Figure 5.3. A hierarchy is forming within the revised problem.

The diagram in Figure 5.3 shows the Warnier form of our new requirements. Notice that as we redefine the problem and add more detailed restrictions it is not necessary to rearrange the complete diagram, as one frequently needs to with flowcharts etc. All we have to do is superimpose the new details and restrictions on to the existing diagram structure. The diagram is therefore actually growing as we successively modify and redefine the known details of the problem. You'll see later that the Warnier diagram is not only documenting and expressing the logical requirements of the problem but it is doing so in a way that will make the transition to a computer language equivalent form remarkably simple.

The ability of the Warnier diagram to display, help formulate, and to grow with the changing logical requirements of a problem, as that problem is examined, is of great importance. Once the quite simple conventions have been learnt these diagrams can be read just like the written English equivalent but, unlike the written English form, a Warnier diagram contains within its deceptively simple notation, the complete solution to the coding of the problem.

The secret of converting a Warnier diagram into a finished program lies in regarding each bracket involving more than one operation as a subroutine. There are certain exceptions to this general statement but the pseudo-BASIC sketch shown in Figure 5.4. should give you the general idea.

A Second Example

For this second example, which again is a general, rather than an Amiga specific illustration, I'm going to design the basic structure of a routine that collects characters from a keyboard device. If the character is a carriage return (ie ASCII 13) then the routine should terminate, if it is another control character then an appropriate control character subroutine should be performed. If the character is not a control character then it should be passed to a printing routine to display it on a VDU or other output device.

Let's first quantify what's known about the problem in terms of the sort of operations which might be needed. We will have to input a character, possibly using an input routine available within the operating system. Some type of check will also need to be made to see whether an input character corresponds to a control character or not. For the purposes of the example we'll regard a control character as one with an ASCII value of less than decimal 32. Additionally some means of printing characters is needed but since such facilities are usually provided by the operating system we'll assume that such a routine is already available.

The first step is to create a Warnier diagram sketch showing those objectives which are relatively obvious from the original statement of the problem.

```
* ========================================================

 P S E U D O - B A S I C - R E P O R T - M O D U L E

* --------------------------------------------------------

INPUT NAME OF FILE

IF FILE EXISTS THEN GOSUB `FILE EXISTS' ELSE PRINT `FILE
DOES NOT EXIST'

RETURN TO CALLING PROGRAM

* --------------------------------------------------------

REM SUBROUTINE.....FILE EXISTS

IF FILE IS RESTRICTED THE GOSUB `RESTRICTED FILE' ELSE
GOSUB `ACCESS'

RETURN

* --------------------------------------------------------

REM SUBROUTINE.....RESTRICTED FILE

INPUT SECURITY CODE

IF SECURITY CODE=CORRECT CODE THEN GOSUB `ACCESS' ELSE
GOSUB `ILLEGAL ACCESS'

RETURN

* --------------------------------------------------------

REM SUBROUTINE.....ILLEGAL ACCESS

WRITE TO I/A LOG FILE THE TIME OF ATTEMPT AND THE ACCESS
CODE

PRINT `THIS IS A RESTRICTED FILE - PLEASE MAKE NO FUR-
THER ATTEMPTS'

RETURN

* --------------------------------------------------------

REM SUBROUTINE.....ACCESS

THIS WOULD BE A ROUTINE TO ACCESS THE DATA IN THE FILE
AND DISPLAY

ON TERMINAL OR PRINTER ETC.

RETURN

* ========================================================
```

Figure 5.4. Pseudo-BASIC code for the first example.

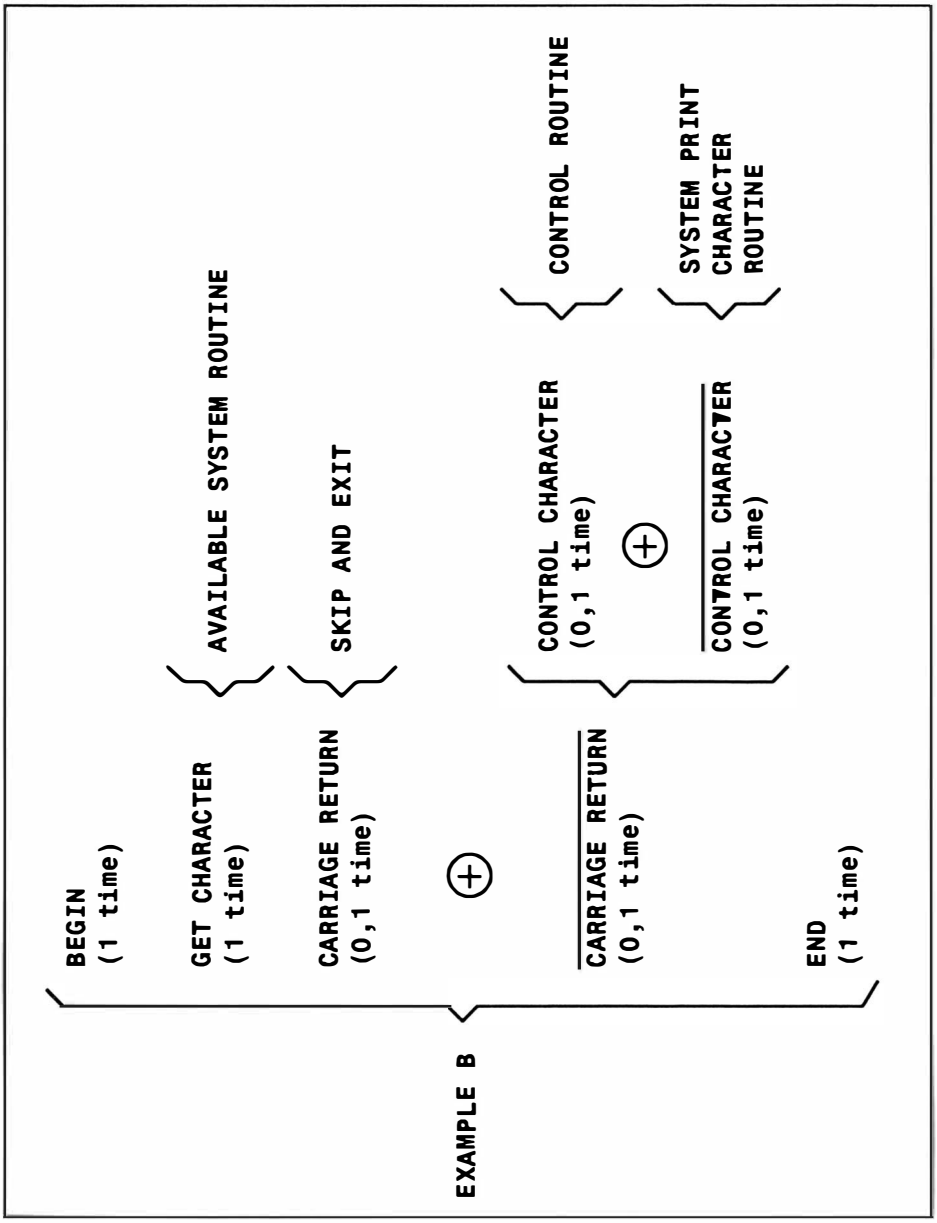


Figure 5.5. First Warnier diagram for the second example.

Figure 5.5 shows a first attempt at describing the problem. The diagram implies that a test can be performed which will indicate whether a given input character is a carriage return or not. Additionally it implies that a character can be tested to see if it is a control character. We should be fairly happy with this initial diagram because all general computer languages, both high and low level, provide the type of testing needed to perform the necessary tests.

At present the Warnier diagram does not indicate that we collect anything more than one character by performing the illustrated operations. It is necessary in practice to perform the operations in Figure 5.5 any number of times from 1 to N times, depending on when the user supplies a carriage return character.

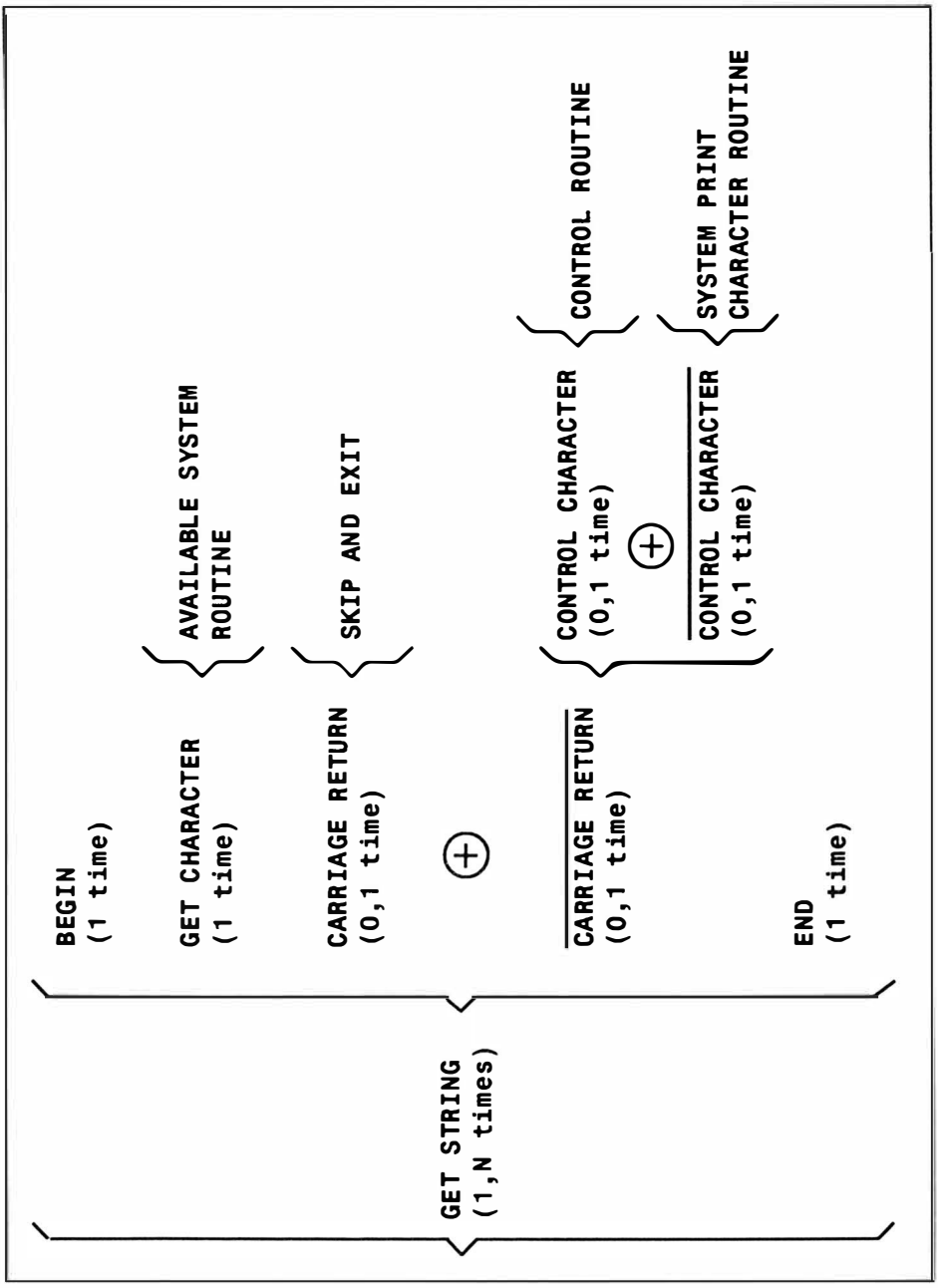


Figure 5.6. Expanded Warnier diagram for the second example.

Figure 5.6 explicitly shows that we perform the operations indicated in Figure 5.5 at least once, and up to a maximum of N times. The labels used are, of course, arbitrary, but it is obviously advisable to choose meaningful English expressions since this enables the diagrams to be more easily understood.

Now that a reasonably accurate representation of the problem is available it's time to consider some more detailed requirements: Let us suppose that the control characters detected are going to be used to perform the operations shown in Figure 5.7.

ASCII code	*Operation to be performed*
8	Move cursor to Left
16	Move cursor to Right
10	Perform a Line Feed
9	Perform a Tab
11	Move cursor Down
12	Move cursor Up
Others	Take no action (ie ignore them all)

Figure 5.7. Actions associated with the control characters.

These operations are a more complex example of the mutually exclusive operation sets mentioned earlier. Notice that in this case the bar notation cannot be used because many alternatives exist. Instead the options are written using their respective names (separated of course by the ⊕ sign to indicate that each *operation subset* is mutually exclusive). Figure 5.8 shows how this situation is represented in Warnier diagram form.

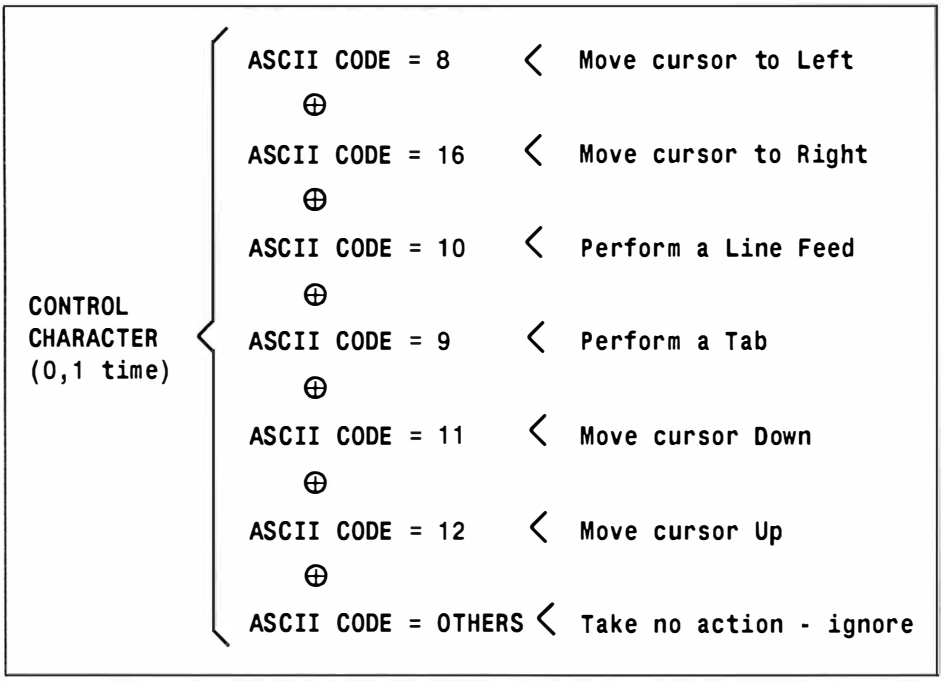


Figure 5.8. Warnier expansion of the CONTROL CHARACTER statement.

Let us now make an alteration to the control character routine by creating some further assumptions. We suppose that if our hypothetical user presses a control key that serves no apparent purpose then either a simple error has been made (the user has pressed the wrong key) or the user is under the impression that the control key pressed serves some function which it does not, in fact, perform. In either case we may, from a practical point of view, decide to provide some means of informing our user that a *useless* or *unsupported* key has been pressed.

I'll assume, since this is a general example, that the VDU screen has either one or two lines available for comments or for collecting responses such as input from the user, or that some type of requester/dialogue boxes are available for these types of simple I/O operations. The implication here then is that most of the screen contains information that must be preserved, so we cannot simply print a menu of control character options on to the screen.

Nowadays of course on machines like the Amiga it is the WIMP (Window, Icon, Mouse, Pull-down menu) system that would handle the screen preservation actions, but for the purposes of this example let's assume that it is the applications program itself that must take all necessary actions.

As far as the example is concerned then we will need both space on the screen to display a menu, and somewhere to save the existing contents of the VDU screen. It might also be useful to ascertain whether the *user* actually needs a menu. Perhaps he or she will often quickly realise that a wrong key has been pressed by mistake and just want some way of getting back to normal operations as quickly as possible.

To tackle this new set of problems it is useful to first consider the new restrictions as a discrete subset of operations, ie concentrate on just the new requirements. Once a suitably structured diagram concerning the new constraints has been created it can then be superimposed onto the original diagram in Figure 5.8.

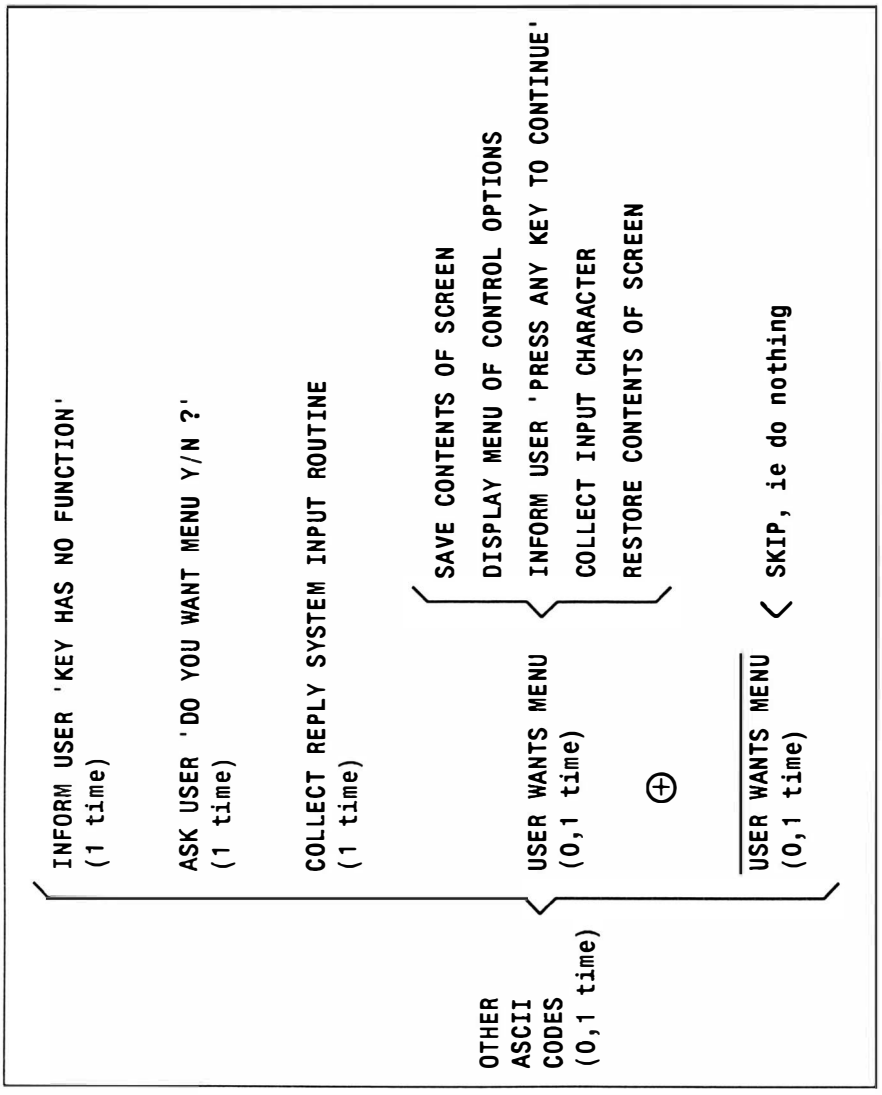


Figure 5.9. New restraints added to Figure 5.8.

The diagram in Figure 5.9 shows our latest requirements in Warnier diagram form. Convince yourself that the known additional details have been expressed in a suitable manner, then look at Figure 5.10 which shows the whole of the control character description including the latest additions.

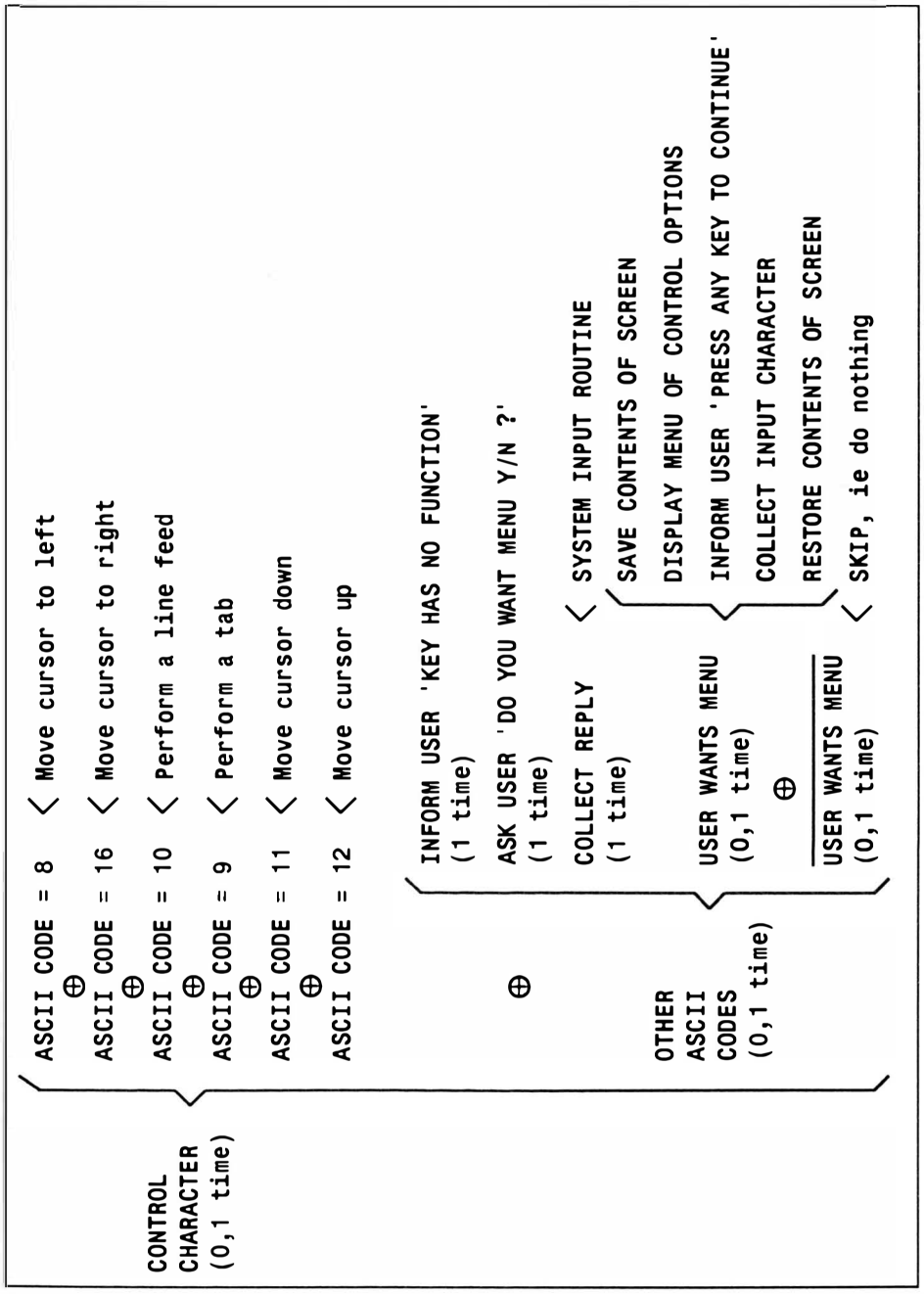


Figure 5.10. The final control character diagram.

I could continue to expand other statements to provide further detailed analysis of the problem. As we do so we reach a point where it is possible to say: *Yes, the operations we are describing in the lower levels of the diagrams (the right-most levels) are easily capable of being coded directly in the language I have chosen to use!* In practice we reach this point far sooner with high-level languages than with assembly languages because more complex operations are supported.

The relevant point to make is that the general principles are the same. The only difference is that when you analyse problems that will be coded in assembly language you will need to carry the analysis further.

In the illustrations given the Warnier diagram was used basically as a tool for expressing, and documenting, ideas and thoughts. The finished design was therefore achieved by a process of *iterative refinement*. There is nothing fundamentally wrong with this approach, even though in practice ideas are likely to change during the time that the initial Warnier diagram sketches are prepared. Very often it is the fact that you can represent your ideas in a pictorial fashion that will help you discover anomalies, faults etc. It is however possible to create Warnier diagrams directly using various logic devices such as truth tables, Karnaugh maps etc, and to check that a diagram is correct mathematically. This book is obviously not, however, the place for such discussions.

The 68000 Connection

You will doubtless have realised that in creating a Warnier diagram we are to a large extent planning the *program control structure* of the piece of software being designed. Consequently conversion to 68000 code revolves essentially around program control structure issues and there are a few points which are worth making about the 68000's instruction set and the various instructions which can be used for creating the necessary control units.

Branches and Jumps

The 68000 as you know has two basic *goto-like* ways of transferring control. The jmp instruction which uses a full sized address, and the bra instruction which uses relative addressing based on a 16 bit displacement. In addition to this there are conditional branch instructions, which take the general form bcc and dbcc, that are able to perform relative branching when specified conditions are met or not met (branch on zero, branch on plus and so on).

The 68000 also supports two basic subroutine type instructions: The branch to subroutine bsr instruction is the relative addressing form of bra which additionally places a return address on the stack

allowing a terminal rts instruction to transfer control back to the instruction immediately after the one that caused the subroutine branch in the first place. The second subroutine instruction of interest is the jump to subroutine jsr form which, like jmp, uses a full sized address rather than a displacement. jsr works like a jmp instruction but like bsr it places a return address on the stack.

In the context of usage flexibility there is a very important difference between the relative branching bra type instructions and full address orientated jmp and jsr forms. The latter instructions have much more scope in terms of available addressing modes. In fact there are seven addressing forms listed as being available for the jmp and jsr instructions:

1. Register Indirect
2. Register Indirect with Displacement
3. Register Indirect with Index
4. Absolute Short
5. Absolute Long
6. PC Relative with Displacement
7. PC Relative with Index

The indirect addressing modes are particularly useful for creating some of the more complex control structures. The instruction:

```
jsr (a5)
```

for instance, performs a subroutine call to a location whose address has been placed in address register a5. The 68000 also has a *load effective address* lea instruction which can compute and load an address register with an address computed using *any* of the 68000's addressing modes. This means that even with the simple indirect subroutine call the processor can be instructed to perform an infinite number of complex subroutine call arrangements. The first instruction of the following fragment, for example, takes an address held in register a2, adds it to the value held in register d4, and then adds a program-specified fixed offset (12 hex in the example) to produce an operand address which is then loaded into register a5. The second instruction performs a subroutine jump to that calculated address:

```
lea $12(a2, d4.l) a5
jsr (a5)
```

Not only does this mean that we've got very flexible conventional run-time (dynamic) and static address calculation facilities but also that things like key-to-address transformation (hash based) schemes are also relatively easily built:

```
jsr     CalculateAddress    calculate hash address in d0
move.l  d0,a5               copy to a5
jsr     (a5)                call appropriate subroutine
```

The net result of all this is simple: the 68000 itself is not likely to place any restrictions on what you can do control-wise because all manner of clever schemes can be devised. In fact once you start working at the processor level you begin to realise that the addressing modes of the 68000, coupled to its relatively symmetrical instruction set, actually tends to liberate, rather then restrict the programmer. At times I sometimes wonder whether it isn't the high-level languages which suffer from shortcomings rather than the low-level ones although I'm sure most people would disagree.

The point again needs to be made that one of the reasons that I feel just as comfortable working with assembly languages as with high-level languages is that before I write one line of assembler code I'll have a logical plan available which shows what must be done!

Black Boxes

I've made quite a point elsewhere of talking about information hiding and *black box* units, subprogram/subroutine units. The ability to create isolated pieces of code which can be used without knowing how they operate makes for re-useable and easily modifiable code units. Inherent in such ideas of modular program construction come two other needs: decent parameter passing schemes as opposed to routines which use a hotchpotch of globally accessible memory locations, and the ability of a routine to create and use variables which are known only to them. Languages like C provide inbuilt mechanisms for parameter passing and use of local variables, but how can we do it from assembler?

There are a number of schemes but one, stack-based allocation, stands out as being particularly important. The idea is simple. As a subroutine is entered the stack pointer register is altered so that some temporary working space is preserved on the stack for the variables and other quantities needed by the routine, conveniently accessed by setting up a *frame pointer* which allows the workspace to be accessed indirectly. The 68000 has a powerful instruction pair called link/unlk which allows this whole process to be automated.

Another important technique, which we've already discussed, is that of preserving and re-instating processor registers during subroutine calls. At the start of the routine you preserve, by pushing onto the stack, those registers which are going to be

utilised during the subroutine call. Just before the routine terminates the pushed values are pulled off the stack and used to return the processor to its original state.

For now though, with the above preliminaries out of the way, it's time to look at some of the basic ways in which the sequence, repetition and alternation building blocks can be tackled with 68000 assembler.

Control Constructs – Sequence

As you might expect, sequence is the easy one. Sequence is implied simply by virtue of the order in which statements are written. If, for example, you need to code something like this:

then, if all the operations were going to be handled as subroutines,you might write something along the lines of:

```
jsr InitializeReplyString
jsr CollectResponse
jsr InterpretReply
```

of course if one or more of the operations were simply enough, ie consisted of just a few relatively obvious instructions, then they might be coded in line.

Suppose that the above routine was using a0 as a reply string pointer and that the strings were using the NULL terminator convention. To initialize a string in such a situation all that needs to be done is to set the first byte (which would be the byte represented by the address held in a0) to NULL, so the above example would just as likely be coded as:

```
move.b  #NULL,(a0)        initialize reply string to ""
jsr     CollectResponse
jsr     InterpretResponse
```

Similarly if you were using some system routine to collect a user string and this routine needed to have the start of the string supplied in d0 you might have a fragment like this:

```
INITIALIZE REPLY STRING
SET UP d0 TO HOLD START OF REPLY STRING
COLLECT USER REPLY WITH SYSTEM CALL
INTERPET USER REPLY
```

In such a case it's not hard to see the sort of translation that would be needed:

```
move.b   #NULL,(a0)    initialize reply string to ""
move.l   a0, d0        system requires start address in d0
jsr      CollectResponse
jsr      InterpretResponse
```

Control Constructs - Repetition

Consider the following fragment:

```
GET CHARACTER
(1, n times)
```

Repetitive sets, when coded, end up as loops. If we choose register d0 as a *loop variable* then the obvious way of coding the above fragment would be along the lines of:

```
         move.b      #LOOPCOUNT, d0
Loop     jsr         GetCharacter
         subq.b      #1,d0
         bne         Loop
```

Of course the 68000 has an automated loop instruction dbcc which handles both the counter modification and, if needed, an extra conditional exit test. Bearing in mind that dbcc quits the loop when the counter register hits -1 (so the count must start at one less than the required value) we'd probably write the above loop like this:

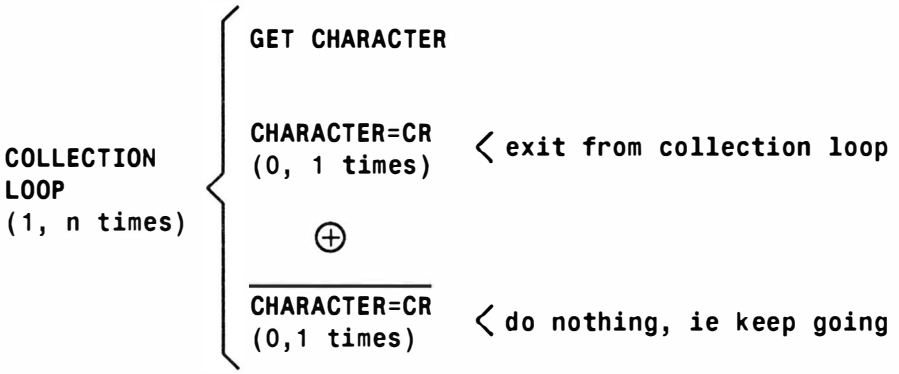
```
Loop     move.b      #LOOPCOUNT-1,d0
         jsr         GetCharacter
         dbra        d0,Loop
```

If the extent of the repetition is not known in advance, as in the now well-worn case of collecting keyboard characters until such time as a return key is detected, then we modify the test conditions accordingly. Supposing that in the above example the GetCharacter

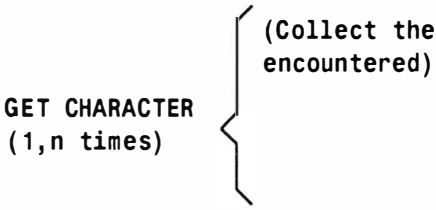
routine, as well as placing the collected character into a string buffer, also returned the character in question in register d0. The code fragment would then need to be something along the lines of:

```
Loop    jsr     GetCharacter
        cmp.b   #CR,d0
        bne     Loop
```

At times you might wish to show the exit conditions explicitly on your Warnier diagrams. The fragment for the above example might therefore have been written as:

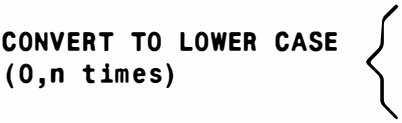


It is not worth being pedantic over the form, or the notation, for such translations. If a repetitive loop requires an exit condition which is obvious to code then there is little point in cluttering up the Warnier diagram with unnecessary detail. Having said that there is, for documentation purposes at least, a case for including some note about any tests which are implied rather than explicitly diagrammed. Bracketed comments do nicely here:



The bottom line then is simple: you take your diagram detail to the point where the actions being specified become easy to code. Obviously the point where this occurs will vary according to your programming abilities and the problem being dealt with!

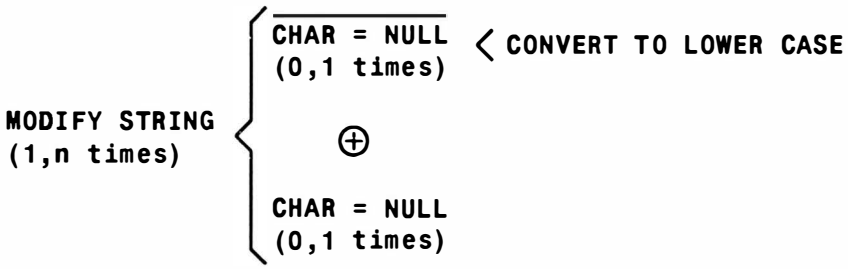
The above loops are post-test forms – the exit condition occurs at the end of the loop. Pre-test repetition, ie repetition of the while/wend variety, is just as easy to create. Take the following diagram fragment:



if we assume that a0 holds the address of the first byte of the string being dealt with, we might code the above fragment like this:

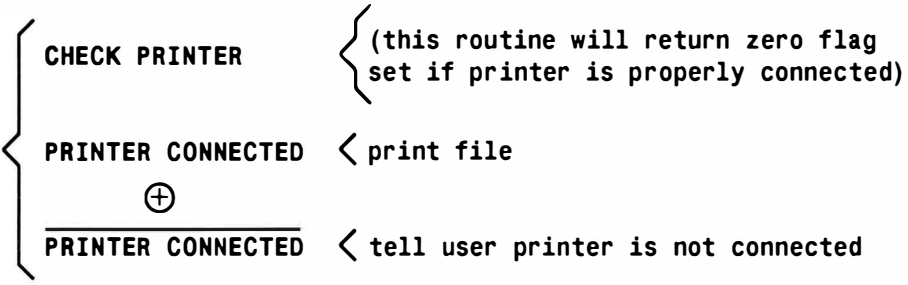
```
      cmp.b    #NULL,(a0)     is first byte a NULL?
      beq      Here
      jsr      ConvertToLowerCase
Here
```

The implication here is that if the string is empty, ie contains only a terminal NULL character, then the ConvertToLowerCase routine is never executed. It's interesting to note, but I'm not going to dwell on this, that the assembly language form actually shows the fundamental nature of the repetitive set which occurs one or more times. The above code actually represents this situation:



Control Constructs – Simple Alternation

To be honest we've already started looking at alternation in the sense of loop termination testing. The if-else type testing needed for fragments like:

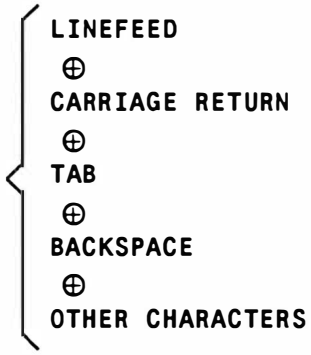


can be coded using these type of schemes:

```
        jsr   CheckPrinter     z flag indicates connection
        beq   Print
        jsr   PrinterMessage
        bra   Here
Print   JSR   PrintFile
Here
```

Control Constructs – Case Alternation

It is possible to extend the above simple alternation schemes to cater for case alternation. This leads to a step by step evaluation of each case. For example:

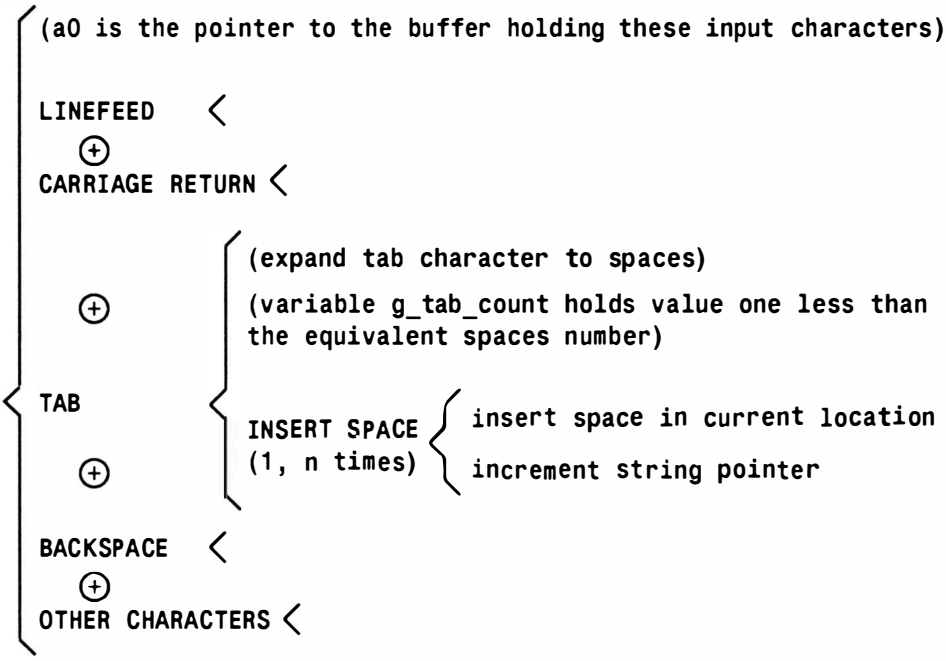


could be coded using this type of framework:

```
LinefeedTest          cmp.b      #LINEFEED,d0
                      bne        CarriageReturnTest
                      do line feed related stuff
                      bra        CaseEnd
CarriageReturnTest    cmp.b      #CARRIAGE_RETURN,d0
                      bne        TabTest
                      do carriage return related stuff
                      bra        CaseEnd
TabTest               cmp.b      #TAB,d0
                      bne        BackspaceTest
                      do tab related stuff
                      bra        CaseEnd
BackspaceTest         cmp.b      #BACKSPACE, d0
                      bne        OtherCharactersTest
```

```
                    do backspace related stuff
                    bra         CaseEnd
OtherCharactersTest ignore or do whatever else is necessary
CaseEnd...
```

Whether the individual actions associated with each case get written as subroutines calls, instead of being written in line, depends to a large extent on what is involved. If you are happy that the necessary code details are easily handled then by all means place them in line. Here's an example. Suppose that the fragment we've just discussed had to expand tab characters to spaces. The relevant details might have been diagrammed as:



The general type of loop for such space insertion would therefore go something like this:

```
                move.b    g_tab_count,d1    get conversion count
InsertSpace     move.b    #SPACE,(a0)       insert space
                addq.l    #1,a1             move to next character
                subq.b    #1,d1             decrease count
                bne       InsertSpace
```

Using post-increment addressing and the specialised dbcc instruction, the above loop can be written more concisely as:

```
            move.b   g_tab_count,d1   get conversion count
InsertSpace move.b   #SPACE,(a0)+     insert space/increment a0
            dbra     d1,InsertSpace
```

There would be no problem in coding those three lines directly. Most assembly language programmers would be able to fill that TAB segment so that the skeleton code framework then looked something like this:

```
LinefeedTest          cmp.b      #LINEFEED,d0
                      bne        CarriageReturnTest
                      do line feed related stuff
                      bra        CaseEnd
CarriageReturnTest    cmp.b      #CARRIAGE_RETURN,d0
                      bne        TabTest
                      do carriage return related stuff
                      bra        CaseEnd
TabTest               cmp.b      #TAB,d0
                      bne        BackspaceTest
                      move.b     g_tab_count,d1
                                   get conversion count
InsertSpace           move.b     #SPACE,(a0)+
                                   insert space/increment a0
                      dbra       d1,InsertSpace
                      bra        CaseEnd
BackSpaceTest         cmp.b      #BACKSPACE, d0
                      bne        OtherCharactersTest
                      do backspace related stuff
                      bra        CaseEnd
OtherCharactersTest   ignore or do whatever else is necessary
CaseEnd...
```

The key, as always, is to only code those aspects which to you seem crystal clear. If you're having trouble figuring out what sort of code should be written for a particular piece of diagram then the chances are that you've not taken the diagram to a sufficient level of detail. The solution is simple – expand your diagrams until they do represent that required detail.

Alternative Schemes for Case Construction

It must be said that, although the above approach has the advantage of being simple, there are occasions when it is inappropriate. One example which springs to mind is where a very large number of individual cases need to be catered for – if, for instance, you have a hundred different cases the above arrangement would lead (on average) to each character being tested fifty times. If you need fast case testing then the above approach is not going to help and alternative schemes need to be found. Here much depends on the particular application but if the values of the case structure entries are close together an indirection table, which provides the addresses of all of the case entries, can be used. You could, for instance, set up a table of routines like this:

```
INDIRECTION_TABLE:  dc.l Sub1, Sub2, Sub3, Sub4, Sub5,
                    dc.l Sub6, Sub7, Sub8...
Sub1:     some relevant code
          rts
Sub2:     some relevant code
          rts
Sub3:     some relevant code
          rts
Sub4:     some relevant code
          rts
Sub5:     some relevant code
          rts
Sub6:     some relevant code
          rts
Sub7:     some relevant code
          rts
Sub8:     some relevant code
          rts
etc...
```

It's then possible to index the appropriate address locations and use an indirect subroutine call to select the appropriate piece of code:

```
move.l     #INDIRECTION_TABLE,a5    base address
(assume that the case data is in d0 so d0 times 4 will
be the required table offset)
```

```
asl.w       #2,d0                   multiply by 4
move.l      (a5,d0.l), a0
jsr         (a0)
```

If it were necessary to transfer control to some place other than the place after the subroutine call you could modify the above scheme by pushing your own return address onto the stack and then follow this with the equivalent jump instruction:

```
move.l      #INDIRECTION_TABLE,a5   base address
(again assume that the case data is in d0)
asl.w       #2,d0                   multiply by 4
move.l      #EndCase,-(a7)          push return address
move.l      (a5,d0.l),a0
jmp         (a0)
(some other code or data, perhaps the indirection table
itself, that shouldn't be executed)
EndCase... continue execution at this point.
```

Design Summary

The overall *diagram<->code* conversion strategy should now be pretty clear. Having described the structure of the program using a Warnier diagram (or set of such diagrams) the conversion proceeds primarily by coding the various bracket levels as subroutines, only adding suitably detailed in-line instructions when the operations being dealt with are straightforward.

The reason why this approach is so effective is simple: It's because most (if not all) of the design issues, as far as program structure is concerned, will have been dealt with *before* any coding is done. Consequently you'll never at this stage have to ask questions like "*whereabouts in the overall program should this piece of code be placed?*", or *"what happens if this routine receives a character other than the ones it expects to receive?"*.

I mentioned earlier that, as far as this type of diagram use is concerned the design process is *iterative.* This begs the question: when do you know that a diagram is finished? The answer is that you know that a diagram is finished when you look at the lower, ie most detailed, diagram levels and think: *"Hey, this isn't so bad. All those things look easy to code!"*.

I certainly do not get such translations right every time, neither does anyone else, and incidentally neither will you, no matter what design techniques you choose to adopt. Fortunately you'll know

when you haven't provided a sufficiently detailed plan – all of a sudden you'll hit coding difficulties because you are not quite sure of what you are doing. That of course is the time to *stop coding*, go back to your design diagrams, and think, preferably in a language-independent way, about what you are trying to do.

I will not be emphasising the pre-code design issues elsewhere in this book and certainly am not going to force you to adopt the use of Warnier diagrams. What I do want to drive home though is this: these pre-coding design issues, as any professional programmer will tell you, really are very important. Some knowledge and experience of either Warnier diagrams or some equivalent technique will make your life as a 68000 coder considerably easier!

6: Program Documentation

Over the years much has been written about the quality of program documentation and in the professional, large-project, arena there are many easily-enforceable guidelines for both user and system documentation. With smaller programs it is usually convenient to adopt a more flexible framework and so I'll restrict my remarks to program comments which occur within the source code.

In-line comments, that is comments placed within the source code itself, should be a valuable documentation aid. Having said that, it is unfortunately not uncommon to find examples of program comments which are at best inadequate and at worst even misleading

Such documentation failings can be serious for several reasons. Firstly, for better or worse, in-line program remarks tend to be long-lived. By their very nature they remain embedded within the code for the duration of its lifetime. Sometimes, even at a professional level, in-line comments may be the only form of program documentation available and if the comments are out-of-date, uninformative, or perhaps downright misleading then the maintenance of the program is likely to prove more difficult than if the program had been left uncommented.

In-line commenting problems fall into a number of recognisable classes:

- Relatively pointless additions which essentially duplicate information that is obvious from looking at the code itself.
- Comments which are misleading or incorrect.
- Situations where so many comments are present that the important ones become hidden amongst a mass of trivial remarks.
- Situations where an insufficient number of comments have been included.
- Situations whereby comments have become dangerous by virtue of the fact that they are out-of-date.

Pointless additions are surprisingly common. A programmer may add a comment which simply duplicates something that is perfectly obvious from the code itself. For example:

```
move.l #0, count        set count to zero!
```

These types of additions arise for a number of reasons. Occasionally the less experienced programmer may include such a remark to remind themselves what they are doing. It's an understandable trait but more experienced programmers reading the code will find such comments of no value whatsoever. There are however occasions where it might be necessary to draw attention to the fact that such an initialisation is important. This example for instance tells the programmer reading the code something very important about the variable in question:

```
move.l #0, count    ;don't forget that this count
                    ;variable must be set to zero each
                    ;time this routine is entered!
```

You will of course find a lot of comments in this book which, once you have some 68000 coding experience under your belt, will be recognised as *stating the obvious*. Such comments have of course been added to ease your passage through the code in the early days!

Comments which are misleading or incorrect can also be particularly troublesome. Programmers examining your program code will invariably accept in-line comments without question and this assumption, that any comments present correctly reflect the actions of the source code, is known to lead to the programmer suffering psychological blind spots. The results? Programmers may fail to recognise errors that might otherwise have been patently obvious.

Over-commenting is perhaps less of a danger but it is worth bearing in mind that rather more sparing use of comments in general might enable you to effectively highlight any difficult areas by providing additional comments in those areas needing special attention. This potential benefit is lost if such areas are buried deep within large numbers of less important comments.

A total lack of comments isn't a danger, but it's a nuisance because you have to work harder to understand what the program is doing if you wish to change something. There are a number of reasons why a programmer might not bother to comment a program. Perhaps the program was originally written for a once-only use, perhaps the programmer thought that the code was self-explanatory. Many programmers do not bother to change comments when they make program modifications. The result, another danger, is that program code and in-line documentation diverge.

Don't make the mistake of thinking that comments are just to help other users and that you understand your code well enough not to need additional remarks. That may be so when you write the program, but you'll be in for a surprise when you regularly start looking back at code you wrote several years ago – it's amazing how code tricks which seemed perfectly obvious at the time seem to loose their *inherent obviousness* with the passage of time. The solution? Make sure that you provide decent in-line documentation and, most importantly, get the appropriate notes into the source code whilst you are creating the program – don't wait until after the program is complete!

Several options exist for improving the quality of source code documentation. Comments should be structured in the same way as the program code itself. Remarks placed within a routine should be such that they apply only to the routine in question, not to the application which it is part of. This ensures that when a routine is re-used in another application, extraneous comments relating to a previous application are not inadvertently included.

Adopting a clean, structured, approach to program design helps to ease potential maintenance and commenting problems. Modules and routines should be created which communicate via well-defined interfaces so that the details of a particular routine can be hidden within that routine. Modules should be given comment headers which explain their purpose. At lower levels subroutines and functions should also contain details which provide an overview of the routines themselves, explain any conventions in use, identify the parameters expected, and indicate the way in which results are returned.

Self Commenting Languages

In-line commenting, whilst important, should still be considered essentially as an addition to, and not a replacement for, any self-documenting facilities of the language itself. Self-documenting facilities? Yes, nowadays almost all languages allow useful conventions to be adopted which can help to make the source code more intelligible and 68000 assembler is no exception.

Use understandable names for variables and symbolic constants. Adopt conventions such as prefixing global variables with the character g_ and suffixing pointer variables using _p, so that the type of variable can be implied from its name:

```
move.l #FALSE, g_exit_flag      ;clear exit flag - user
                                has decided not to quit
```

is a much preferred alternative to code which reads like this:

```
move.l #0, ef                   ;clear global exit flag
                                ;- user has decided not
                                ;to quit
```

Don't get carried away with such conventions. You are after all aiming to produce guidelines which can help, not build rigid restrictions which will hinder. For the most part all that's needed is a common-sense understanding of the usefulness of in-line documentation, coupled to a consistent methodical approach. A bit of thoughtfulness in these areas will pay handsome dividends.

Guidelines

Before leaving the topics of languages, documentation and so forth there's one last point to make. Whatever conventions you adopt you will need more documentation than any language alone can provide. Programmers are of course more noted for their *Let's do some coding* attitudes than for any excessive desire to document their programs. But eventually failure to keep adequate notes will cost dearly, both in lessons not learnt and in lost time. The following guidelines provide a reasonable starting point although I'm sure that you are not going to be short of your own ideas:

- The golden rule is simple. Document *whilst* you are developing the program and not afterwards. By all means tidy up the development notes after the program is complete but don't wait this long before you make any notes at all. In this respect design techniques based on Warnier diagrams provide their own documentation as far as the progress of the design path goes. You'll usually need however to keep plenty of other notes as well.

- If possible try to develop a pseudo-standard layout for all your projects. Produce development notes that, in conjunction with any design work, will show what the objectives of writing the program were, and explain the reasons behind your approach. The task of producing this documentation is not quite as onerous as it might seem. If you have a text editor program then you can keep most of the documentation on disk, which has the advantage that it is very easy to keep up to date.
- Keep all of your design diagrams etc, and make notes about the problems you encounter during the development. Especially note any assumptions you make that might affect program operation if they were changed in the future. Note also which parts of the code are dependent on, eg the operating system I/O characteristics, particular control characters that might vary from system to system etc.
- If the routines are small then include the documentation with source code. Remember, if a routine requires a particular format for the data that it works on, then provide some sort of indication within the routine itself so that the general ideas behind it are apparent. Use titles that indicate what operations the routines perform.
- Keep some details within the source code itself telling you the name of the program, when it was written, where any additional documentation may be found and notes about other points which might be relevant. A simple scheme is usually all that is required as such that shown in Figure 6.1. below. Don't bother about trying to understand what the code does but do notice how much use I've made of understandable labels, variable names and in-line comment.

```
* ========================================================== *
* AUI-SPELL PATCH:  word_count.s for version 0.10            *
*                                                            *
* Programmer:       Paul Overaa                              *
*                                                            *
* Date:             1st March 91                             *
*                                                            *
* Patch for analysing an ASCII file and counting             *
* words and linefeeds.                                       *
* ---------------------------------------------------------- *
* a0   is loaded with the address of the start of the buffer
* a1   holds the start of the current word
* d4   holds the character count of the current word
* d5   is loaded with the total number of characters in the
* file
       XDEF    _WordCount
       XREF    _g_buffer_p
       XREF    _g_filesize
       XREF    _g_line_count
       XREF    _g_word_count
lowercase_z    equ  $7A
lowercase_a    equ  $6
1uppercase_z   equ  $5A
uppercase_a    equ  $41
LINEFEED       equ  $0A
* ---------------------------------------------------------- *
_WordCount  movem.l a2-a6/d2-d7,-(sp)    preserve for Lattice
* It's easy to get confused about the next line of code so
* here's a general note which might help..... If
* the C program had a declaration like UBYTE g_buffer[10000]
* then the address of the variable would be the start
* address of the buffer area and we'd use immediate address
* -ing, i.e. move.l #_g_buffer_p,a0, to load a0. BUT.......
* since we are actually using AllocMem() to get memory we
```

```
* have made the declaration LONG g_buffer_p, so it's the
* CONTENTS of g_buffer_p that need to be loaded into a0,
* hence we use a move.l _g_buffer_p, a0 instruction instead !
       move.l  g_buffer_p,a0      buffer start - see above note
       move.l  g_filesize,d5      characters in file
       move.l  #0,_g_word_count   no words yet !
* ------------------------------------------------------------ *
FINDSTART      cmpi.b  #lowercase_z,(a0)   is char a-z ?
               bhi     NOTLOWERCASE
               cmpi.b  #lowercase_a,(a0)
               bcs     NOTLOWERCASE
               move.l  a0,a1               put word start in a1
               moveq   #1,d4         initialize character count
               bra     START_FOUND         now look for end
NOTLOWERCASE   cmpi.b  #uppercase_z,(a0)   is char A-Z ?
               bhi     NOTLETTER
               cmpi.b  #uppercase_a,(a0)
               bcs     NOTLETTER
               move.l  a0,a1               put word start in a1
               moveq   #1,d4         initialize character count
               bra     START_FOUND         now look for end
NOTLETTER      cmpi.b  #LINEFEED,(a0)      end of line char ?
               bne     NOTLETTER1
               addq.l  #1,_g_line_count    count line
NOTLETTER1     addq.l  #1,a0         point to next character
               subq.l  #1,d5     decrease characters left count
               bne     FINDSTART     and see if that's the word
                                     start
               bra     FINISH
START_FOUND    addq.l  #1,_g_word_count    count this word
FINDEND        addq.l  #1,a0         point to next character
               subq.l  #1,d5     decrease characters left count
               beq     FINISH        end of file found so quit
               cmpi.b  #lowercase_z,(a0)   is char a-z ?
```

```
                bhi     NOTLOWERCASE2
                cmpi.b  #lowercase_a,(a0)
                bcs     NOTLOWERCASE2
                addq.b  #1,d4     increment 8 bit character count
                bra     FINDEND
NOTLOWERCASE2   cmpi.b  #uppercase_z,(a0)   is char A-Z ?
                bhi     NOTLETTER2
                cmpi.b  #uppercase_a,(a0)
                bcs     NOTLETTER2
                addq.b  #1,d4         increment character count
                bra     FINDEND
NOTLETTER2      cmpi.b  #LINEFEED,(a0)      end of line char ?
                bne     NOTLETTER3
                addq.l  #1,_g_line_count    count line
NOTLETTER3      addq.l  #1,a0         move to next character
                subq    #1,d5     decrease characters left count
                bne     FINDSTART
* ------------------------------------------------------------ *
FINISH          movem.l (sp)+,a2-a6/d2-d7 re-instate for Lattice
                rts         back to C
* ============================================================ *
```

Figure 6.1. A typical piece of documented code.

Since the programs that you write are part and parcel of your documentation it is worth digressing for a moment to make the following point: in the same way that a standardised documentation layout helps to provide consistency, so does a standardised program layout. But all your programs are different? Well yes, to a certain extent this is true, but there are many things about the overall structure that will often be similar and a bit of consistency in style and overall layout can go a long way!

7: An Introduction to the Amiga Environment

Unless you have come to the Amiga via the world of Unix or the mainframe, most of the ideas related to multi-tasking will be new to you. Similarly there may be a lot of other issues concerning the protocols which Amiga programs need to adopt that may seem rather complex, to say the least. None of this complexity however is there just for the sake of it and by learning about and applying the rules that your programs must follow to co-exist in a safe and system controlled manner, you will save yourself much grief when you move on to the writing of larger programs.

You know already that on the Amiga many programs can be running at the same time. Imagine the chaos which would ensue if one program suddenly decided it wanted to take over control of the disk hardware whilst another program was using it. These types of *contention* issues, where two or more programs could conceivably be trying to use the same system resources at the same time, cannot be solved at the hardware level. On the Amiga a software system has been devised which solves this problem, thus making it possible for many different programs to share a common set of hardware resources. A

key element in this scenario is the Amiga's multi-tasking Exec software. But before discussing Exec itself, a few words about some other Amiga entities are needed.

Devices

As far as hardware access is concerned the Amiga places a software layer, based on the use of a software entity called a *device*, between the real hardware and the applications programs. If, for example, your program wishes to gain access to the serial port it must try to *open* the serial device. Providing the device is successfully opened the program then writes or reads its serial data using the serial device and *not* the underlying hardware.

This arrangement provides all programs with a standardised way of communicating with the Amiga's hardware and neatly solves the potential contention issues. It doesn't alter the fact that sometimes, because a piece of hardware is already in use, a program will not always be able to open the corresponding device, but it does mean that programs can ask and be informed about what is and what is not available for use at any given time and can therefore take some appropriate actions.

If, for instance, during the time the serial device was being exclusively used by one program, another program tried to gain access to the serial device to read and write totally unrelated data, the *open serial device* request would fail. This is the system's way of telling the second program that the underlying hardware is not available for use.

In short then the Amiga's devices provide this sort of standardised software interface between the programs which may be running and the hardware itself. See Figure 7.1.

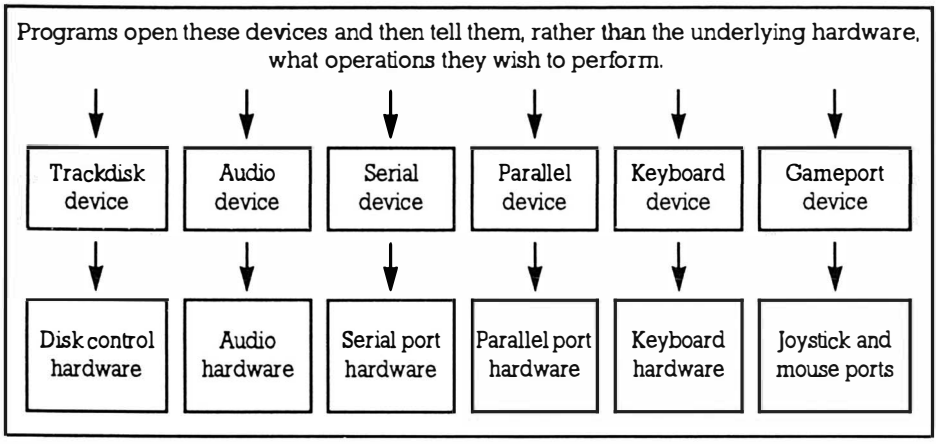


Figure 7.1. Beneath the device software lies the real Amiga hardware.

Because of this approach you'll realise that, initially at least, it is the *devices* which the programmer needs to understand rather than the underlying hardware. There are incidentally other Amiga devices, such as the Console and Input devices, which are not directly tied to particular hardware units.

The device software barrier is not the only one which isolates an Amiga programmer from the underlying hardware because a similar situation exists with the main processor itself. On the Amiga the chances, even once you are an experienced system programmer, of getting anywhere near the 68000 microprocessor's on-chip interrupt system are very remote unless you are prepared to take over the whole machine. Interrupts are hardware signals which cause the processor to stop what it is doing and execute a pre-determined piece of code called an *interrupt routine.*

Why? Again, in a word, multi-tasking. This time the issues are to do with how the processor is able to appear to run more than one program at any given time. In reality a single 68000 chip can only run one program at a time, so the only way that the Amiga can *multi-task* is for the processor time to be physically shared amongst the various programs wishing to run. Each program in turn has to be given a bit of time to run and when this time slot is up the program has to be suspended whilst another program is activated.

This, as you might imagine, is not a trivial task. Each program must think that it has a *virtual machine* all to itself. Programs must have their own stacks and whenever the execution of a program is temporarily suspended, things like current microprocessor registers will need to be preserved. When the same program is again given the chance to run, all of this information must be re-instated before the program can continue running.

Such tricks are achieved with the help of some clever programming of the 68000 interrupts. Exec keeps track of the state of the multi-tasking game both at the end of all interrupt processing and on occasions when a particular task has indicated that it wishes to sleep, ie become inactive, for a while. A typical example of this latter situation would be a program which is waiting for a user to hit a gadget before doing anything. Such programs can call a Wait() function which results in program execution being suspended until a gadget is actually selected by the user. The benefits should be obvious – during such times the processor doesn't have to waste time running a program which is effectively sitting idle but it can be getting on with something else.

Enter Exec

The software which performs this task switching magic is called Exec. Every time, for example, a vertical blanking interrupt occurs the current tasks are examined and, depending on the system conditions, a decision is made as to whether to allow the current program to continue running or whether to suspend it and give another program the chance to run.

The process of deciding which task should be running, and then kicking it off (getting it going) if necessary, is called task-scheduling. If all tasks have equal priority then they are given equal shares of the processor's time and each task, providing it is in fact ready to run, takes its turn using an *I'm next for some processor time* task queue arrangement, known as a *round robin* scheme. Because the tasks themselves have no say in whether they run or not, this time-slicing is called pre-emptive task-scheduling.

For now though we need to get back to the interrupts issues. The 68000 has three interrupt lines which are used together to provide interrupts of differing priority. It's important, at this stage, to point out that the Amiga's interrupt system is not purely based on the 68000 facilities – something is happening at a higher hardware level. One of the Amiga custom chips, the 4703 (known as Paula) is actually watching fifteen different sources of interrupt, both hardware and software instigated, and it's this chip that then generates the real 68000 signals.

So, disk, serial I/O related, copper, vertical blanking, blitter, audio,software generated interrupts and a number of other interrupt sources all pass through Paula as interrupts of varying priority levels. One of Exec's most important jobs is to *housekeep*, ie look after, the whole of this interrupt system. Another is to provide multi-tasking facilities for the whole machine, ie to organise and perform pre-emptive task scheduling. When you also realise that the Amiga system allows any number of applications programs to set up their own interrupt jobs and that these, when executed with Exec's blessing, slot neatly into the existing system interrupt arrangements, you'll conclude that we are talking serious software here. Exec deserves, and should be treated with, the utmost respect!

Now for the bottom line. Exec, in order to achieve this magic, *must* keep absolute control not only over the real 68000 hardware interrupt system but the whole of the interrupt subsystem. This is why you will never, for example, deal with the 68000 interrupts directly – you will deal with Exec, the software layer which will handle your needs and translate them into a form suitable for the Amiga's complex multi-tasking environment.

The beauty of Exec is that the multi-tasking is effectively transparent so your programs will rarely need to worry about the underlying complexity. Other facilities, such as those which allow messages to be passed between various tasks, are not transparent and it important to understand them if you wish to program at the Exec level.

AmigaDOS – the Amiga's Disk Operating System

AmigaDOS is a multi-processing operating system designed primarily for the single user. This is different from say Unix which was designed to be a multi-user, multi-tasking, operating system.

AmigaDOS handles the disk filing system and allows many jobs (processes) to run simultaneously. Much of the magic of AmigaDOS, the Amiga's disk operating system, is actually due to the underlying Exec facilities. In a sense AmigaDOS is built on top of the Exec and trackdisk components of this system jigsaw puzzle so, from a purely schematic viewpoint, we can show the arrangement as in Figure 7.2.

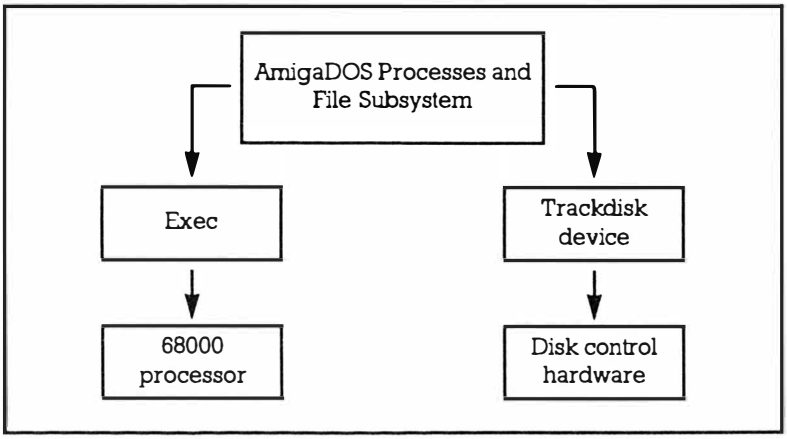


Figure 7.2. Programs interact with the hardware via AmigaDOS, Exec and system devices.

If we now superimpose this sketch onto that of Figure 7.2 shown earlier, a useful picture starts to emerge. See Figure 7.3.

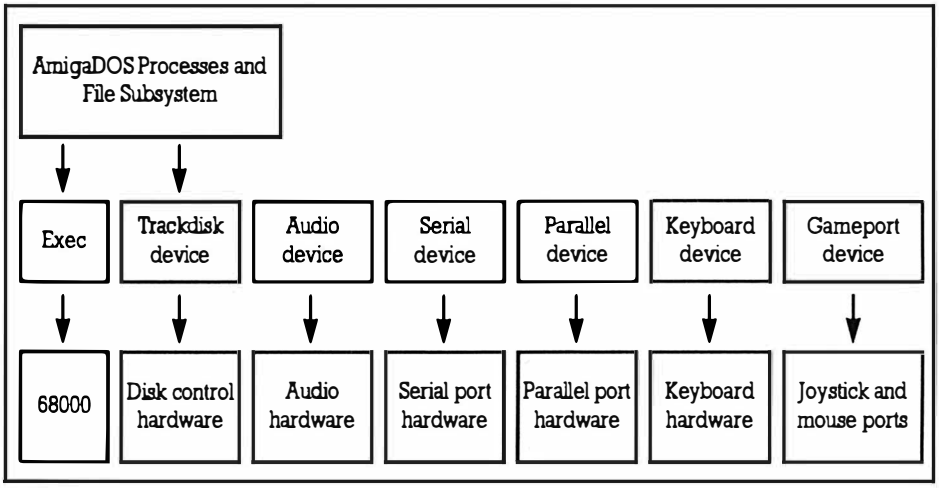


Figure 7.3. Programs interact with the hardware via AmigaDOS, Exec and system devices.

Already you should realise that the Amiga programmer is, to a very large extent, isolated from the real hardware. This is true even for the low-level programmer unless, as is the case with some games programmers, they are prepared to take over the whole machine and forfeit all the advantages of multi-tasking.

The Amiga System Libraries

Another important component of the Amiga's software is the system's library routine arrangement. Library routines are just generally useful routines which have been written and included as part of the operating system software.

Where the Amiga differs from that of many less sophisticated computers is in the actual arrangement which has been adopted to implement these libraries. If you wanted to use a certain system call in the good old *eight bit* days (of CP/M machines and computers like the Sinclair ZX81, Apple II and Commodore 64), the chances are that you would use either a function number arrangement, where you made a call to a fixed entry location but provided a value in one of the processor registers which told the operating system which service you required, or alternatively you would actually know the memory address of the system routine being called.

For Amiga programmers those days are over because most of the time you will not know where the system routines are. Some may be held in ROM, some will be placed into memory as the machine starts operating, and some taken from disk as and when a program decides that they are needed! Worse than that, the routines which

are loaded into memory are not assigned fixed locations, they essentially get placed in any convenient area that is available and that means that the location of the library routines can change each time a library is used.

To move into this area of Amiga programming there are two things you'll need to know. Firstly how to find these system routines, and secondly how to use them once you have found them. These are questions which I'll deal with in Chapter 10.

Intuition, the Amiga's high-level graphics interface which we've all come to understand and love, is built on the facilities provided by the graphics and layers libraries. By working in conjunction with the input device, a slightly higher-level device that is continually being fed information from the Amiga's keyboard and gameport devices, Intuition is kept informed about what, if anything, users are doing in the outside world.

The Amiga's Workbench uses Intuition facilities to provide its WIMP orientated user interface. Intuition, like Exec, is essentially a mass of pre-written routines much the same as any of the other system library. Because of the way both of these components interact with other parts of the system it is however useful to show them as distinct components.

The Final Picture

On top of everything we've discussed comes the applications programs themselves – the programs which you run to do useful work! As you'll doubtless already know, the Amiga supports both WIMP orientated interaction(using Intuition's windows, gadgets, menus etc) and command line CLI/Shell type programs.

Programmers can interact with Intuition to achieve many high-level WIMP orientated operations, can access the hardware via the Amiga's device mechanisms, can use a large number of pre-written library functions to simplify common programming tasks, and can allow AmigaDOS to handle the nitty gritty details of disk file management and related housekeeping jobs. In addition to this the graphics/display subsystem (which includes both hardware components, such as the copper and the blitter circuits, and software components for handling things like animated graphics) is also available to any applications program which needs it.

When we put all of this together we end up with a picture, which though far from complete, should provide a working appreciation of how the various Amiga system components fall into place.

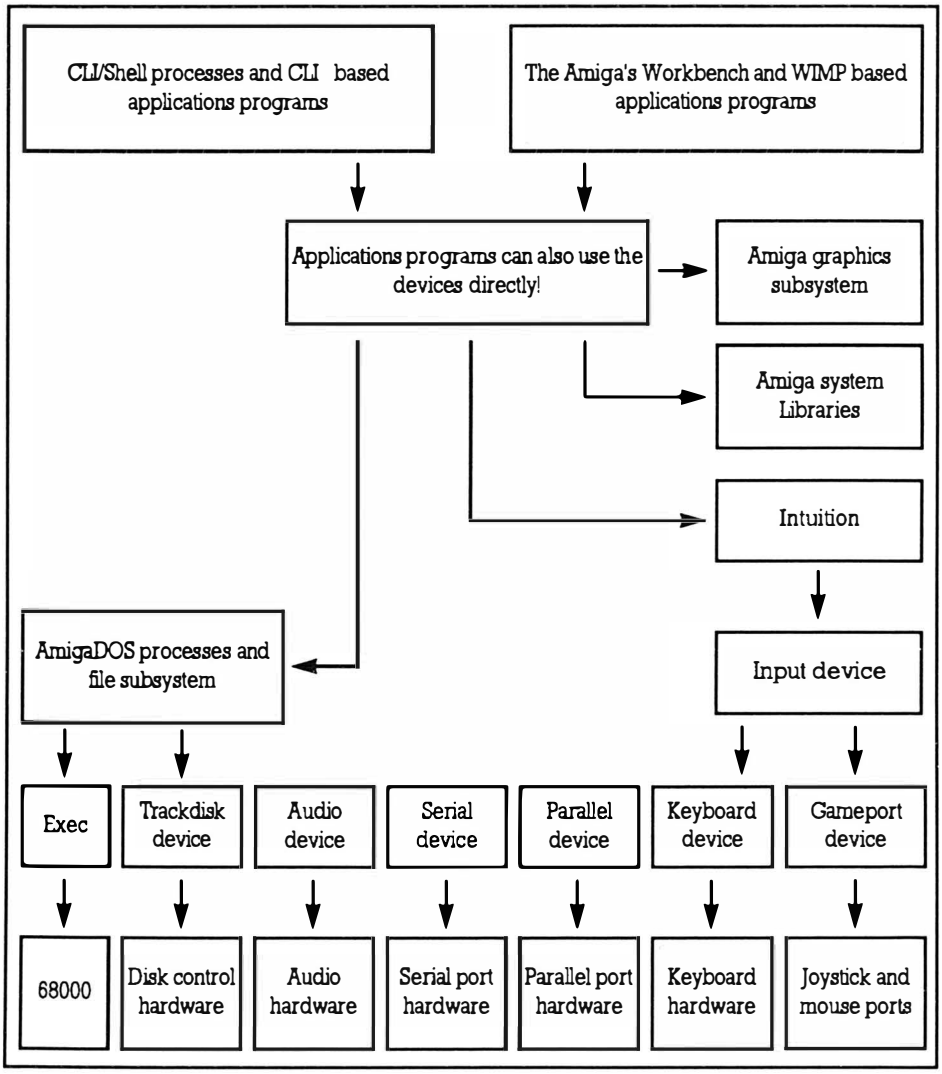


Figure 7.4. Relationship between the main software components and the underlying hardware.

As you will now appreciate, Exec, Devices, AmigaDOS, System Libraries and Intuition itself are extremely important. Understanding these components is absolutely essential if you wish to become a serious Amiga programmer. Luckily all that is really needed initially is an overall appreciation of the system coupled with some more detailed information on areas which are likely to be immediately useful to you. It is these latter topics that I'll deal with over the next few chapters but to finish this chapter here are a few general notes on some hardware related issues that you may already have been exposed to.

The PAD, Chip Memory, Bus Contention, and the ECS

Part of the power of the Amiga is undoubtedly due to the custom chips known as Paula, Agnus and Denise. These chips, known collectively as the PAD, are capable of running in parallel with the main 68000 processor – using odd clock cycles when the 68000 is not accessing external memory. A *gate* mechanism controls access of the system bus and thus ensures that the RAM/ROM chips, the 68000 processor, the I/O chips, and the PAD chips are all connected to the system bus at the appropriate times.

I've already mentioned the relationship of the 4703 Paula chip to the interrupt subsystem. The PAD also controls twenty five direct memory access (DMA) channels which allow RAM access to be achieved without using the 68000 processor. These DMA channels are dedicated to specific uses – 6 channels are for the screen bitplane access, 8 for sprites data, 1 for the co-processor (copper), 4 for the blitter, 2 for disk DMA and 4 for audio.

DMA access is restricted to chip memory. You've no doubt heard the terms chip memory and fast memory and as likely as not you already know what they mean. Just in case however a few words of explanation are in order.

In actual fact there's nothing different about particular RAM chips themselves which lead to labels like *chip memory* and *fast memory.* It is all to do with the way the gate mechanism grants access to the system bus and to the effect on certain areas of addressable memory. Here are some details. The Amiga's Motorola 68000 16/32 bit processor has an address space of 16 megabytes and, with the Amiga's memory map, 8 megabytes of this are available for random access memory (RAM). The reason that not all of this addressable memory is the same stems from the fact that part of the RAM address space is shared by both the 68000 processor and the Amiga's three custom chips. It is this shared memory that is commonly referred to as *chip* memory.

Now I've already mentioned that Paula, Agnus and Denise handle a number of specific tasks involving graphics, general screen display operations, DMA etc. The blitter incidentally, the device which can move pixel data around the screen at speeds approaching one million pixels per second, is part of the Agnus chip. The important point about all of this is that, under certain conditions these powerful chips can actually lock out the main 68000 processor, an operation known as cycle-stealing. This only happens when absolutely necessary (and during these cases the custom chips are performing operations more efficiently than the 68000 could do

anyway) but the end result nevertheless is that programs actually running in chip memory at such times get somewhat rudely prevented from doing so!

Some clever hardware tricks however allow the 68000 processor, even whilst locked out of chip memory space, to still access RAM memory outside of this region. This non-chip memory, called fast memory for fairly obvious reasons, is therefore an ideal place for having your runable programs. For maximum speed therefore it is worth remembering that, ideally, you want to have both chip and fast memory available – programs can therefore run in fast memory and will not be slowed down by any custom chip cycle-stealing operations!

Fat Agnus

The amount of address space that these original custom chips could share was limited to a 19-bit address. This meant that the above mentioned bus contention problems only affected the lower 512K of the machine. It also meant that no matter how much RAM was available in the machine the custom chips could only access that lower 512K. In the early Amiga days this wasn't too much of a limitation but as Amiga programs (especially graphics and animation programs) have grown in size and power the 512K limitation is now becoming a little restrictive.

To put these numbers into perspective a single 5 bitplane high resolution PAL screen will soak up 100K of chip memory, and a corresponding interlaced display takes 200K, ie almost 40% of all the chip memory available on a 512K machine. When you realise that DMA sound samples, graphics objects and various other items often need to be stored in custom chip accessible memory then 512K begins to look almost miserly.

Several years ago Commodore began working on an enhanced chip set (ECS) and this included a replacement for Agnus called *Fat Agnus*. This new version, so called because of its physical shape, effectively does the same job as the original chip but reduces the support chip component count – all clock generation for the Amiga system for instance is now incorporated into Fat Agnus as are the control signals for handling chip RAM access.

The big difference as far as chip memory goes though is that Fat Agnus now has address lines which can access twice as much memory. Hence a machine fitted with Fat Agnus has one megabyte of shared address space and so can have one megabyte of chip memory fitted. Obviously this is a big advantage for graphics intensive operations like animation especially when a suitable amount of additional fast memory is also available to the system!

The Copper

The Amiga contains a beam-synchronised graphics co-processor which can execute its own programs, called copper lists. It is able to effectively track the display video beam as it moves down the screen and can be programmed to carry out specific operations, such as changing bitplane pointers, altering the colour values in the hardware colour registers or using the blitter to carry out high-speed graphics operations. The copper can even affect external memory by issuing a CPU interrupt. There are some excellent display tricks which can be done by programming this chip but these fall firmly into the domain of Amiga systems programming and are not suitable material for an introductory assembly language book.

An Admission of Guilt

The overview you've just read has been made deliberately easy going. Many things which perhaps could have been mentioned have been left out. Why? It is because to mention them would have meant that I would have to have explained them and that would have turned a hopefully easily understood general overview into a more detailed, but far more disjointed, account. Subsequent chapters will now deal with a number of 68000 system programming issues in more detail but I am hoping that now the general Amiga system framework has been outlined, at least some of the topics will be less traumatic for the newcomer than they might otherwise have been.

8: The Amiga System Include Files

The Amiga has a large collection of system include (header) files available. In fact two distinct versions of these files exist, one set for C programmers and the other set for assembly language programmers. The file set which assembly language programmers use have a .i (i for include) name convention whereas the corresponding C language equivalents use .h (h for header) suffix filenames. Essentially the material which they contain serves identical purposes but, because of the differences between low-level 68K assembler and the high-level C language, there are equivalent differences in the way various definitions are created. This book is devoted to assembly language so I'll be talking almost exclusively about the .i include files. Bear in mind that when I mention an include file such as exec/memory.i that there is a corresponding file exec/memory.h available for those working in C.

So, what do these files contain? Basically thousands of predefined constants, template definitions for things like screens and windows, and macros all designed to make life easier for you the programmer. That said, they only make life easier if you understand them and are familiar enough with them to use them effectively.

An Example System Include File

The best way to learn how to get the maximum benefit from the Amiga include files is to look at them, use them, and think about them – slowly but surely you will learn to find your way around them and, with practice, learn to use them in the way Commodore intended. If you are new to assembler you have a golden opportunity to study them in detail. Make the most of this opportunity, the effort which has gone into them is considerable and, along with examples from the world of Unix and the mainframe, these Amiga system include files are amongst the best ever written!

Purely from the point of view of space it is not practical to list every Amiga system file. Nevertheless an example of a .i include file is going to be given in order to provide a reference point for subsequent discussions. The following file, which is the 1.3 release intuition/screens.i systems file, is reprinted courtesy of Commodore-Amiga Inc:

```
IFND  INTUITION_SCREENS_I
INTUITION_SCREENS_I     SET   1
**
** $Filename: intuition/screens.i $
** $Release: 1.3 $
**
**
**
** (C) Copyright 1987,1988 Commodore-Amiga, Inc.
**        All Rights Reserved
**
   IFND EXEC_TYPES_I
   INCLUDE "exec/types.i"
   ENDC
   IFND GRAPHICS_GFX_I
   INCLUDE "graphics/gfx.i"
   ENDC
   IFND GRAPHICS_CLIP_I
   INCLUDE "graphics/clip.i"
   ENDC
   IFND GRAPHICS_VIEW_I
   INCLUDE "graphics/view.i"
```

```
    ENDC
    IFND GRAPHICS_RASTPORT_I
    INCLUDE "graphics/rastport.i"
    ENDC
    IFND GRAPHICS_LAYERS_I
    INCLUDE "graphics/layers.i"
    ENDC
; ===========================================================
; ===Screen =================================================
; ===========================================================
STRUCTURE Screen,0
    APTR sc_NextScreen    ; linked list of screens
    APTR sc_FirstWindow   ; linked list Screen's Windows
    WORD sc_LeftEdge      ; parameters of the screen
    WORD sc_TopEdge       ; parameters of the screen
    WORD sc_Width         ; null-terminated Title text
    WORD sc_Height        ; for Windows without ScreenTitle
    WORD sc_MouseY        ; position relative to upper-left
    WORD sc_MouseX        ; position relative to upper-left
    WORD sc_Flags         ; see definitions below
    APTR sc_Title
    APTR sc_DefaultTitle
    ; Bar sizes for this Screen and all Window's in this Screen
    BYTE sc_BarHeight
    BYTE sc_BarVBorder
    BYTE sc_BarHBorder
    BYTE sc_MenuVBorder
    BYTE sc_MenuHBorder
    BYTE sc_WBorTop
    BYTE sc_WBorLeft
    BYTE sc_WBorRight
    BYTE sc_WBorBottom
    BYTE sc_KludgeFill00 ; This is strictly for word-alignment
    ; the display data structures for this Screen
    APTR sc_Font                    ; this screen's default
                                    ; font
    STRUCT sc_ViewPort,vp_SIZEOF    ; describing the Screen's
                                    ; display
```

```
    STRUCT sc_RastPort,rp_SIZEOF    ; describing Screen
                                    ; rendering
    STRUCT sc_BitMap,bm_SIZEOF      ; auxiliary graphexcess
                                    ; baggage
    STRUCT sc_LayerInfo,li_SIZEOF   ; each screen gets a
                                    ; LayerInfo
    ; You supply a linked-list of Gadgets for your Screen.
    ; This list DOES NOT include system Gadgets. You get the
    ; standard system Screen Gadgets by default
    APTR sc_FirstGadget
    BYTE sc_DetailPen     ; for bar/border/gadget rendering
    BYTE sc_BlockPen      ; for bar/border/gadget rendering
    ; the following variable(s) are maintained by Intuition
    ; to support the DisplayBeep() color flashing technique
    WORD sc_SaveColor0
    ; This layer is for the Screen and Menu bars
    APTR sc_BarLayer      ; was "BarLayer"
    APTR sc_ExtData
    APTR sc_UserData      ; general-purpose pointer to User data
    LABEL sc_SIZEOF
; --FLAGS SET BY INTUITION ----------------------------------
; The SCREENTYPE bits are reserved for describing various
; Screen type available under Intuition.
SCREENTYPE    EQU   $000F   ; all the screens types available
; --the definitions for the Screen Type----------------------
WBENCHSCREEN EQU    $0001   ; Ta Da! The Workbench
CUSTOMSCREEN EQU    $000F   ; for that special look
SHOWTITLE     EQU   $0010   ; this gets set by a call to
                            ; ShowTitle()
BEEPING       EQU   $0020   ; set when Screen is beeping
CUSTOMBITMAP EQU    $0040   ; if you are supplying your own
                            ; BitMap
SCREENBEHIND EQU    $0080   ; if you want your screen to open
                            ; behind already open screens
SCREENQUIET   EQU   $0100   ; if you do not want Intuition to
                            ; render into your screen
                            ; (gadgets, title)
STDSCREENHEIGHT     EQU  -1 ; supply in NewScreen.Height
; ========================================================
; === NewScreen ==========================================
```

```
; ========================================================
STRUCTURE NewScreen,0
    WORD ns_LeftEdge      ; initial Screen dimensions
    WORD ns_TopEdge       ; initial Screen dimensions
    WORD ns_Width         ; initial Screen dimensions
    WORD ns_Height        ; initial Screen dimensions
    WORD ns_Depth         ; initial Screen dimensions
    BYTE ns_DetailPen     ; default rendering pens (for
                          ; Windows too)
    BYTE ns_BlockPen      ; default rendering pens (for
                          ; Windows too)
    WORD ns_ViewModes     ; display "modes" for this Screen
    WORD ns_Type          ; Intuition Screen Type specifier
    APTR ns_Font          ; default font for Screen and
                          ; Windows
    APTR ns_DefaultTitle  ; Title when Window doesn't care
    APTR ns_Gadgets       ; Your own initial Screen Gadgets
    ; if you are opening a CUSTOMSCREEN and already have a
    ; BitMap that you want used for your Screen, you set the
    ; flags CUSTOMBITMAP in the Types variable and you set
    ; this variable to point to your BitMap structure. The
    ; structure will be copied into your Screen structure,
    ; after which you may discard your own BitMap if you want
    APTR ns_CustomBitMap
LABEL     ns_SIZEOF
    ENDC  ; INTUITION_SCREENS_I
```

You'll notice that the intuition/screens.i file starts by conditionally including a number of other files. The exec/types.i file for instance provides C language type definitions of a number of standard variable types, such as WORD, APTR and so on. These are not typedef style definitions as such – they are based on macro definitions which are as near as the 68000 assembly language programmer can get. STRUCTURE is another macro that is important because it provides the 68000 coder with high-level C type data structure facilities. The use of these and other important system macros will be dealt with in the next chapter.

A number of EQUate style definitions are also present but the bulk of the file includes two data structure definitions known as a Screen and NewScreen. To appreciate the significance of these structures it's necessary to know a little about what they represent.

Screen definition, in the Intuition sense, is achieved by setting up a complex data block known as a Screen structure. A quick look at the field definitions given in the RKM manuals or your compiler include files will convince you that building such screen structures from scratch is far from easy. Display memory has to be allocated, and a great many associated structures have also to be created and initialised. Fortunately you will never have to do this because Intuition itself can handle most of the setting-up procedures automatically.

To open a custom screen all you the programmer has to do is define the basic characteristics of the screen you require. This is done by initialising a much smaller structure called a NewScreen structure. Once these NewScreen details are defined it is possible to use an Intuition routine called OpenScreen(). This function takes the parameters provided in the NewScreen structure, builds the real Intuition Screen structure needed to describe the display, and then returns a pointer to the structure it has prepared. As usual if things go wrong you'll get a NULL-pointer returned which is, of course, the system's way of telling you that the OpenScreen() request failed!

You'll see from the example include file that, to the assembly language programmer, a NewScreen structure looks like this:

```
STRUCTURE NewScreen,0
   WORD ns_LeftEdge      ; initial Screen dimensions
   WORD ns_TopEdge       ; initial Screen dimensions
   WORD ns_Width         ; initial Screen dimensions
   WORD ns_Height        ; initial Screen dimensions
   WORD ns_Depth         ; initial Screen dimensions
   BYTE ns_DetailPen     ; default rendering pens (for
                         ; Windows too)
   BYTE ns_BlockPen      ; default rendering pens (for
                         ; Windows too)
   WORD ns_ViewModes     ; display "modes" for this Screen
   WORD ns_Type          ; Intuition Screen Type specifier
   APTR ns_Font          ; default font for Screen and
                         ; Windows
   APTR ns_DefaultTitle ; Title when Window doesn't care
   APTR ns_Gadgets       ; Your own initial Screen Gadgets
   APTR ns_CustomBitMap
LABEL   ns_SIZEOF
```

From the practical viewpoint the thing that is most important to the programmer working at the Intuition level is an understanding of the fields present in the NewScreen structure. For the most comprehensive details of screen use, and all the other Intuition objects, you need to have access to the official RKM manuals. Here however are a few details of the information held in the NewScreen structure.

ns_LeftEdge

The field represents the x position of the screen as it opens. It is provided for upward compatibility only and should be set to zero at the current time.

ns_TopEdge

This represents the y position of the screen as it opens and since most Intuition screens will open with their top edges in line with the real top edge of the display this value is usually also set to zero.

ns_Width

This field represents the width of the screen and is usually set to the nominal values of either 320 (for a low res display) or 640 (for a high res display).

ns_Height

This defines the height of the screen in scanlines. Non-interlaced PAL displays commonly use a value 256 (200 for equivalent NTSC displays).

ns_Depth

This field identifies the number of bitplanes being used for the screen.

ns_DetailPen

This identifies the colour register to be used for details such as the screen title.

ns_BlockPen

This is another colour register number which this time identifies the colour register which will be used for area fills.

ns_ViewModes

A number of flags are defined in the system headers which allow certain display attributes to be set:

HIRES	selects high-resolution mode
LACE	selects an interlaced display

SPRITES	set this flag if you wish to use sprites
DUALPF	in theory this flag tells the system that the screen will be using two separate playfields (playfield is just another term for screen background). In practice there are better ways of creating dual playfield displays.
HAM	this flag informs the system that you wish to use the *hold and modify* display mode.
EXTRA_HALFBRITE	informs system that an extra bitplane for extra half brite mode will be used.

ns_Type

This field can be set using a number of predefined flag values:

CUSTOMSCREEN	you will always set this flag because *all* screens which are explicitly opened will be custom screens.
SCREENBEHIND	if this flag is set the screen will open behind any existing screens. It is sometimes useful to do this so that any preliminary screen drawing operations can be hidden from the user. When the screen preparation is complete it can be brought to the front of the display.
SCREENQUIET	screens opened with this flag set do not have the usual title bar or gadget rendering.
CUSTOMBITMAP	normally Intuition allocates a bitmap structure and the associated bitplane display memory. If this flag is set you are effectively telling Intuition not to bother to do this. In other words you are indicating that you will supply the appropriate bitmap structure and bitplane memory.

ns_font

This is a pointer to a TextAttr structure used to describe the default font for the screen. Set it to NULL if you wish to use the font specified in the Preferences settings.

ns_DefaultTitle

This is a pointer to a NULL terminated screen title string. Set to NULL if a title is not required.

ns_Gadgets

This field, which will be the first item in a list of user-defined screen gadgets, is unused at present. It is provided for future system expansion and should currently be set to NULL.

ns_CustomBitMap

If you have set the CUSTOMBITMAP flag in the NewScreen. Types field then you *must* supply a pointer to a suitably initialised BitMap structure in this field.

Basically then the NewScreen structure is a template (a description) of a giant block of data containing items related to the creation of a real Intuition Screen structure. In order to use an Intuition Screen you must create one of these data blocks and, having filled it with suitable details, you will then be able to use this ready-made system routine to carry out the job of creating the screen.

Function:	**OpenScreen()**
Description:	Open a custom Intuition Screen
Call Format:	screen_p=OpenScreen(new_screen_p);
Registers:	D0 A0
Arguments:	new_screen_p – pointer to initialised NewScreen structure
Return Value:	screen_p – pointer to an Intuition Screen structure. If the screen could not be opened a NULL pointer is returned.

Custom screens, which are what the screens which we have been discussing are called in the official system literature, have to be explicitly closed before the program terminates and a CloseScreen() call is available for this purpose.

Function:	**Close Screen()**
Description:	Close an Intuition Screen
Call Format:	CloseScreen(screen_p);
Registers:	A0
Arguments:	screen_p – pointer to an existing Screen structure
Return Value:	None

It should be apparent from the above discussion that an Amiga programmer is provided with an immense amount of system support. Equally apparent should be the fact that it is virtually impossible to program the Amiga without having access to details of the library functions, flag definitions, structure templates and so on, that the Amiga programmer is expected to use. This being so, it's time that some very important books were mentioned.

The Official Documentation

Throughout this book you'll find references to the Addison Wesley Amiga Technical reference manuals. Why? It is because they constitute the *official* Amiga programming documentation and, whether you've obtained them yet or not, it is worthwhile knowing a bit about their contents. The manuals have recently been updated

to include additional material relevant to Workbench 2 and the following notes will give you a summary-style rundown on what you can expect to find in the current versions.

Amiga ROM Kernel Reference Manual - Includes & Autodocs

This volume, as the name suggests, contains details of all of the Amiga's Include files and function autodocs. It also however contains a host of other useful items.

The first section provides the library summaries and it must be said at the outset that this material is essential for the serious Amiga user. Why? It's because it contains details and use instructions for every routine in every library. Function descriptions are organised alphabetically, library by library and because an alphabetical function index is also provided it is easy to find your way around.

Following the function details comes the devices section which contains straight summaries of the device calls etc. This is followed by the disk/cia/potgo and miscellaneous resource summaries after which comes the very hefty C and assembly language *include* file listings. This volume, incidentally, also includes the source code for a sample library.

Plenty of other reference charts are provided which give details of the Amiga libraries and their function offsets, assembly language include file *structure* prefixes, and structure offset reference details. There is also a hardware register map and a C language include file cross-reference table.

Amiga ROM Kernel Reference Manual - Libraries

This volume deals with Intuition (the Amiga's high level programming interface) and cover the use of screens, windows, gadgets, menus etc, from the programmers viewpoint. There are plenty of examples (mainly in C) to help the newcomer and the material is, in general, relatively straightforward to understand - so the reader has a moderately easy introduction to what is undoubtedly a most complex computer system.

Hidden beneath the Amiga's Intuition interface lie some very complex software components. One such component which both merits, and gets, special attention is the multi-tasking *Exec* system. Topics covered include the use of Exec functions, library organisation, message passing, interrupts, and Exec's I/O techniques. These are dealt with in detail and because they require a grasp of some difficult concepts this stuff is hard work even for experienced programmers.

This is also the volume where you can get authoritative details of the Amiga's superb graphics facilities. As well as general introductions you'll find accounts of such things as the Amiga's

display modes, image formation, viewport creation etc, and very detailed accounts of sprite handling, Bobs, and the use of the system's animation facilities.

Amiga ROM Kernel Reference Manual - Devices

This manual provides separate chapters to each of the all-important Amiga devices, namely the audio, clipboard, console, gameport, input, keyboard, narrator, parallel, printer, SCSI, serial, timer and trackdisk devices. There's a chapter on the low-level hardware control functions and on the the Interchange File Format (IFF). The IFF material provides useful introductory notes, the EA IFF 85 document, and the details of Form specifications. The graphics, music/sound-sampling, and all the other IFF areas are well covered as are many third party registered Form definitions. There is a good selection of code examples together with a reasonable level of tutorial style help.

Amiga Hardware Reference Manual

After a brief introduction this volume dives straight in with a look at the Amiga's co-processor unit, its instruction set, and its use. This sets the scene for a discussion of the playfield hardware and its relationship to the Amiga's display facilities. The Amiga's sprite hardware, audio hardware, and the now famous *blitter* chip all get a similar detailed treatment with the last two chapters being used to describe the remaining aspects of the Amiga's system control and interface hardware.

If you like (or need) to get your hands dirty, ie have to understand and program the Amiga at a low level, or if you want to understand how to achieve things like vertical and horizontal smooth scrolling, then the hardware manual is the place to look.

Amiga User Style Interface Guide

This volume, as the title suggests, is more about user interface issues than coding. The volume provides basic advice on Intuition style and consistency together with notes on Workbench, Shell, AREXX, the clipboard IFF data sharing scheme and related issues.

You'll find additional details of these and a number of other important Amiga reference books in the bibliography.

9: Macro Programming and its Benefits

With assembly languages, as with any other computer languages, you frequently find that similar sequences of instructions crop up again and again. Now with sequences that are identical one solution is of course to write the instructions as a subroutine rather than waste space by having the same instructions duplicated in various places throughout the program. The subroutine approach reduces program size and has a number of benefits as far as program structure is concerned but there are still times when inserting duplicate sections of code is necessary, eg to eliminate the time in calling the subroutine. Often subroutines are inappropriate simply because the various sequences of instructions are only similar and not completely identical.

Macros provide a powerful solution to this dilemma because they allow the programmer to assign symbolic names to sets of instruction sequences and, whenever the name is encountered, the assembler automatically expands it to produce the original set of instructions. This facility is not restricted to predefined, absolutely fixed, instruction sequences. Macros which contain parameter placeholder markers can be created so that, when the macro is used, parameters provided with each particular instance are

inserted into the code that is generated. This makes it possible for the macro programmer to generate a variety of code fragments from each macro definition.

Motorola style macro definitions start with a label followed by the MACRO keyword and end with the ENDM keyword. Lower case macro and endm are also accepted but to my mind the upper case versions mark the macro segment more clearly. The basic macro format therefore takes this type of form:

```
my_macro_name MACRO
<main body of macro code>
ENDM
```

Parameters are specified using the backslash (\) character followed by any alphanumeric character and as an example this macro code:

```
LIBCALL MACRO
   move.l   a6,-(sp)
   move.l   \2,a6
   jsr      \1(a6)
   move.l (sp)+,a6
   ENDM
```

would, if used in conjunction with the following line of a program:

```
LIBCALL _LVODisplayBeep, _IntuitionBase
```

generate this sequence of instructions:

```
move.l   a6,-(sp)
move.l   _IntuitionBase,a6
jsr      _LVODisplayBeep(a6)
move.l (sp)+,a6
```

There is incidentally a reserved assembler symbol, NARG, which takes as its value the count of the number of parameters passed. When used in conjunction with the assembler directives IFGT (if greater than) and FAIL it becomes possible to add parameter count error checking to a macro. The above example could for instance be written as:

```
LIBCALL MACRO
   IFGT  NARG-2
         FAIL       ;too many arguments
   ENDC
   move.l   a6,-(sp)
```

```
move.l    \2,a6
jsr       \1(a6)
move.l (sp)+,a6
ENDM
```

This particular macro, which I look at again in Chapter 10, is actually already present in the system's exec/libraries.i include file (under the name LINKLIB) and is used to generate library access code.

Macros resemble subroutines in the sense that they provide a shorthand reference to a frequently used set of instructions. It should be obvious from the above discussion however that macros are *not* subroutines. The code for a subroutine will occur only once within a program, and program execution branches to the subroutine. On the other hand, each time a macro is used the assembler will insert a copy of the appropriate instructions (with any parameter-specified alterations).

The advantages of the macro are numerous: shorter source programs, the ability to take advantage of pieces of tried and tested code, easier code changes and so on. In short, macros allow assembly language programming to be done at a significantly higher level than was previously possible and they are in fact an essential part of Amiga assembly language programming.

A great many pre-defined macros have in fact been made available to the programmer in the system header files. It is not possible to discuss all of them but a number of them are discussed later. Because of its importance in some of the code that we'll look at in later chapters, one system macro does however deserve special mention.

The STRUCTURE Macro

I mentioned in Chapter Eight that the Amiga's C header files contain, amongst other things, a mass of pre-defined structure definitions which relate to system objects such as screens and windows and that the assembly language .i include files contain similar *structure* definitions.

Now 68000 assembly language certainly doesn't support the use of C style structures directly, but a macro has been developed which lets the assembly language programmer work with the next best thing. It is called STRUCTURE and it is, arguably, one of the most important system macros available. On the Amiga its use will *flavour* almost all the assembly language code you write making it cleaner, more comprehensible, and easier to maintain.

Firstly however a bit of C code for comparison. Suppose we were defining a C structure called ColourRange which stored details about minimum and maximum colour values, a flag to indicate whether values were increasing or decreasing, the amount of the increase, and the current RGB values. Using C we might decide to use something like this:

```
struct    {
          UBYTE     Minimum;
          UBYTE     Maximum;
          UBYTE     UpDownFlag;
          UBYTE     Adjustment;
          ULONG     Red;
          ULONG     Green;
          ULONG     Blue;
          }ColourRange;
```

What the include file's STRUCTURE macro allows us to do is to write similar definitions in assembler. Here's the above ColourRange STRUCTURE equivalent:

```
STRUCTURE ColourRange,0
          UBYTE     Minimum
          UBYTE     Maximum
          UBYTE     UpDownFlag
          UBYTE     Adjustment
          ULONG     Red
          ULONG     Green
          ULONG     Blue
          LABEL     ColourRange_SIZEOF
```

The values UBYTE and ULONG are themselves macros which have been designed to calculate the sizes of C variable types. UBYTE (unsigned byte) for example actually equates to the value 1.

STRUCTURE then, is a macro that calculates the offsets for the member labels which you've used in your definition. In the above example the result would be these offsets. Minimum would equate to 0, Maximum to 1, UpDownFlag to 2, Adjustment to 3, Red to 4, Green to 8 and Blue to 12. The definition includes a preliminary offset and a further terminal macro called LABEL which is normally used to generate a SIZEOF label. The benefit of generating a size value is that it becomes possible to reserve space for one type of structure within another structure definition.

The include files, as mentioned above, provide macros which calculate the sizes of all the usual C types, BYTE, UBYTE, BOOL, WORD, LONG etc, so the net effect is that if, for example, you use ULONG in the STRUCTURE definition, the macro will arrange to add 4 (because a ULONG variable is 4 bytes long) to the offset counter after the current assignment has been made.

The benefits? Firstly, the code is a lot more readable. Secondly, if at some stage you make changes to the defined structure you don't have to worry about the offsets in your existing code – because the macro calculates the new displacements for you. Thirdly it lets you work, as far as the structures go, with almost highlevel language ease. The best way to illustrate the advantages of this macro approach is to give you a system orientated example and the one I've chosen concerns an Intuition communications facility.

The Intuition Message System

If you had to cope with everything that Intuition took an interest in you, as a programmer, would have your work cut out. Fortunately programs can be selective about the type of events they wish to receive. If, for instance, a program needs to know when disks are inserted or removed it asks Intuition to send it a message about these events as, and when, they occur. If the program doesn't need to worry about disk insertion and removal then it just does not ask for those types of messages to be sent in the first place.

One of the ways in which Intuition can be coaxed into sending information to a program is via Intuition's Direct Communications Message Port system, affectionately called the IDCMP. This is built upon the Exec message system arrangement and provides a two way communication process which allows your program to both receive and transmit messages. IntuiMessages then, carry information to and from a window's IDCMP ports and are based on this type of system defined message structure:

```
STRUCTURE IntuiMessage,0
   STRUCT im_ExecMessage,MN_SIZE
   LONG im_Class
   WORD im_Code
   WORD im_Qualifier
   APTR im_IAddress
   WORD im_MouseX
   WORD im_MouseY
   LONG im_Seconds
   LONG im_Micros
```

```
APTR im_IDCMPWindow
APTR im_SpecialLink
LABEL im_SIZEOF
```

The easiest way to gain access to an IDCMP is to specify one or more of the IDCMP flags when you open a window. If Intuition sees that you've done this it will automatically create a pair of message ports for that window. One port, the WindowPort, is used by Intuition, the other is referred to as the UserPort and is for the program's use. Intuition arranges for signal bits to be allocated to the message ports and it is by looking at these signal bits that we can tell when messages have arrived.

In order to use IntuiMessages you need to be able to extract information from the structure. Here's the purpose of the various fields:

The im_ExecMessage field contains message characteristics, such as the length of the message's body data, which are needed by the Exec. You are unlikely to want this information and you certainly should not interfere with it.

im_Class is a variable whose bits correspond directly with the equivalent IDCMP flags. You will usually check the contents of this variable against particular flag definitions so that you know what type of message you have received.

The im_address of the object to which the message refers is provided in the im_IAddress field. Whenever you have to find out about the current state of Intuition objects, eg whether a Gadget is on or off, you'll use this address to locate the object's structure.

The im_Code and im_qualifier fields depend very much on the type of message, eg if the keyboard device is providing raw keyboard data then the im_code field will contain the untranslated character and the im_qualifier field will tell you whether the Shift or Ctrl keys were also pressed.

Each message is stamped with mouse co-ordinates and the system time. im_MouseX and im_MouseY are the co-ordinates of the mouse at the time given by the im_Seconds and im_Micros fields. The other two fields in the structure are im_IDCMPWindow, which is a pointer to the relevant Window structure, and im_SpecialLink which is used only by the system.

The IDCMP Flags

Standard names for the IDCMP flags are available in the include files. They should always be used in preference to numeric values or non-standard names. The flags are used to both select which

types of messages you wish to receive and to distinguish between the various types of message that may arrive at your message port. The definitions fall into a number of categories and you will find them in the Intuition include files. The place to look for full tutorial explanations is the RKM libraries manual. Here however are brief details of some of the predefined flag values:

Gadget flags

GADGETUP When the user releases the left mouse button over a gadget that has the RELVERIFY flag set, the program receives a message of this class.

GADGETDOWN If the gadget was created with the GADGIMMEDIATE flag set then this message is sent when the gadget is selected.

CLOSEWINDOW If you have a close gadget in your window then setting this flag will give you a message telling you when it has been selected. Intuition doesn't close anything, but leaves that up to the applications program.

Mouse Flags

MOUSEBUTTONS Causes reports about mouse button events to be reported providing they do not mean anything to Intuition. The Code field of the message tells you which button was pressed or released. It will contain one of four flags: SELECTUP, SELECTDOWN, MENUUP or MENUDOWN.

Menu Flags

MENUPICK You'll get a message if the user has pressed the menu button. If an item was selected then the menu number will be in the Code field. If no selection was made this field will be set to MENUNULL.

Miscellaneous Flags

DISKINSERTED If this flag is set you will be told about disks being inserted *or* removed.

DISKREMOVED Again you will be told about disks being inserted or removed. Two flags are needed because when these events happen you need to know which one has occurred.

Indirect Addressing With Displacement

Now the big question. Knowing that the system provides a ready made template for an IntuiMessage *structure style* block of data, how do we get information into it (or from it)? It turns out that the 68000's indirect addressing schemes come in very useful but, before discussing these issues, however let's first set the scene as far as the IntuiMessage structure is concerned.

If you count the number of bytes present in each field and then work out the displacements of each field relative to the base of the IntuiMessage you'll get these results:

Displacement	Field
48	im_SpecialLink
44	im_IDCMPWindow
40	im_Micros
36	im_Seconds
32	im_MouseY
30	im_MouseX
28	im_IAddress
24	im_Qualifier
22	im_Code
20	im_Class
0	im_ExecMessage

You will never need to calculate these *offsets* when using a system defined object because the displacements have been provided for you (using the STRUCTURE macro) in the include files. Since the offset calculations have been done, all you have to do is use them, and that's where indirect addressing comes in.

Indirect addressing, as you'll already know from earlier discussions, implies that instead of specifying an address, we specify the location of the address. If we take an example of ordinary register indirect addressing such as:

```
move.l (a0),d2
```

then we are using register indirect addressing to specify the location of the source operand, ie we are effectively saying that data should be taken from the location whose address is in register a0, and then copied into register d2. Now if register a0 was being used to hold the *base address* of the structure we would be able to use instructions like that shown above to access the data held in the first field of the structure. Ideally however what we'd like to be able to do is have a structure base address in the specified register

– and then be able to access any given field of that structure. Fortunately we can, because the 68K chip kindly lets us specify a displacement value as well, like this:

```
move.l im_Class(a0),d2
```

If a0 had been loaded with an IntuiMessage pointer then the above instruction would retrieve data from the im_Class field of the IntuiMessage and copy it to register d2.

We could just as easily have copied the data to some memory locations. Moving data into memory locations labelled *qualifier*, *code* and *class*, for example, could use instructions like these:

```
move.w im_Qualifier(a0), qualifier
move.w im_Code(a0), code
move.l im_Class(a0), class
```

The reasons that the Amiga programmer is able to write this style of code are threefold. Firstly, there is the fact that the Amiga system makes extensive use of C type structure definitions to define its data structures. Secondly, there is the existence of the STRUCTURE macro that enables the assembler programmer to work with such structures in a relatively high-level, label orientated, way. Lastly of course the 68000 chip makes the whole approach possible by providing register indirect addressing with displacement.

10: Libraries and the Amiga

Libraries, for the Amiga programmer, are the source of much confusion simply because the term is used in a number of different contexts. C compilers for instance will have their own libraries of standard functions, such as printf(), and when a reference to such a function is used within a program it causes the construction of an equivalent *unresolved* reference in the intermediate object code file. At link time the linker must, with some guidance from the programmer, find the library file that contains the function and physically copy it into the program being created. The Amiga-specific library, called amiga.lib, is another linker library.

The AmigaDOS documentation refers to linker libraries as *scanned libraries* but on top of this the AmigaDOS technical documentation also refers to library units, known as *resident libraries*. A resident library seems to be a set of routines that are created and linked apart from the program which uses them – thus forming a separately loadable module. Little has been published about these facilities and they do not appear to be used to any great extent. At one time it was rumoured that the facility might even be dropped.

Lastly, the Amiga also uses another type of library based on a dynamic Exec run-time library system. These also

exist quite separately from the applications programs which use them and are arranged in such a way that any number of programs can use them simultaneously, or at least appear to do so within Exec's multi-tasking framework. It is these run-time libraries that form the subject matter for the remainder of this chapter.

Unlike many less sophisticated machines where the location of a system function is static you will rarely know, until the time you come to use the library, where the functions are. Some libraries are currently positioned in read only memory (ROM), others may be available in RAM because they've been loaded during system startup. A great many of these libraries however will remain on disk until the first applications program indicates that it needs such a library routine. Programs tell Exec that a library is needed by attempting to *open* it using an OpenLibrary() function. When such a call is made Exec does several things. It searches its lists of libraries which are already open and available. If the library is found then Exec simply returns the address of the library and makes an internal note that another program is now using it. If the library is not already open, Exec passes on the request to AmigaDOS asking it to look for, and then load, the specified library. AmigaDOS looks in the LIBS: logical device. If you boot from the Workbench disk for instance then this logical device will have been assigned to SYS:LIBS, ie the LIBS directory of the Workbench disk.

If AmigaDOS finds the library, it scatter loads it as per normal and tells Exec where it has been placed. Exec then records the fact that the library is now available by adding it to its list of *available* libraries. Exec will never attempt to remove these library modules whilst they are in use, but should the last user of a particular active library indicate that they no longer need access to the routines, which they do by executing a CloseLibrary() function, Exec's library manager may then remove the memory copy of the library and release the associated memory so that it is free for other use.

As far as an applications program is concerned, most of these operations are transparent and this is so even at the assembly language programming level. All a program has to do to use a given library is open it using the Exec OpenLibrary() function, and then use the library routines in much the same way that the OpenLibrary() function was itself used. The only thing which the applications program must do is ensure that the OpenLibrary() call was successful and it does this by checking that the address returned is non-NULL. If the address returned has a zero value then the system hasn't been able to open the library.

Why would a library fail to open? The system might not have been able to find it on disk, the specified version might not be available, the programmer might simply have spelt its name wrongly within

the program, or the system might even be running out of memory and have insufficient space to load a new library. The important point is that you must not make any library function calls unless you have got a valid base pointer or you will doubtless get a visit from the Amiga guru!

If an applications program follows this protocol it never needs to concern itself with where the routines are in memory, nor with the fact that other programs may also be using the same routines. This obviously makes for an extremely powerful and flexible library system and there's no doubt that much of the Amiga's power has stemmed directly from its run-time library arrangements. Here, to start with, are the details of the Exec functions which handle the opening and closing of a library:

Function:	**OpenLibrary()**
Description:	Open a run-time library
Call Format:	base_address=OpenLibrary(library_name, version);
Registers:	D0 A1 D0
Arguments:	library_name – the address of a null terminated string version – a library version number
Return Value:	base_address – the address of the base of the library. If the library could not be opened a NULL value is returned.
Notes:	User must not attempt to use any library functions if this function did not succeed.

Function:	**CloseLibrary()**
Description:	Close a previously successfully opened library
Call Format:	CloseLibrary(base_address);
Registers:	A1
Arguments:	base_address – the library base address
Return Value:	None
Notes:	User must not make library calls to a library after it has been closed.

Before examining some example library code fragments, it is worthwhile looking beneath the surface of Exec's run-time library system to see what makes it tick. Once this material has been understood the library code conventions will start to make a lot more sense.

Run-Time Library Formats

An Exec library is basically just a collection of routines which are accessed via a jump table. This is a table which provides offset values (6 bytes long) which are used to calculate the address of the function. The base address returned by the OpenLibrary() call is actually the address of the start of a library structure and this data

structure is sandwiched between the jump table and other library specific data. The net result is that, once set up in memory, the library looks like Figure 10.1.

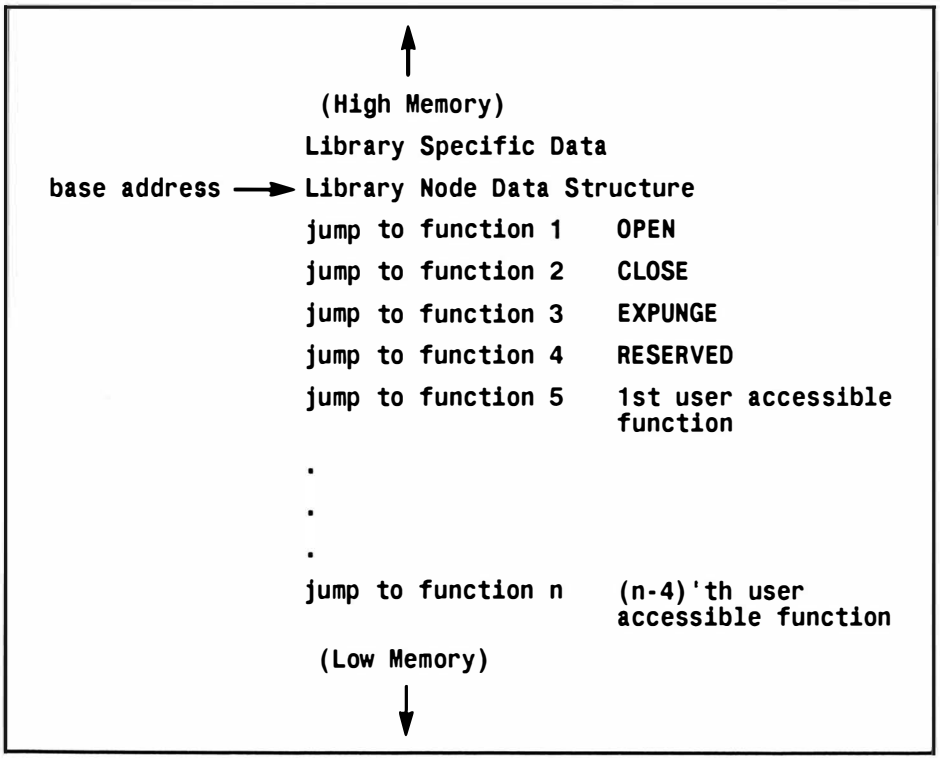


Figure 10.1. Library structure in memory.

The first four function jump entries OPEN, CLOSE, EXPUNGE and RESERVED must always be present. OPEN is an entry point called when the library is opened and is the routine responsible for incrementing the count of the number of users of a particular library. CLOSE is a corresponding routine which decreases the user count and, when the count gets to zero (ie the last library user indicates that the library is no longer needed) it may instigate an EXPUNGE operation which in more familiar terms simply means that the library is prepared for removal. The RESERVED vector is currently unused but is present as a gateway for system expansion.

The jump table entries are each six bytes long and so indirect addressing can be used along with negative displacements to identify any given function entry. These offsets, called library vector offsets (LVOs), mean that the programmer can associate with each library a set of LVOs like as shown in Figure 10.2.

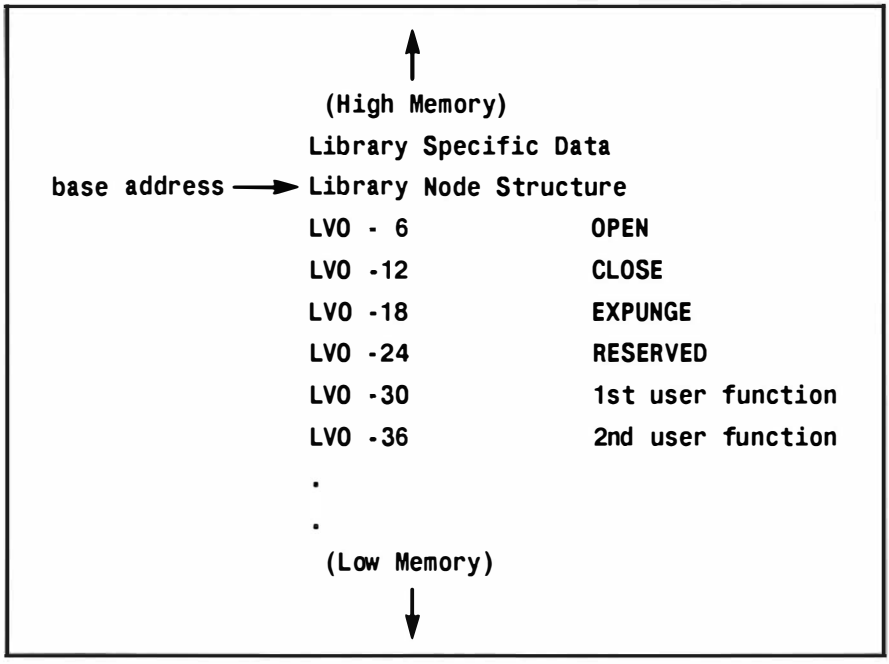


Figure 10.2. Library offset vectors.

I've already mentioned that the first stage in using a library is to open it by using the Exec OpenLibrary() function. You may now be wondering how it is possible to open the Exec library in the first place. The simple answer is that you do not need to because the Exec library never has to be opened. Exec's base address, known as SysBase, is also permanently available. It is stored in memory location 4 (known as AbsExecBase) during system start up and so the Exec library is alive and kicking from the word go. AbsExecBase incidentally is the only absolute memory location present in the Amiga memory map (apart from things like the 68000 processor's exception vectors).

Opening a Library

By convention we place the base address of the library in register a6, and then make an indirect subroutine call using the appropriate library vector offset (LVO) value to specify the routine to be executed. I've already mentioned that in the case of the Exec library the base address is already available and so this can be loaded directly from AbsExecBase.

The bare bones code for an OpenLibrary() Exec call might therefore look like this:

```
move.l _AbsExecBase, a6     get the base address of Exec library
jsr _LVOOpenLibrary(a6)     make the indirect subroutine call
```

In practice you will probably want to preserve the original contents of the a6 register and, as we've seen earlier, the easiest way of doing this is to push the contents onto the stack beforehand:

```
move.l a6, -(sp)            preserve original contents of a6
move.l _AbsExecBase, a6     get the base address of Exec library
jsr _LVOOpenLibrary(a6)     make the indirect subroutine call
move.l (sp)+, a6            restore a6 to original value
```

You might incidentally be forgiven for thinking that any register could be used to perform the indirect subroutine call. This is most definitely not the case in general and there is a strict system convention which says that a6 must always be loaded with the base address. Why? It's because many library functions will call other library functions in order to carry out their work. When this is done the function doing the nested library call must also follow the system conventions and provide a library base address and by convention it will expect it to be present in register a6. Exceptions to the a6 rule do exist but to be honest it is safer if you forget about any special cases and regard the a6 rule as absolute!

You'll notice in the above code fragment that AbsExecBase and the LVO value have underscore prefixes. This stems from an internal C language convention and the underscore used in all assembly language forms has been introduced simply to provide compatibility between C and assembler header files and code.

LVO offset values can be acquired in a number of ways. Firstly you could link your code with amiga.lib (which contains all of the LVO definitions).This would require that you tell your assembler that you are expecting the LVO reference to be resolved at link time so, somewhere near the beginning of your code you would need to include the statement:

```
XREF _LVOOpenLibrary
```

XREF is an assembler pseudo-op which tells the assembler that a value for the reference in question is going to be supplied at a later stage, ie at link time. Note, if you forget to use an XREF declaration the assembler will try to resolve the reference, fail, and then flag the use of that reference as an error.

Another approach is to include a header file of the LVO definitions in your program and the advantage here is that it is then possible to avoid linking with amiga.lib. This can firstly save time and secondly, if an include file containing the system start-up code is used, you can (by asking the assembler to create directly executable code) even eliminate the linking stage altogether.

Alternatively you could look up the numerical LVO value using a table of function offsets and use the values directly. You will find an abbreviated set of tables in Appendix B and from the Exec entries you'll see that the LVO value for the Exec OpenLibrary() function is -552, ie -0228 hex. The assembly language programmer is therefore quite at liberty to define the displacement in this fashion:

```
move.l  _AbsExecBase, a6    get the base address of Exec library
jsr     -552(a6)            make the indirect subroutine call
```

The trouble with this latter approach however is that you will lose the inherent documentation that the LVO references provide. Let's face it, the number -552 doesn't, unless you've memorised all of the LVO tables, exactly tell you what library call is being made. The reference _LVOOpenLibrary is much more meaningful and in practice things can even be improved further.

The System LINKLIB Macro

The header file exec/libraries.i includes a piece of generalised macro code, called LINKLIB, that performs the task of preserving a6, loading a specified library pointer into a6, performing the indirect subroutine call using a specified offset, and then reinstating the original contents of a6 afterwards. The full details, which include argument count checking, can be obtained from the header file itself but in essence the job which is carried out is this:

```
move.l  a6, -(sp)                   preserve original contents of
                                    a6
move.l  <LibraryPointer>, a6        get the base address of
                                    library
jsr     <_LVORoutineName>(a6)       make the indirect subroutine
                                    call
move.l  (sp)+, a6                   restore a6 to original value
```

The bottom line therefore is that by including the exec/libraries.i file you can generate the appropriate library call code by writing:

```
LINKLIB _LVOOpenLibrary, AbsExecBase
```

This is the officially offered macro but many programmers, for reasons of improved readability, prefer to use a modified macro which adds the _LVO prefix automatically.

It's certainly not a good idea to modify the existing system macro (such changes lead to much confusion if other programmers have to read your code), but there's nothing to stop you creating an extended macro which tags on the extra _LVO characters to the function name. Here's one which will do the job.

```
CALLSYS MACRO
LINKLIB _LVO\1,\2
ENDM
```

If you include this macro in your code you'll then be able to create the appropriate library opening code using this simplified scheme:

```
CALLSYS OpenLibrary, AbsExecBase
```

To simplify things further it is equally possible to bury the library base references inside the macros. Devpac users, for instance, are provided with files that include both explicit LVO offsets and library specific calling macros. In the case of the above example the Devpac programmer, by including the Devpac specific exec_lib.i file, can just write:

```
CALLEXEC OpenLibrary
```

Brief Library Details

You can find full details of the Amiga's extensive library routines and listings of the include files in the Includes & Autodocs volume of the Addison Wesley RKM manuals. Here are brief details of the some of the most useful libraries together with their standard base names:

diskfont.library **library base name: DiskfontBase**

This library contains routines for building and disposing of font detail arrays and for loading fonts from disk.

dos.library **library base name: DOSBase**

This contains all of the AmigaDOS file and disk I/O and process handling support routines.

exec.library **library base name: SysBase**

Routines for task control, list manipulation, I/O handling, messages and ports, interrupt and memory management.

graphics.library **library base name: GfxBase**

This is the library that provides support for Views, Viewports, RastPorts, BitMaps, GELS and all of the associated graphics and animation primitives. Included in this library are routines for controlling the Blitter and Copper chips.

intuition.library **library base name: IntuitionBase**

This library makes the complex WIMP graphics and WIMP control programming a piece of cake. These Intuition routines are built upon facilities provided by the graphics, layers and exec libraries and provide support for screens, windows, menus, gadgets, requesters, IDCMP communications ports and much more!

layers.library **library base name: LayersBase**

This library is not directly used that often by most programmers. It handles some quite difficult areas including the management of window refreshing, buffering of obscured areas, manipulation of damage lists, locking and unlocking of layers for handling contention problems etc. The layers library is of course used heavily by Intuition itself!

translator.library **library base name: TransBase**

Contains the Translate() function which can convert English text into phonetic strings.

maths libraries

A number of maths libraries for single and double precision operations are also available. Both Motorola fast (single precision) format and IEEE double precision formats are supported. Here are their names and library base names:

mathffp.library **library base name: MathBase**

mathieeedoubbas.library **library base name: MathIeeeDoubBasBase**

mathieeedoubtrans.library **library base name: MathIeeeDoubTransBase**

mathtrans.library **library base name: MathTransBase**

A number of other libraries are also available and under Version 2.0 of the system software further libraries have been added. Few of these are likely to be of much interest (or use) during your early assembler programming days but, if you are curious and would like comprehensive details, you should consult the official documentation.

Putting the Pieces Together

Having dealt in some detail with the library arrangements and their usage conventions it is time to look at some example code. Example CH10-1 which follows uses the Exec OpenLibrary() function to open the intuition library:

```
* ---------------------------------------------------------------
* Example CH10-1.s
* ---------------------------------------------------------------
; some system include files...
     include exec/types.i
     include exec/libraries.i
     include exec/exec_lib.i
* ---------------------------------------------------------------
; a macro to extend LINKLIB and thus avoid the explicit
; use of the _LVO prefixes in the function names...
CALLSYS   MACRO
          LINKLIB _LVO\1,\2
          ENDM
* ---------------------------------------------------------------
; EQUate definitions...
_AbsExecBase EQU   4
* ---------------------------------------------------------------
; main program code...
     lea       intuition_name,a1  library name start in a1
     moveq     #0,d0              any version will do
     CALLSYS   OpenLibrary,_AbsExecBase     macro (see text
                                            for details)
     move.l    d0,_IntuitionBase  store returned value
     beq       EXIT               test result for success
; if we reach here then the intuition library is open and
; its functions can be safely used!
; as it happens however all we shall do for this example
; is close the library like this...
     move.l    _IntuitionBase,a1  base needed in a1
     CALLSYS   CloseLibrary, _AbsExecBase
; and terminate the program...
EXIT clr.l     d0
     rts                          logical end of program
* ---------------------------------------------------------------
; variables and static data...
_IntuitionBase     ds.l     1
intuition_name     dc.b 'intuition.library',0
* ---------------------------------------------------------------
```

Here are a few additional notes, sectioned off to correspond to the main divisions within the program, to help you find your way around the code.

Firstly, some includes:

exec_libraries.i	**needed because it contains the system LINKLIB macro**
exec_types.i	**has been included because it contains definitions needed by exec_libraries.i**
exec_lib.i	**contains LVO values for the Exec functions**

The CALLSYS macro was explained earlier in the text.

EQUate Definitions

The fixed location AbsExecBase, which holds the address of the Exec library, has been explicitly stated in this example. Your assembler may contain the value in one of its include files. The value is also present in amiga.lib and if you are creating an object code file that will subsequently be linked you should remove the EQUate and replace it with a XREF _AbsExecBase declaration as described later.

The Main Code

Loads the address of the first byte of the library name into register a1, and puts a zero value in register d0 (to signify that we are not bothered which library version we get). For details of the data which needs to be loaded into the registers see the OpenLibrary() function details provided earlier. The CALLSYS macro has been used to generate the exec library use code. The returned base address, as you will see from the OpenLibrary() function description, comes back in register d0. This value is stored in a variable called _IntuitionBase and it is important to realise why we perform the beq (branch on equal to zero) instruction *after* storing the returned value. The system documentation makes a point of telling programmers that they should *not* rely on the status flags as being consistent with the returned value. In the current example this means that even if d0 returns with a zero value we cannot assume that the processor's zero flag is set. Consequently the value in d0 is moved to the _IntuitionBase variable and since this move *will* modify the zero flag to reflect the zero/non-zero state of the returned value we are then able to make an effective state test.

To keep things simple this first example does not make use of the library once it is open. It simply closes it again, using the CloseLibrary() function, and then terminates. Notice that the conditional branch beq instruction ensures that the CloseLibrary() function is only ever called *if* the intuition library was successfully

opened in the first place. Also, for simplicity, I've loaded and used the exec library base directly from location 4 (_AbsExecBase) – normally a program will load this library base into a variable called _SysBase (the system's standard exec library base name).

Note also that register d0 is cleared just before the program terminates. This is an AmigaDOS convention to indicate that the program completed successfully. Programs may use d0 (and many system commands do this) to return an error code.

Lastly, space has been reserved for storing the intuition library base and for holding the intuition library name. Following the normal C-style string convention the text string has been NULL terminated.

A Second Example

The following example is identical to the previous one except for two small changes. Firstly, I've set up the _SysBase variable. Secondly, once the intuition library is open it gets used! The duplication is deliberate and, since most of the following code will be familiar, all you'll need to worry about are three additional lines of code. Here's the code:

```
* ------------------------------------------------------------

* Example CH10-2.s

* ------------------------------------------------------------

; some system include files...
     include exec/types.i
     include exec/libraries.i
     include exec/exec_lib.i
* ------------------------------------------------------------
; a macro to extend LINKLIB and thus avoid the explicit
; use of the _LVO prefixes in the function names...
CALLSYS   MACRO
          LINKLIB _LVO\1,\2
          ENDM
* ------------------------------------------------------------
; EQUate definitions...
_AbsExecBase       EQU  4
_LVODisplayBeep    EQU  -96
* ------------------------------------------------------------
; main program code...
```

```
     move.l    _AbsExecBase,_SysBase   store Exec library
base
     lea       intuition_name,a1  library name start in a1
     moveq     #0,d0              any version will do
     CALLSYS   OpenLibrary,_SysBase    macro (see text for
                                       details)
     move.l    d0,_IntuitionBase  store returned value
     beq       EXIT               test result for success
; now let's make an intuition call to flash the screen...
     move.l    #0,a0              flash ALL screens
     CALLSYS   DisplayBeep,_IntuitionBase
; all done so we can now close the library as before and
quit...
     move.l    _IntuitionBase,a1  base needed in a1
     CALLSYS   CloseLibrary,_SysBase
EXIT clr.l     d0
     rts                          logical end of program
* ------------------------------------------------------------
; variables and static data.
_IntuitionBase     ds.l      1
_SysBase           ds.l      1
intuition_name     dc.b 'intuition.library',0
* ------------------------------------------------------------
```

What changes have been made? Well, to start with I've defined the _SysBase variable and loaded the exec library base into it:

```
     move.l    _AbsExecBase,_SysBase   store Exec library
                                       base
```

and I've added these two lines of code:

```
     move.l    #0,a0              flash ALL screens
     CALLSYS DisplayBeep,_IntuitionBase
```

The following description of the DisplayBeep() routine should make it clear why a0 needs to be loaded with a zero value before calling the function:

Function:	**DisplayBeep()**
Description:	Cause a screen to flash
Call Format:	DisplayBeep(screen_address);
Registers:	a0
Arguments:	screen_ address – address of an Intuition Screen
Return Value:	None
Notes:	If a NULL screen address is supplied Intuition will flash *all* screens including those of the Workbench and other programs!

You'll notice that the format for calling the intuition library function is no different from the original Exec calls that were used to open the intuition library itself. Admittedly we've got a different library base and a different LVO reference, but the mechanism is exactly the same as before!

One other change has been made – I have added the following EQUate definition:

```
_LVODisplayBeep EQU -96
```

By now you probably know the reason well enough but I'll work through the explanation once more for good measure. To use an intuition library, such as DisplayBeep(), we need to know the LVO value for the function. In this particular case I simply looked up the numerical value and created my own definition. This is a common solution if you are using an assembler which can create directly executable, as opposed to linkable, code.

Devpac, for instance, which can produce both executable and linkable code, provides include files which contain these values. In fact if the Devpac user included the intuition/intuition_lib.i file (which contains the _LVODisplayBeep offset) they would not need to add the EQUate line shown above to the example program.

The XREF Orientated Pathway

At the risk of driving many of you nuts, I'm going to re-use the second example to show the changes which allow the _AbsExecBase,_LVOOpenLibrary, _LVODisplayBeep, and _LVOCloseLibrary references to be resolved at link time rather than at assembly time.

The conventional way for the assembler programmer to indicate that the above references are external would be to use XREF statements like this:

```
XREF    _AbsExecBase
XREF    _LVOOpenLibrary
XREF    _LVODisplayBeep
XREF    _LVOCloseLibrary
```

Now this is all very well but having removed the _LVO prefixes from the bulk of the previous code it would be a pity to have to reintroduce them just to provide suitable XREF statements. There is in fact a system macro called EXTERN_LIB (defined in the exec/types.i file) that will add the _LVO suffix automatically. This allows us to write the last three _LVO references as:

```
EXTERN_LIB     OpenLibrary
EXTERN_LIB     DisplayBeep
EXTERN_LIB     CloseLibrary
```

The following program uses these EXTERN_LIB macro statements (along with the single XREF _AbsExecBase declaration) to tell the assembler which values will not be known until the resultant object code has been linked with other files. Notice incidentally that inclusion of the exec_lib.i is no longer necessary because the Exec offset values are themselves also available from amiga.lib:

```
* ------------------------------------------------------------

* Example CH10-3.s

* ------------------------------------------------------------

; some system include files...

              include exec/types.i

              include exec/libraries.i

* ------------------------------------------------------------

; a macro to extend LINKLIB and thus avoid the explicit

; use of the _LVO prefixes in the function names...

CALLSYS   MACRO

          LINKLIB _LVO\1,\2

          ENDM

* ------------------------------------------------------------

; declare external references...

          XREF          _AbsExecBase

          EXTERN_LIB    OpenLibrary

          EXTERN_LIB    DisplayBeep
```

```
          EXTERN_LIB    CloseLibrary
* ---------------------------------------------------------------

; main program code.

     move.l    _AbsExecBase,_SysBase   store Exec library
base

     lea       intuition_name,a1  library name start in a1

     moveq     #0,d0              any version will do

     CALLSYS   OpenLibrary,_SysBase    macro (see text for
                                       details)

     move.l    d0,_IntuitionBase  store returned value

     beq       EXIT               test result for success

; now let's make an intuition call to flash the screen...

     move.l    #0,a0              flash ALL screens
     CALLSYS   DisplayBeep,_IntuitionBase
; all done so we can now close the library as before and
quit...
     move.l    _IntuitionBase,a1  base needed in a1
     CALLSYS   CloseLibrary,_SysBase
EXIT clr.l     d0
     rts                          logical end of program
* ---------------------------------------------------------------
; variables and static data...
_IntuitionBase     ds.l      1
_SysBase           ds.l      1
intuition_name     dc.b 'intuition.library',0
* ---------------------------------------------------------------
```

11: An Overview of Some Important Rules

With some knowledge of both 68000 assembler programming and the overall layout of the Amiga programming environment under our belt we are almost in a position to do some *real* Amiga programming. Before doing so however there are still a few loose ends to be tied up as far as conventions and general program frameworks are concerned.

As we've already seen, the Amiga is a multi-tasking machine and because of this there is never any guarantee that a system call will be successful. A memory allocation call could fail if some other application has previously grabbed all available RAM. Similarly a request for use of the serial device could fail (some other program might previously have been granted exclusive access), or some important fonts or libraries might be missing from the system directories.

Because of these eventualities there are three golden rules which Amiga programmers must learn to obey. These rules have already been mentioned but, since they are important, they're worth restating before we do any real Amiga programming at all.

- Always make sure you get what you ask for!
- Always provide a robust error path so that if the system cannot provide the required facilities your program closes down in a proper fashion.
- Always give back to the system any memory, device, or other facility which you explicitly acquire!

A great many other rules/guidelines exist which Amiga programmers should obey. Not all of these will make sense at the moment but they've been gathered together in this chapter for easy reference.

- Never make assumptions about memory, system configurations (eg the presence of particular drives or device names), or the contents of system structures which are designated as private. Do not for instance assume that particular library bases or system structures will always exist at a particular location. Above all *never* call ROM routines directly.
- If you need to access a system structure that may be shared between other tasks, remember to lock out other tasks, eg by forbidding multi-tasking. This will prevent other tasks attempting to change the structure whilst you are in the middle of looking at it.
- The Amiga's operating system does not monitor the size of a program's stack. Many compilers however allow stack checking code to be added to the compiled application code and the assembler programmer can make similar code additions. Although such checks slow the program down, they are useful particularly during the development of recursive routines which may become deeply nested.
- Remember that any data which is to be accessed by the Amiga's custom chips (bitplanes, image data, sound samples and so on) *must* be placed in chip memory.
- Do not use poll based loops to wait for external events. The system has methods for allowing a task to sleep by Wait()ing on particular signal bits – use them. Similarly you should not use software delay loops for creating timing delays.
- Do not disable either interrupts or multi-tasking for long periods of time.
- Do not access the hardware directly.
- Do not assume that system flags and system options are limited to values currently available – current arrangements may change. If for example you look for a PAL display and don't find one you must *not* assume the display is NTSC (even though it is at the

present time). You must explicitly check for both PAL and NTSC displays and then, to be really safe, provide an error handling shutdown path which recognises the existence of any unknown display type.

- Do not tie up system resources unnecessarily. For example, if your program does not need constant use of a printer then only open the printer device when the program actually needs it and close it as soon as possible. That way other programs will also be able to use the printer device.
- Get into the habit of checking for memory loss during program development. The amount of free memory available after your program has run should be *exactly* the same as it was to start with. If it isn't then some debugging is clearly needed.
- All non-byte fields must be word aligned
- All address pointers must be 32 bits. Do *not* use the upper 8 bits for data.
- Do not use self-modifying code
- Custom chips' registers are read only or write only. Do not write to read only registers and do not read from write-only registers.

There are also a few guidelines aimed specifically at the assembly language programmer.

- System library functions must be called with register a6 holding the library or device base. Libraries and devices, as mentioned in the last chapter, will assume a6 is valid at the time of such a function call.
- Registers d0, d1, a0 and a1 are scratch registers and their contents must be considered lost after a system library call. The contents of all other registers can be assumed to be preserved.
- System functions that return a value may not necessarily affect the processor's condition codes.
- Do not use a clr instruction on hardware registers which are triggered by access because it can cause the hardware register to be triggered twice. Instead use move(.size)#0, location instead.
- Do not use the *move sr* instruction. If you wish to get a copy of the processor condition codes use the Exec library's GetCC() function.
- Do not use the tas instruction on the Amiga. Direct Memory Access (DMA) can conflict with this specialised instruction.

Many of these rules will not overly concern you during your early programming days but it is worth pointing out that in days gone by many Amiga programmers have come to grief because they ignored the rules altogether. The best idea, at least in my view, is to always make the maximum effort to abide by the system conventions.

12: Some Introductory Shell/CLI Programs

This chapter aims to provide some simple, but runable, Amiga assembly language programs which will tie together some of the issues that I've been talking about. Before doing this however there are a number of environment issues to be discussed, starting first and foremost with the differences between CLI/Shell started programs and Workbench started programs.

Normal programs on the Amiga run as AmigaDOS *processes*. These, in terms of their multi-tasking capabilities are based on an Exec task but processes are more powerful (and more generally useful) because they have additional DOS capabilities. When you start a program from a Shell/CLI window you do it by typing its name followed by any parameters (arguments) that are needed. The AmigaDOS CLI/Shell process will, on seeing this, allocate some memory for a stack for your program, store a program *stack size* on the program stack itself and then push a return address on this stack. The AmigaDOS CLI/Shell, which as mentioned is running as a process, stores the CLI/Shell command line on its own stack and then provides your program with the address of the first character of any arguments you supplied on the command line in a0 and the argument character count in d0.

One important point to remember is that the CLI/Shell does *not* create a new process for your program; it transfers control to your program by jumping to your program's code and so your program runs as part of the CLI/Shell process. Because of this your program can inherit a certain amount of run-time information and, as well as the command line arguments discussed above, it can also find out where the CLI/Shell is getting its input from and where its output is going. These I/O details represent addresses and are conventionally known as the CLI/Shell input and output handles.

When a program runs from the Workbench AmigaDOS starts it as a completely separate process and in this case there will be no command line and no CLI/Shell input-output handles available, so Workbench started programs need to set up their own I/O facilities and have to carry out some rather awkward message-orientated Workbench operations.

The job of creating generally useful program start-up code is quite complex. It includes deciding whether a program has started from the Workbench or a CLI/Shell, possibly parsing (separating) CLI/Shell arguments so that they can be provided to languages like C in an easy to use fashion, possibly opening up the DOS library and setting up standard I/O handles and so forth. Commodore provides some standard code, called the start-up code, which takes care of many of these interfacing details and in fact nowadays a variety of start-up modules are available and, depending on what your program is doing, you are free to choose according to your needs. Almost all high-level language compilers and 68000 assembler packages will offer some form of standard start-up code for you to use. It is normally based on the Commodore recommendations and, if it has been written to be used with a high-level language like C, the chances are that it will expect the start location of your program code to be labelled as _main.

The code may be supplied as a piece of source code that can be included at the beginning of your program – the assembler therefore generates, and includes, the appropriate start-up code as it assembles your program. This is obviously useful if your assembler allows the creation of directly executable programs. Start-up code may on the other hand be supplied as a separately compiled module and in this case you have to ask the assembler to create *linkable* (as opposed to executable) code and then use the linker program to add the start-up code to the front of your program. This is not a difficult job and I'll be discussing some linker-orientated issues later in this chapter.

Collecting Default I/O Handles

Despite the fact that most start-up code will, for CLI/Shell programs, open the DOS library and set up the standard I/O handles (known conventionally as _stdin and _stdout) it is useful to see exactly what has to be done. It's not a difficult job and basically all a program needs to do is open the DOS library, and then make calls to two DOS functions known as Input() and Output(). Opening the DOS library is no different to opening any other run-time library and so the code required will follow the general outline of that indicated in Chapter 10. Here are some brief details of the two DOS calls that are needed once the library is open:

Function:	**Input()**
Description:	Identify a program's initial input file handle
Call Format:	file_handle = Input()
Registers:	d0
Arguments:	None
Return Value:	file_handle – the programs initial input file handle.

Function:	**Output()**
Description:	Identify a program's initial output file handle
Call Format:	file_handle = Output()
Registers:	d0
Arguments:	None
Return Value:	file_handle – the programs initial output file handle.

The library opening code, which should already be familiar, takes this form:

```
move.l    _AbsExecBase,_SysBase     set up SysBase variable
lea       dos_name,a1               library name start in a1
moveq     #0,d0                     any version will do
CALLSYS   OpenLibrary,_SysBase      macro (see text for details)
move.l    d0,_DOSBase               store returned value
```

In a real program we would of course need to check that the returned library base was valid and the easiest way to do that is to check the zero flag after the library base (which comes back in register d0) has been moved to the _DOSBase variable. If the library open was successful we can then use Input() and Output() to identify the I/O handles. For example, we can collect the output handle like this:

```
CALLSYS   Output,_DOSBase        get default output handle
move.l    d0,_stdout             store output handle
```

Again in a complete program it is necessary to check the returned d0 value.

Outputting Text Messages

Writing text messages back at the CLI/Shell is obviously a useful thing for a program to be able to do. Luckily it is an easy task because once a file handle is available there is a general DOS function, called Write(), which can be used to do the job.

Function:	**Write()**			
Description:	Write data to a file			
Call Format:	length_written = Write(file, buffer_p, data_length)			
Registers:	D0	D1	D2	D3
Arguments:	file	– file handle		
	buffer_p	– pointer to buffer holding the data		
	data_length	– length of the data		
Return Value:	length_written	– number of bytes actually written		
Notes:	A length_written value of –1 will indicate an error.			

The above Write() function is *not* incidentally just for writing text messages. It is a general function used to write bytes of data to any DOS file. Having said that, if you use _stdout as the file handle and the user hasn't redirected the output using DOS's > operator, then DOS will indeed write the data back at the CLI/Shell window.

You'll see from the above description of Write() that the function needs to know how much data is being written. This means that to use Write() to send text messages to the CLI/Shell window you'll need to know how long each text string is. Static program text is usually set up using define byte (dc.b) assembler directives like this:

```
message          dc.b 'test text'
```

One way to work out the number of characters is to actually count them and in the above example this is easy enough to do. With larger pieces of text this approach obviously becomes tedious and error prone and there is in fact a far better way of doing the job – you place an additional label at the end of the text and then use the EQUate directive to set it to a value based on the current assembler location counter value *minus* the start of the original string, like this:

```
message          dc.b 'test text'
message_SIZEOF   EQU *-message
```

The result is that the assembler automatically sets the second label to the size of the preceding string. I adopt a convention whereby the sizes of all message strings are represented by a label formed by taking the original string label and adding _SIZEOF to it. Why? It's because it is then possible to create a macro that, given the string label, can form the size label automatically. Since Write() uses registers d1-d3 it is useful to preserve those registers on the stack before loading them with the data needed by the DOS call. The following macro does this, sets up d1-d3 as indicated earlier (note how my _SIZEOF convention is used to put a string size in d0), makes the DOS call, and then finally reinstates the contents of registers d1-d3:

```
WRITEDOS MACRO
    movem.l   d1-d3,-(sp)       preserve registers d1-d3
    move.l    \2,d1             DOS output file handle
    move.l    #\1,d2            start of message
    move.l    #\1_SIZEOF,d3     size of message
    CALLSYS   Write,_DOSBase    DOS call to write message
    movem.l   (sp)+,d1-d3       restore registers d1-d3
    ENDM
```

With this macro available the assembler programmer can create the necessary code by writing this type of statement:

```
WRITEDOS <text_label>,<dos_handle>
```

In the above text message example the line needed is:

```
WRITEDOS message, _stdout
```

which gets expanded to this type of code:

```
    movem.l   d1-d3,-(sp)       preserve registers d1-d3
    move.l    _stdout,d1        DOS output file handle
    move.l    #message,d2       start of message
    move.l    #message_SIZEOF,d3     size of message
    CALLSYS   Write,_DOSBase    DOS call to write message
    movem.l   (sp)+,d1-d3       restore registers d1-d3
```

Obviously the CALLSYS macro gets expanded in a similar fashion with CALLSYS itself causing the _LVO prefix to be added to the Write label and generating a further reference to the system LINKLIB macro.

```
movem.l   d1-d3,-(sp)          preserve registers d1-d3
move.l    _stdout,d1           DOS output file handle
move.l    #message,d2          start of message
move.l    #message_SIZEOF,d3   size of message
LINKLIB   _LVOWrite,_DOSBase   DOS call to write message
movem.l   (sp)+,d1-d3          restore registers d1-d3
```

LINKLIB is of course also expanded so the final code produced by the assembler looks like this:

```
movem.l   d1-d3,-(sp)          preserve registers d1-d3
move.l    _stdout,d1           DOS output file handle
move.l    #message,d2          start of message
move.l    #message_SIZEOF,d3   size of message
move.l    a6, -(sp)            preserve contents of a6
move.l    _DOSBase, a6         base address of library
jsr       _LVOWrite(a6)        indirect subroutine call
move.l    (sp)+,a6             restore a6
movem.l   (sp)+,d1-d3          restore registers d1-d3
```

Be quite clear of the advantages of this macro orientated approach. Three generally useful macros have allowed us to create all of the above code by simply writing:

```
WRITEDOS message, _stdout
```

Already the macros are doing a good job of hiding the somewhat *messy* details of the function calls. In effect they are allowing us to write 68000 assembler code at a much higher level than would otherwise have been possible!

If we take our macro definitions, define space for some variables, and include the appropriate header files it's possible to create a short program which puts all of the ideas we've been talking about together. The following example opens the DOS library, sets up _stdout, and then prints a message on the screen:

```
*---------------------------------------------------------------
* Example CH12-1.s
*---------------------------------------------------------------
; some system include files...
     include exec/types.i
     include exec/libraries.i
     include exec/exec_lib.i
*---------------------------------------------------------------
CALLSYS  MACRO
         LINKLIB _LVO\1,\2
         ENDM
; CALLSYS macro is used to extend LINKLIB and thus avoid
; the explicit use of the _LVO prefixes in the function
; names...
*---------------------------------------------------------------
WRITEDOS MACRO
         movem.l   d1-d3,-(sp)   preserve registers d1-d3
         move.l    \2,d1         DOS output file handle
         move.l    #\1,d2        start of message
         move.l    #\1_SIZEOF,d3      size of message
         CALLSYS   Write,_DOSBase     DOS call to write
                                      message
         movem.l   (sp)+,d1-d3   restore registers d1-d3
         ENDM
; WRITEDOS is used to Write() DOS text messages and
; control character streams. The macro expects the user
; to supply a text label followed by a valid DOS output
; handle.
; Usage:      WRITEDOS <text_label>,<dos_handle>
; Example:    WRITEDOS message, _stdout
; Within the program each message X must have a
; corresponding size EQUate, X_SIZEOF, containing the
; size of the message. An easy way to set this up is to
; define the size label immediately after defining the
; message itself and use the assembler's location counter
; to do the length calculation, like this...
;            message            dc.b 'test text'
```

```
;             message_SIZEOF     EQU *-message
*---------------------------------------------------------------
; EQUate definitions...
_AbsExecBase  EQU       4
LF            EQU       10
*---------------------------------------------------------------
; main program code...
     move.l   _AbsExecBase,_SysBase   set up SysBase
                                      variable
     lea      dos_name,a1             library name start in a1
     moveq    #0,d0                   any version will do
     CALLSYS  OpenLibrary,_SysBase    macro (see text for
                                      details)
     move.l   d0,_DOSBase             store returned value
     beq      EXIT                    test result for success
; if we reach here then the DOS library is open and its
; functions can be safely used!
     CALLSYS  Output,_DOSBase         get default output handle
     move.l   d0,_stdout              store output handle
     beq      CLOSELIB
; have obtained valid output handle so message can be
; written...
     WRITEDOS message, _stdout        get DOS to write message
; all done so now we can close DOS library...
CLOSELIB move.l    _DOSBase,a1        base needed in a1
     CALLSYS  CloseLibrary, _SysBase
; and terminate the program...
EXIT     clr.l     d0
         rts                         logical end of program
*---------------------------------------------------------------
; variables and static data...
_stdout       ds.l      1
_SysBase      ds.l      1
_DOSBase      ds.l      1
dos_name      DOSNAME
message       dc.b 'this is just my line of test text',LF
message_SIZEOF     EQU *-message
*---------------------------------------------------------------
```

The format of the library calls should be familiar from earlier chapters and you should note that not only have any calls that could fail been checked but that the program takes the appropriate actions if things go wrong. If, for example, the Output() function fails then the program branches directly to the section which closes the DOS library. In other words it does *not* attempt to output a message.

You'll notice that space for the programs variables, _stdout,_SysBase etc, have been created using the assembler's define storage (ds.l) directives and on seeing the directive:

```
_stdout ds.l 1
```

the assembler will set aside four bytes of uninitialised memory. When long word (or word) values are specified the assembler will ensure that the location is word-aligned (to prevent addressing errors when the program is run). What happens at the assembly stage of course is that, on seeing such a directive, the assembler simple adds 4 (or 5 if the location needs padding) to its location counter.

You may, incidentally, be wondering why a clr.l d0 instruction occurs just before the end of the program. It's because although Amiga programs terminate via a simple return from subroutine (rts) instruction AmigaDOS, by convention, expects to see either a zero or an AmigaDOS error code in register d0. Nothing serious will happen of you don't do this but given the system rules it is best to stick to them!.

The next program extends the ideas we've been discussing to the printing of several text strings:

```
*---------------------------------------------------------------
* Example CH12-2.s
*---------------------------------------------------------------
; some system include files...
        include exec/types.i
        include exec/libraries.i
        include exec/exec_lib.i
*---------------------------------------------------------------
; see text and notes with earlier programs
CALLSYS  MACRO
        LINKLIB _LVO\1,\2
        ENDM
*---------------------------------------------------------------
```

```
; see text and notes with earlier programs
WRITEDOS MACRO
         movem.l   d1-d3,-(sp)   preserve registers d1-d3
         move.l    \2,d1         DOS output file handle
         move.l    #\1,d2        start of message
         move.l    #\1_SIZEOF,d3 size of message
         CALLSYS   Write,_DOSBase     DOS call to write
                                      message
         movem.l   (sp)+,d1-d3   restore registers d1-d3
         ENDM
*---------------------------------------------------------------
; EQUate definitions...
_AbsExecBase  EQU      4
LF            EQU      10
*---------------------------------------------------------------
; main program code...
     move.l    _AbsExecBase,_SysBase   set up SysBase
                                       variable
     lea       dos_name,a1         library name start in a1
     moveq     #0,d0               any version will do
     CALLSYS   OpenLibrary,_SysBase    macro (see text for
                                       details)
     move.l    d0,_DOSBase         store returned value
     beq       EXIT                test result for success
; DOS library is open and its functions can be safely
; used...
     CALLSYS   Output,_DOSBase     get default output handle
     move.l    d0,_stdout          store output handle
     beq       CLOSELIB
; have obtained a valid output handle so messages can be
; written...
     WRITEDOS message1,_stdout     write messages
     WRITEDOS message2,_stdout
     WRITEDOS message3,_stdout
     WRITEDOS message4,_stdout
; all done so now we can close DOS library...
CLOSELIB move.l    _DOSBase,a1    base needed in a1
```

```
        CALLSYS   CloseLibrary, _SysBase
; and terminate the program...
EXIT    clr.l     d0
        rts                          logical end of program
*-------------------------------------------------------------
; variables and static data...
_stdout         ds.l      1
_SysBase        ds.l      1
_DOSBase        ds.l      1
dos_name        DOSNAME
message1        dc.b 'Once you have seen how easy it is to
                write',LF
message1_SIZEOF     EQU *-message1
message2        dc.b 'one line of text using the WRITEDOS
                macro...',LF
message2_SIZEOF     EQU *-message2
message3        dc.b 'you should be able to write any
                number of',LF
message3_SIZEOF     EQU *-message3
message4        dc.b 'similar programs yourself!',LF
message4_SIZEOF     EQU *-message4
*-------------------------------------------------------------
```

Getting Data From The CLI/Shell Command Line

I mentioned earlier that when a CLI/Shell program starts, the registers a0 and d0 contain the start address of the command line and its length. The following example starts by collecting this info and storing it in two variables (which I've called cli_args_p and cli_args_size). Having done that, it continues as per the earlier example by printing some text using DOS's Write() function. The difference however in this program is that it is not a static text string that is being printed – we print the arguments supplied on the command line when the program was started. The main purpose of the example is to illustrate how user supplied arguments can be collected but, by way of a simple loop illustration, I've actually arranged to print the command line as many times as there are characters, removing the last character each time a line is printed. If, for example, the user types *ThisIsMyTest* the program will respond by displaying:

```
ThisIsMyTest
ThisIsMyTes
ThisIsMyTe
ThisIsMyT
ThisIsMy
ThisIsM
ThisIs
ThisI
This
Thi
Th
T
```

Here's the code that shows how it is done:

```
* ---------------------------------------------------------------
* Example CH12-3.s
* ---------------------------------------------------------------
; some system include files...
        include exec/types.i
        include exec/libraries.i
        include exec/exec_lib.i
* ---------------------------------------------------------------
; see text and notes with earlier programs
CALLSYS  MACRO
        LINKLIB _LVO\1,\2
        ENDM
* ---------------------------------------------------------------
; see text and notes with earlier programs
WRITEDOS MACRO
     movem.l  d1-d3,-(sp)        preserve registers d1-d3
     move.l   \2,d1              DOS output file handle
     move.l   #\1,d2             start of message
     move.l   #\1_SIZEOF,d3      size of message
     CALLSYS  Write,_DOSBase     DOS  call to write
                                 message
     movem.l  (sp)+,d1-d3        restore registers d1-d3
     ENDM
```

```
* ------------------------------------------------------------
; EQUate definitions...
_AbsExecBase  EQU       4
LF            EQU       10
* ------------------------------------------------------------
; main program code...
     move.l   _AbsExecBase,_SysBase   set up SysBase
                                      variable
     move.l   a0,cli_args_p           save DOS supplied
                                      CLI pointer
     move.l   d0,cli_args_size        and command
                                      argument length
     lea dos_name,a1              library name start in a1
     moveq    #0,d0                   any version will do
     CALLSYS  OpenLibrary,_SysBase
     move.l   d0,_DOSBase             store library base
     beq      EXIT                    check result
; DOS library is open and its functions can be safely
; used!
     CALLSYS  Output,_DOSBase     get default output handle
     move.l   d0,_stdout          store output handle
     beq      CLOSELIB
; valid output handle is available so do the argument
; print...
     move.l   cli_args_size,d3    orig argument size
     subq.l   #1,d3               ignore terminal linefeed
     beq      CLOSELIB            no arguments provided
PRINT move.l  _stdout,d1          DOS output file handle
     move.l   cli_args_p,d2       needed since DOS
                                  destroys d2
     CALLSYS  Write,_DOSBase      print d3 characters of
                                  argument
     WRITEDOS linefeed, _stdout   print a linefeed
     subq.l   #1,d3               decrease character count
     bne      PRINT          keep going if d3 is non-zero
     WRITEDOS linefeed, _stdout   print linefeed to finish
; all done so now we can close DOS library...
CLOSELIB move.l    _DOSBase,a1    base needed in a1
```

```
        CALLSYS   CloseLibrary, _SysBase
; and terminate the program...
EXIT    clr.l     d0
        rts                        logical end of program
* ------------------------------------------------------------
; variables and static data...
_stdout           ds.l      1
_SysBase          ds.l      1
_DOSBase          ds.l      1
cli_args_p        ds.l      1
cli_args_size     ds.l      1
dos_name          DOSNAME
linefeed          dc.b LF
linefeed_SIZEOF   EQU *-linefeed
* ------------------------------------------------------------
```

Note: Because the WRITEDOS macro is not designed to handle messages whose lengths are not defined by a _SIZEOF label, the DOS Write() function call had to be set up manually!

Using The Amiga.lib Library Print Function

One alternative to using the DOS based Write() function directly can be found in the amiga.lib linker library. There is a high-level routine called printf(), styled on the C function of the same name (see Appendix A for details) which allows you to both print and specify the format of text and numbers (decimal and hexadecimal).

Linker libraries, as explained earlier, are a collection of routines and data that can be used by your program. When using routines which are external to the source code that you are actually writing it is necessary to tell the assembler that some of the routine references that it will find in the program will not actually be found in the source itself, but the reference will be resolved (ie the routine in question will be found) later, namely at the time the program is linked.

To do this we use the assembler's XREF pseudo-op. So to declare the print() function, which to the assembler programmer is the reference to a routine called _printf, we use this statement:

```
XREF _printf
```

Having created a program with such a definition we ask the assembler to create linkable code. By convention the assembler will usually create a file with a '.o' filename extension to signify an object code module. Once the object code module is available it can be linked.

If the source file is called ExampleCH12-4.s then the assembler will create an object code file called ExampleCH12-4.o, and to link this with the amiga.lib library you would use this sort of command line:

```
blink ExampleCH12-4.o to ExampleCH12-4 library amiga.lib
```

It may be necessary, depending on your assembler/tool environment to add filepaths to tell blink where the files and libraries are. If, for example, your program files are in Ram and the amiga.lib library is in a df0: directory called LIB then you would use a blink command line which looked like this:

```
blink ram:ExampleCH12-4.o to ram:ExampleCH12-4 library
df0:LIB/amiga.lib
```

Either way the result, at the end of the day, is that blink will take the specified object code file, add the necessary library code, and produce a runable (executable) program.

As far as the source code is concerned however there is a little more to using the printf() routine than just telling the linker where it is. The amiga.lib printf() function has its own special needs and amongst them comes access to a valid stdout handle – in other words printf() will need to know where the output should be sent. In fact, unless the linker can *see* the _stdout label in your program, the link operation will fail.

This is where another assembler pseudo-op, called XDEF, comes in handy. XDEF ensures that labels are visible to the linker and to make _stdout available in this fashion we'd write:

```
XDEF _stdout
```

Many of the routines present in amiga.lib expect to have access to library bases and so these also frequently need to be XDEF's. To make the DOS library base, known conventionally as _DOSBase, externally visible, we would therefore use this statement:

```
XDEF _DOSBase
```

C Function Call Conventions

Unfortunately there is a big difference between the Amiga's run-time libraries, such as the exec and DOS libraries, and the amiga.lib linker library as far as both use and the way that the library routines expect to be given their data. The parameter passing conventions of the run-time library routines, as we have already seen, are register based – the data required for the routines are placed into appropriate 68000 registers prior to using the function.

The amiga.lib routines have been written to use a C style convention whereby any data that must be passed to the function is passed on the stack. For obvious reasons this approach is called stack-based parameter passing and the snag, as far as the newcomer to assembler programming is concerned, is that it is necessary to know how to do this before the routines can be used.

Luckily the basic outline is reasonably simple. Place any required parameters onto the 68000's stack, perform a normal jsr (or perhaps bsr) type subroutine call, then adjust the stack pointer so that it points to the position specified before the parameters were pushed onto it. In effect this latter adjustment serves the same purpose as pulling the parameters off the stack, but the single numerical adjustment is quicker.

From C, the printf() function takes this form:

```
printf(format_string, arg1, arg2,.... argN);
```

and (as you'll see in Appendix A) text strings are specified by pointers representing the addresses of their first bytes. To print a single text string you would therefore use this type of call:

```
printf(format_string, text_string);
```

The format string can incidentally be quite complex but for our immediate purposes all you need to be aware of is the fact that the format string for printing a single text string followed by a line-feed is:

```
dc.b '%s',LF, NULL
```

This tells the printf() function to expect a string pointer. The terminal NULL incidentally is, as mentioned before, a C-style way of indicating the end of the string.

C function call conventions result in parameters being pushed onto the stack in a right to left order. For the printf() function call illustrated above, this means that the part of the stack that we are interested in ends up looking like Figure 12.1.

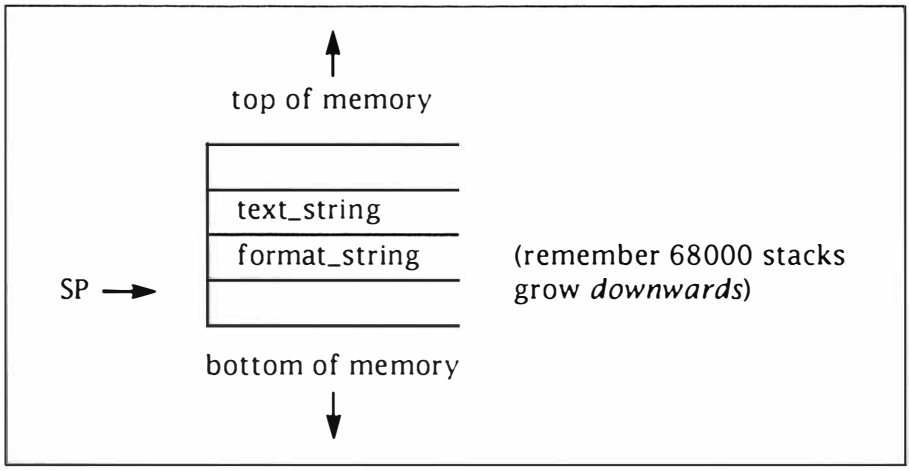


Figure 12.1. The Stack for the print(f) function call.

This situation is exactly what our program must provide before we can use the amiga.lib printf() function. To achieve it we therefore need to push firstly the address of the text string, and then secondly the address of the format string, onto the stack. There is in fact a special instruction for pushing the address of a specified operand onto the stack – it is called a *push effective address* (pea) instruction and for pushing the address of a labelled memory location it can be used like this:

```
pea     text_string
pea     format_string
```

The pea instruction can be used with *any* 68000 addressing mode and the result is always that the *address* of the specified operand (not the operand itself) will be pushed onto the stack. The complete amiga.lib C style printf() function call therefore follows this type of use pattern:

```
pea     text_string     push text string address
pea     format_string   push format string address
jsr     _printf         make the amiga.lib call
addq.l  #8,sp           adjust stack
```

Notice that, as mentioned earlier, it is *not* necessary to pull the text and format string pointers from the stack – instead we use a addq.l #8 instruction to add 8 (the numerical equivalent of two long words) to the stack pointer. This effectively adjusts the stack pointer register so that it has the same value as it had before we pushed our parameters onto the stack.

Anyway, that's enough of such things for the moment. Now that these preliminary explanations are out of the way here is some runable example code that will illustrate the ideas I've been discussing:

```
* ------------------------------------------------------------
* Example CH12-4.s
* ------------------------------------------------------------
; some system include files...
        include exec/types.i
        include exec/libraries.i
        include exec/exec_lib.i
* ------------------------------------------------------------
; external reference declarations...
        XREF _printf
        XDEF _stdout
        XDEF _DOSBase
* ------------------------------------------------------------
CALLSYS  MACRO
        LINKLIB _LVO\1,\2
        ENDM
; CALLSYS macro is used to extend LINKLIB and thus avoid
; the explicit use of the _LVO prefixes in the function
; names...
* ------------------------------------------------------------
; EQUate definitions...
_AbsExecBase  EQU      4
LF            EQU      10
NULL          EQU      0
* ------------------------------------------------------------
; main program code...
     move.l   _AbsExecBase,_SysBase   set up SysBase
                                      variable
     lea      dos_name,a1         library name start in a1
     moveq    #0,d0               any version will do
     CALLSYS  OpenLibrary,_SysBase    macro (see text for
                                      details)
     move.l   d0,_DOSBase         store returned value
```

```
     beq       EXIT                test result for success
; if we reach here then the DOS library is open and its
; functions can be safely used!
     CALLSYS   Output,_DOSBase     get default output handle
     move.l    d0,_stdout          store output handle
     beq       CLOSELIB
; Have obtained valid output handle so message can be
; written. This time because we are using the amiga.lib
; printf() routine, things must be done in C style so not
; only must parameters be passed on the stack but ALL
; strings must be NULL terminated...
     pea       message             push message address
     pea       format_string       push format string
                                   address
     jsr       _printf             use amiga.lib printf()
     addq.l    #8,sp               shortcut way to adjust
                                   stack
; all done so now we can close DOS library...
CLOSELIB move.l     _DOSBase,a1    base needed in a1
         CALLSYS    CloseLibrary, _SysBase
; and terminate the program...
EXIT     clr.l      d0
         rts                       logical end of program
* ------------------------------------------------------------
; variables and static data...
_stdout       ds.l      1
_SysBase      ds.l      1
_DOSBase      ds.l      1
dos_name      DOSNAME
message       dc.b 'my line of printf() test text',NULL
format_string dc.b '%s',LF,NULL
* ------------------------------------------------------------
```

printf() Debugging

The amiga.lib library's printf() routine is often useful as a debugging aid because it can be used to dump the contents of specified registers back at the CLI/Shell window. The following

program, ExampleCH12-5.s, is almost identical to the previous one except that it uses printf() to print the contents of a numerical variable – namely, the contents of _SysBase, ie the base address of the exec library:

```
* ------------------------------------------------------------------
* Example CH12-5.s
* ------------------------------------------------------------------
; some system include files...
        include exec/types.i
        include exec/libraries.i
        include exec/exec_lib.i
* ------------------------------------------------------------------
; external reference declarations...
        XREF _printf
        XDEF _stdout
        XDEF _DOSBase
* ------------------------------------------------------------------
CALLSYS  MACRO
        LINKLIB _LVO\1,\2
        ENDM
; CALLSYS macro is used to extend LINKLIB and thus avoid
; the explicit use of the _LVO prefixes in the function
; names...
* ------------------------------------------------------------------
; EQUate definitions...
_AbsExecBase  EQU      4
LF            EQU      10
NULL          EQU      0
* ------------------------------------------------------------------
; main program code...
     move.l   _AbsExecBase,_SysBase       set up SysBase
                                          variable
     lea      dos_name,a1        library name start in a1
     moveq    #0,d0              any version will do
     CALLSYS  OpenLibrary,_SysBase    macro (see text for
                                      details)
     move.l   d0,_DOSBase        store returned value
```

```
     beq       EXIT                test result for success
; if we reach here then the DOS library is open and its
; functions can be safely used!
     CALLSYS   Output,_DOSBase     get default output
                                   handle
     move.l    d0,_stdout          store output handle
     beq       CLOSELIB
; Have obtained valid output handle so message can be
; written. This time the amiga.lib printf() routine is
; being used to print the contents of the _SysBase
; variable...
     move.l    _SysBase,-(sp)      push library base
     pea       format_string       push format string
                                   address
     jsr       _printf             use amiga.lib printf()
     addq.l    #8,sp          shortcut way to adjust stack
; all done so now we can close DOS library...
CLOSELIB move.l     _DOSBase,a1    base needed in a1
         CALLSYS    CloseLibrary, _SysBase
; and terminate the program...
EXIT     clr.l      d0
         rts                       logical end of program
* ------------------------------------------------------------
; variables and static data...
_stdout       ds.l      1
_SysBase      ds.l      1
_DOSBase      ds.l      1
dos_name      DOSNAME
format_string dc.b '%lx hex',LF,NULL
* ------------------------------------------------------------
```

Using Multiple Run-Time Libraries

Depending on what a program needs to do it may open any number of libraries simultaneously. When lots of these system orientated operations are being done it is however necessary to be careful about the order in which particular operations are done, and in fact whether certain things are done at all! As far as opening/closing

and other system allocate/deallocate issues are concerned, the safest rule of thumb is to always arrange to close things down in the reverse order to that used during program start-up.

Even with small programs, such as those we are discussing in this chapter, some care is needed. The next example deals with the opening of two libraries and I've used a number of test and conditional branch instructions to create the type of control structure in Figure 12.2.

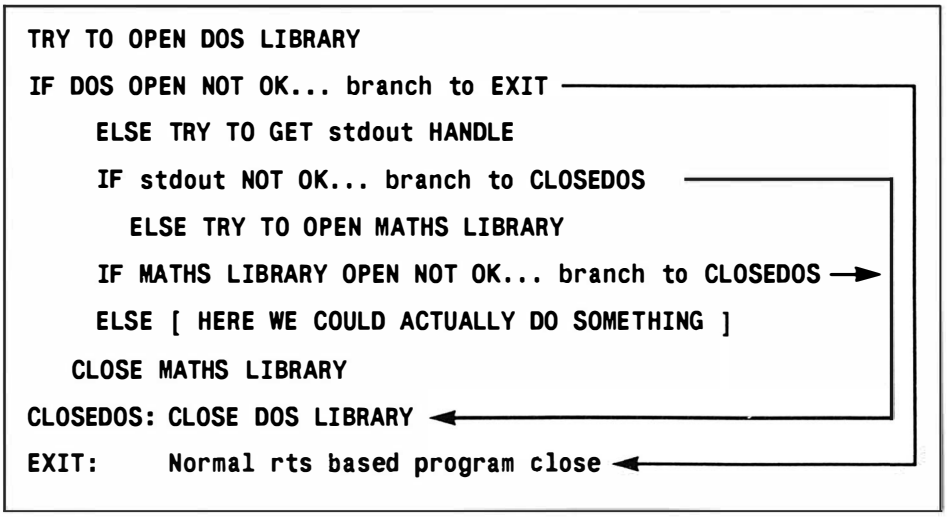


Figure 12.2. Control structure utilising test and conditional branch instructions.

The example itself, since I've chosen to use the amiga.lib printf() function, is another that will require you (assuming that your assembler gives you a choice) to create linkable, as opposed to directly executable code. Most of the detail should be familiar from earlier examples and, as you'll see from the source code, nothing much happens once the libraries are open – in fact all we do is just close them again. There is however a purpose behind this apparent madness and, as you'll see later, it concerns shortcomings in the continued use of the *do it or branch over it* philosophy. For the moment though here is the program that the above pseudo-code sketch in Figure 12.2. represents:

```
*------------------------------------------------------------------
* Example CH12-6.s
*------------------------------------------------------------------
; some system include files...
        include exec/types.i
        include exec/libraries.i
        include exec/exec_lib.i
```

```
* ------------------------------------------------------------
; external reference declarations...
        XREF _printf
        XDEF _stdout
        XDEF _DOSBase
* ------------------------------------------------------------
CALLSYS  MACRO
        LINKLIB _LVO\1,\2
        ENDM
; CALLSYS macro is used to extend LINKLIB and thus avoid
; the explicit use of the _LVO prefixes in the function
; names...
* ------------------------------------------------------------
; EQUate definitions...
_AbsExecBase  EQU      4
LF            EQU      10
NULL          EQU      0
* ------------------------------------------------------------
; main program code...
     move.l   _AbsExecBase,_SysBase   set up SysBase
                                      variable
     lea      dos_name,a1         library name start in a1
     moveq    #0,d0               any version will do
     CALLSYS  OpenLibrary,_SysBase    macro (see text for
                                      details)
     move.l   d0,_DOSBase         store returned value
     beq      EXIT                test result for success
; if we reach here then the DOS library is open and its
; functions can be safely used!
     CALLSYS  Output,_DOSBase     get default output
                                  handle
     move.l   d0,_stdout          store output handle
     beq      CLOSEDOS
; now let's try and open the maths library...
     lea      math_name,a1        library name start in a1
     moveq    #0,d0               any version will do
     CALLSYS  OpenLibrary,_SysBase    macro (see text for
                                      details)
```

```
        move.l   d0,_MathBase        store returned value
        beq      CLOSEDOS            test result for success
; all library openings were OK so do a sign on message...
        pea      intro_message       push intro message
                                     pointer
        pea      format_string       push format string
                                     address
        jsr      _printf             use amiga.lib printf()
        addq.l   #8,sp               shortcut way to adjust
                                     stack
; here we could DO SOMETHING
; now print a goodbye message...
        pea      goodbye_message     push message pointer
        pea      format_string       push format string
                                     address
        jsr      _printf             use amiga.lib printf()
        addq.l   #8,sp               shortcut way to adjust
                                     stack
; all done so now we can close maths library...
CLOSEALL move.l    _MathBase,a1      base needed in a1
         CALLSYS   CloseLibrary, _SysBase
; close DOS library...
CLOSEDOS move.l    _DOSBase,a1       base needed in a1
         CALLSYS   CloseLibrary, _SysBase
; and terminate the program...
EXIT     clr.l     d0
         rts                         logical end of program
* ------------------------------------------------------------
; variables and static data...
_stdout             ds.l     1
_SysBase            ds.l     1
_DOSBase            ds.l     1
_MathBase           ds.l     1
dos_name            DOSNAME
math_name           dc.b 'mathffp.library',NULL
format_string       dc.b '%s',LF,NULL
intro_message       dc.b 'all libraries opened',NULL
goodbye_message     dc.b 'program now closing down',NULL
* ------------------------------------------------------------
```

A Glimpse of Some Potential Problems

Obviously in real, ie larger, Amiga programs many more things need to be done and to illustrate what I consider to be a rather important shortcoming of a lot of assembler code the next program adds a few more *things to do* to the framework used by the example CH12-5.s program just given. The mathtrans library, which is a library used to provide pre-written transcendental maths functions such as sin, cos, exp and so on is opened. Strictly speaking the normal mathffp library does *not* need to be open in order to use the mathtrans library because when the mathtrans library does need to use mathffp facilities it will open the mathffp library itself. If however you wish to use mathffp and mathtrans facilities together you should explicitly open both libraries for your own use. In the examples which follow I've opened both libraries just to illustrate how it's done and secondly to give a little flexibility should you wish to use these programs to experiment, with either mathffp functions or additional mathtrans functions.

During the course of the program two new amiga.lib functions are used which allow string representations of numbers, ie numbers stored as the equivalent ASCII strings, to be converted to Motorola fast floating point (ffp) form and back again. These ffp number representations are long word (ie 32 bit) arrangements which have been designed to represent floating point numbers in a way that simplifies many mathematical operations. They consist of a 24 bit mantissa (shown as Ms in the following sketch), an exponent sign bit (S), and a seven bit exponent (E) arranged like this:

```
bit 31          24 23          16 15          8 7           0
    M M M M M M M M  M M M M M M M M  M M M M M M M M  S E E E E E E E
```

The decimal range allowed is very roughly from plus or minus one times ten to the power plus or minus 19, ie:

$$(+/-)\ 10^{19} <-> 10^{-19}$$

For full details of the ffp format you can consult the official Motorola literature but for now our only concern with the ffp format is that to use the mathtrans library's SPExp() exponential function on a number it is necessary to have the number, in ffp form!

The amiga.lib afp() and fpa()

The amiga.lib library contains two functions which can convert a string of characters representing a number into ffp form and back again. As with the amiga.lib printf() both afp() and fpa() use stackbased parameter passing so to convert the string form of a

number into ffp form it is necessary to push the start address of the string onto the stack and then make the afp() call (ie do a jsr _afp) in the same way that the printf() call was handled:

```
pea       number          push pointer
jsr       _afp            an amiga.lib routine
addq.l    #4,sp           adjust stack
```

The apf() routine delivers a result in d0 and this is quite useful because the run-time mathtrans library routine SPExp(), the routine which I'll be using to calculate the exponential of the supplied number, expects the number in register d0. Remember the run-time libraries take their parameters in registers. As with all run-time library functions our CALLSYS macro can be used so the source code for the exponential call will just be:

```
CALLSYS SPExp,_MathTransBase    values sent/returned in d0
```

Now there is a snag with the exponential function, which is why I've used it as an example. Even though a supplied number is within the fast floating point allowed number range there is no guarantee that the result of raising e to the power of that number will be. Basically this means that SPExp() could fail and the function autodocs tell us that if this does occur the routine will return with the 68000 processor's overflow (V) flag set!

I'll not be doing this in the example which follows but obviously this potential for failure cannot ordinarily be ignored. For the moment though, for reasons of simplicity, I will forget about it and instead will convert the result back to ASCII string form using the amiga.lib fpa() function. After the above SPExp() call the ffp result will be in register d0 so conversion just involves pushing the address of the buffer, where the ASCII converted result is going to be stored, onto the stack, then pushing the contents of d0, making the jsr call, and adjusting the stack like this:

```
pea       result          push result pointer
move.l    d0,-(sp)        push ffp value
jsr       _fpa            convert back to ASCII
addq.l    #8,sp           adjust stack
```

Having converted our ffp number to an equivalent ASCII string we can then use the amiga.lib print() function to deliver the result back at the CLI/Shell window like this:

```
pea       result          push sum string pointer
pea       format_string   push format string address
jsr       _printf         use amiga.lib printf()
addq.l    #8,sp           shortcut way to adjust stack
```

The only thing we now need to discuss is where we will get our original number from. I've chosen to collect it from the CLI/Shell command line and, for example purposes, I've decided that instead of just using it via the originally supplied a0 pointer, we shall copy it to a buffer area. As you now know, when a CLI/Shell program starts register d0 contains a count of the number of characters that follow the program's name on the command line. If the user does not supply any parameters then d0 will be 1 and the single character will in fact be the command line's terminal linefeed.

It's therefore quite easy to check whether the user has supplied a number or not by using this immediate addressing form of a cmpi instruction at the start of the program:

```
cmpi #1,d0
```

If this comparison sets the zero flag then d0 equals 1 and the user hasn't supplied any other characters. If this was the case there would be little point in the program continuing because there is no number to convert. I mentioned earlier that a buffer would be allocated to store the number and, since I'll be using a static declaration (based on a ds.b declaration), this could lead to problems. Why? It's because if a user typed in a number with more characters than I had allowed for then the operation which copied data into the buffer would fill the buffer and then write over any number of succeeding bytes (destroying their contents). On the Amiga this could even mean that memory belonging to another program is destroyed!

It should then be very obvious that we mustn't allow this to happen and so, if the user has indeed supplied some data, we'll need to check its length to see that it will fit into the buffer. A cmpi comparison instruction, followed by a *branch on greater than* (bgt) conditional branch will do the job nicely and in the next example you'll see this type of test:

```
cmpi    #number_SIZEOF,d0
bgt     EXIT                line too long so quit!
```

You'll notice that I've used the same SIZEOF naming convention on the buffer as I did with text strings in earlier programs and providing the command line data which fits the buffer we are, at last, able to safely copy the command line data. The following fragment uses the 68000's powerful *indirect addressing with autoincrement* addressing scheme in conjunction with an automated decrease and branch always (dbra) instruction. In the following fragment the address of the number buffer is loaded into register a1 and the count present in d0, after having 2 subtracted so that the terminal command line line-feed is ignored, is used as the loop control register. Remember that all automated dbcc type

instructions exit when the countdown value reaches -1 and so to copy X characters you'd need to set the loop control register to X-1. In this example I want to disregard the last character hence I set it to d0-2 rather than d0-1! After the command line data has been copied we have to place a terminal NULL character at the end of the string because the documentation tells us that this is what the amiga.lib string <-> ffp conversion routines expect. Now that the explanations are out of the way, here is the loop which performs the command line copy operation:

```
        lea     number,a1           destination pointer
        subq    #2,d0               disregard terminator
LOOP    move.b  (a0)+,(a1)+         copy string
        dbra    d0,LOOP
        move.b  #NULL,(a1)          NULL terminate string
```

and if we put that together with the preliminary command line existence and size checks we get this sort of framework:

```
        cmpi    #1,d0           check for data?
        beq     EXIT            no data so quit!
        cmpi    #number_SIZEOF,d0
        bgt     EXIT            line too long so quit!
        lea     number,a1       destination pointer
        subq    #2,d0           disregard terminaton
LOOP    move.b  (a0)+,(a1)+     copy string
        dbra    d0,LOOP
        move.b  #NULL,(a1)      NULL terminate string
```

and when this is added to a program based on the library opening/closing and usage scheme used in earlier programs we finally end up with our program, ExampleCH12-7.s, which when given a number on the command line in this fashion:

```
program name <some number>
```

will print the exponential of the number.

On disk the program has been called ExampleCH12-7 and so if, for example, the user types:

```
ExampleCH12-7 1.001243
```

the program will print the value $e^{1.001243}$ ie 2.72!

What I'd like you to do as you study the following source code is to pay attention to the increasing number of conditional branches that are needed to make sure that pieces of code get executed, or not executed, as required:

```
* ------------------------------------------------------------
* Example CH12-7.s
* ------------------------------------------------------------
; some system include files...
        include exec/types.i
        include exec/libraries.i
        include exec/exec_lib.i
* ------------------------------------------------------------
; external reference declarations...
        XREF _printf
        XREF _afp
        XREF _fpa
        EXTERN_LIB SPExp
        XDEF _stdout
        XDEF _DOSBase
* ------------------------------------------------------------
CALLSYS  MACRO
        LINKLIB _LVO\1,\2
        ENDM
; CALLSYS macro is used to extend LINKLIB and thus avoid
; the explicit use of the _LVO prefixes in the function
; names...
* ------------------------------------------------------------
; EQUate definitions...
_AbsExecBase  EQU      4
LF            EQU      10
NULL          EQU      0
* ------------------------------------------------------------
; main program code starts by checking for a CLI/Shell
; argument line...
     cmpi     #1,d0              check for data?
     beq      EXIT               no data so quit!
; providing one exists we check that it isn't oversize...
     cmpi     #number_SIZEOF,d0
     bgt      EXIT               line too long so quit!
; since it is OK we copy it to the number buffer...
```

```
        lea     number,a1           destination pointer
        subq    #2,d0               disregard terminator
LOOP    move.b  (a0)+,(a1)+         copy string
        dbra    d0,LOOP
        move.b  #NULL,(a1)          NULL terminate string
; and then continue by opening libraries etc...
        move.l  _AbsExecBase,_SysBase   set up SysBase
                                        variable
        lea     dos_name,a1         library name start in a1
        moveq   #0,d0               any version will do
        CALLSYS OpenLibrary,_SysBase    macro (see text for
                                        details)
        move.l  d0,_DOSBase         store returned value
        beq     EXIT                test result for success
; if we reach here then the DOS library is open and its
; functions can be safely used!
        CALLSYS Output,_DOSBase     get default output
                                     handle
        move.l  d0,_stdout          store output handle
        beq     CLOSEDOS
; now let's try and open the maths library...
        lea     math_name,a1        library name start in a1
        moveq   #0,d0               any version will do
        CALLSYS OpenLibrary,_SysBase    macro (see text for
                                        details)
        move.l  d0,_MathBase        store returned value
        beq     CLOSEDOS            test result for success
; and the mathtrans library...
        lea     mathtrans_name,a1   library name start in a1
        moveq   #0,d0               any version will do
        CALLSYS OpenLibrary,_SysBase    macro (see text for
                                        details)
        move.l  d0,_MathTransBase   store returned value
        beq     CLOSEMATHS          test result for success
; at this point the DOS, maths, and mathtrans libraries
; are all open so we can do some sums...
; first convert the number to fast floating point form...
        pea     number              push pointer
```

```
     jsr       _afp                an amiga.lib routine
     addq.l    #4,sp               adjust stack
; result is in d0 already so now calculate the exp()
     CALLSYS   SPExp,_MathTransBase    values
                                       sent/returned in d0
; not being done in this example but this is where we
; should check the overflow flag to see whether the
; result is valid!
; instead back to ASCII form (ffp result is already in
; register d0)
     pea       result              push result pointer
     move.l    d0,-(sp)            push ffp value
     jsr       _fpa                convert back to ASCII
     addq.l    #8,sp               adjust stack
; and print result...
     pea       result              push sum string pointer
     pea       format_string       push format string
                                   address
     jsr       _printf             use amiga.lib printf()
     addq.l    #8,sp               shortcut way to adjust
                                   stack
; all done so now we can close the libraries...
CLOSETRANS   move.l  _MathTransBase,a1  base needed in a1
             CALLSYS CloseLibrary, _SysBase
CLOSEMATHS   move.l  _MathBase,a1       base needed in a1
             CALLSYS CloseLibrary, _SysBase
CLOSEDOS     move.l  _DOSBase,a1        base needed in a1
             CALLSYS CloseLibrary, _SysBase
; and terminate the program...
EXIT     clr.l     d0
         rts                         logical end of program
*---------------------------------------------------------------
; variables and static data...
_stdout             ds.l      1
_SysBase            ds.l      1
_DOSBase            ds.l      1
_MathBase           ds.l      1
```

```
_MathTransBase      ds.l      1
dos_name            DOSNAME
math_name           dc.b 'mathffp.library',NULL
mathtrans_name      dc.b 'mathtrans.library',NULL
format_string       dc.b '%s',LF,NULL
                    EVEN
number              ds.b 32
number_SIZEOF       EQU *-number
result              ds.b 16
* ------------------------------------------------------------
```

You'll see from the previous listing that the example CH12-7 program has a number of identifiable jobs to do, namely:

1. Check the command line.
2. Copy it if it exists and is not too long.
3. Open the DOS library.
4. Get the stdout handle.
5. Open the maths library.
6. Open the mathtrans library.
7. Convert copy of the command line to a ffp number.
8. Calculate the exponential of the number.
9. Convert the result to a string.
10. Print the result.
11. Close the mathtrans library.
12. Close the maths library.
13. Close the DOS library.
14. Quit back to the CLI/Shell.

Quite a number of these jobs can fail because of libraries not opening and this is especially true of the mathtrans library because this is one of the run-time libraries that resides on disk. A lot of checks have been made within example CH12-7 but more are needed because, as mentioned, it is possible that the user will provide a number, such as 99.18, whose exponential is too great to be expressed in ffp form. In this latter case the SPExp() routine would fail and although this would not cause any system damage the result, if used, would be meaningless!

Now to be honest it is possible to add more checks and continue program development along the lines that we have been doing, adding more branches to cater for the various control flow possibilities as they are required. The trouble is though that this type of development gets increasingly difficult as programs get larger. The solutions are three-fold. Firstly, it helps to isolate particular, well defined, jobs as subroutines. Secondly, it helps if you can work with the types of high-level IF-THEN_ELSE, DO-WHILE, and CASE type control structures that high-level languages offer. Thirdly, it turns out that it also helps to be able to adopt the same type of nested subroutine schemes that were mentioned in Chapter 5 being able, for example, to use code equivalent to this BASIC style construct:

```
IF (x) THEN GOSUB XXXX
     ELSE GOSUB YYYY
```

Unfortunately the 68000 itself does not provide conditional subroutine calls, ie instructions which only perform a subroutine call when certain flag conditions are met. Having said that, all is not lost because it is possible to create them quite easily. To see how it's done it is necessary to understand what happens when a *jump to subroutine* type (jsr or bsr) instruction is executed. When we reach a part in a program represented for example by:

```
          .
          .
          .
          jsr    SomeRoutine
HERE:     next instruction
          .
          .
          .
 /\/\/\/\/
SomeRoutine  instructions
               .
               .
               .
               .
               rts    end of subroutine
/\/\/\/\/
```

On encountering the jsr instruction the processor will push the address of the NEXT instruction (labelled HERE in this example) onto the stack. Having done that, control passes to the subroutine that I've called SomeRoutine. When this routine terminates the rts instruction tells the processor to pull an address from the stack and place it in the 68000's program counter register. When this happens with the above example the address labelled HERE gets jammed into the program counter and the processor immediately continues execution from that point, which is of course the instruction immediately after the original subroutine call.

This little scenario tells us exactly what we need to do to create our own *conditional* subroutine calls. We must:

1. Identify a return address and push it onto the stack.
2. Make a suitable flag-setting test.
3. On the basis of the result use conditional branch or jump instructions to pass control (or not pass control) to the appropriate subroutine.

The subroutines themselves should of course be written as a normal subroutine, ie some code terminating with a return from subroutine rts instruction. Here's a code fragment which should give you the general idea:

```
MATHS_OPEN   pea   MATHS_OPEN1   push a return address
             jsr   OpenTrans     zero flag clear on failure
             beq   TRANS_OPEN    next subroutine level
             rts
MATHS_OPEN1  jsr   CloseMaths
             rts
TRANS_OPEN instructions
             .
             .
             .
             .
             rts
```

This is actually a piece of code which tries to open the mathtrans library and, depending on whether the open library call is successful, a subroutine call to TRANS_OPEN may, or may not, be generated. It works like this. Firstly a *push effective address* (pea) instruction is used to place a return address (MATHS_OPEN1) on the stack. The next instruction is a normal subroutine call designed so that success/failure is indicated by the setting, or clearing, of the

68000's zero flag. As this information is received the beq specified branch is either taken or ignored. The result is that the TRANS_OPEN subroutine call is only taken *if* the OpenTrans routine was successful! When the routine labelled TRANS_OPEN terminates, via a rts instruction, the MATHS_OPEN1 label address is pulled from the stack and execution therefore continues from the MATHS_OPEN1 (jsr CloseMaths) position.

Now at first reading this might seem like a rather convoluted way of doing this, but it turns out to be very powerful because it allows us to program control structures in a way which is similar to a high-level language. The benefits are that if you are able to sketch out a program structure using pseudo-code, Warnier diagrams or some similar high-level design technique, then the nested conditional control structure approach will let you mirror that high-level design sketch very easily indeed. In Figure 12.3. and 12.4. there are a couple of the diagrams which I used to sketch out the basic needs of the last program.

Figure 12.3. tells us that we must only try to get stdout if the DOS opened successfully and that we only need open the maths library if a valid stdout handle is available (couldn't print results otherwise). More detail can be given for the bracket labelled *Maths open OK* and of course my interest at this point revolved around adding those overflow issues that were ignored in the previous program. Figure 12.4. is an expansion of the relevant part of the Figure 12.3.

The reason I've given these design sketches, and I ought to mention that I've not by any means provided full details of the design pathway, is to let you compare the bracket subsets with the nested subroutines that are present in the 68000 code of Example 12.8. You'll see from the code which follows that I have coded most of the diagram brackets as subroutines using my *conditional subroutine call creation* approach. I've also adopted a convention whereby different faults are represented by error numbers. When an error occurs an appropriate number gets stored in a special location (which I've called error_flag) and at the end of the program this value is used to print a message.

You'll notice some other changes in the code explanations of which follow. I have now isolated the library opening and closing code into separate subroutines and, in the case of the library opening routines I use the zero flag as a success/failure indicator. No checks are made on the close library routines and there is a good reason for this – in this next example, and indeed in all of the examples that I've dealt with, you'll find that the library closing code is only ever executed *if the library was successfully opened in the first place*. Hence, the library closing routines will never fail and so do not need to be checked!

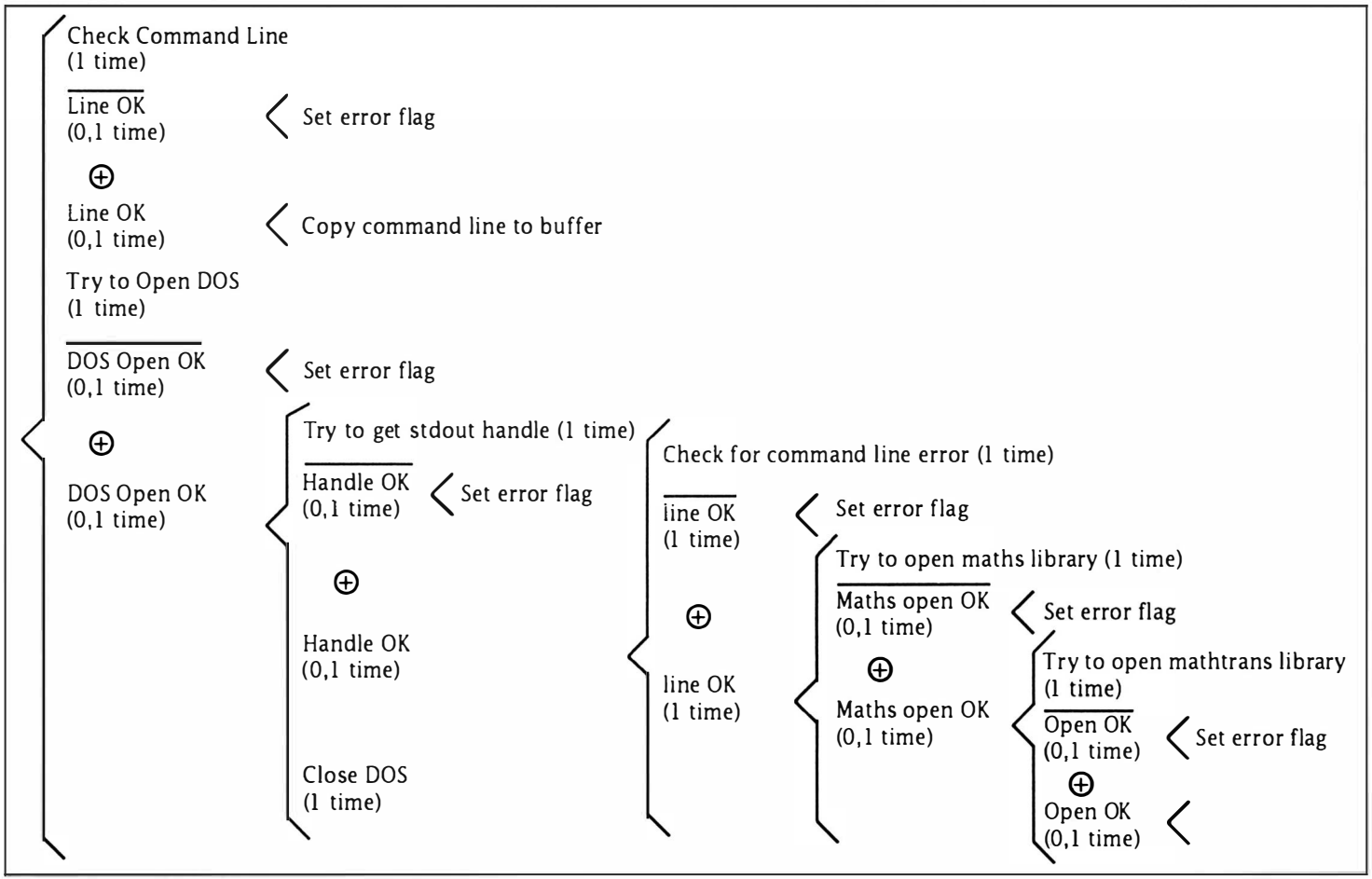


Figure 12.3. Warnier sketch of some of the things which program CH12-7 has to do.

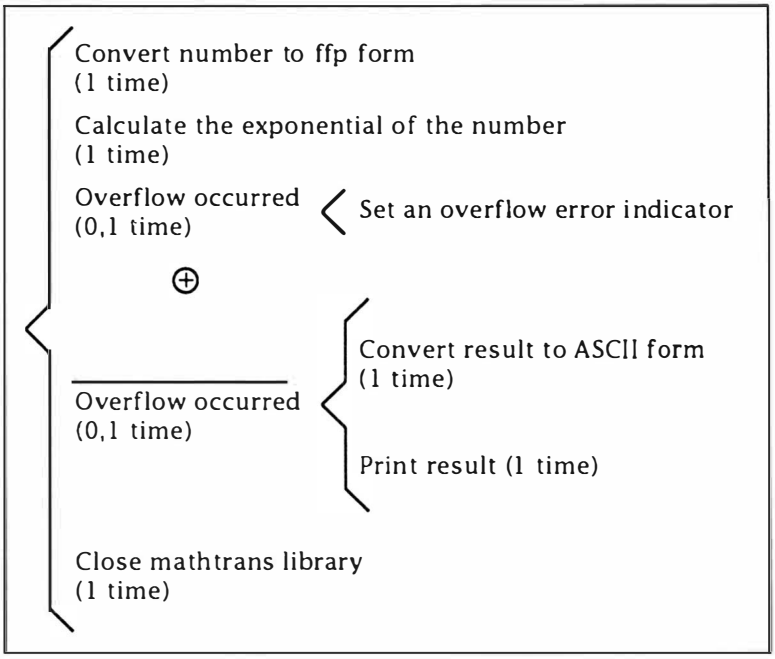


Figure 12.4. These constraints show what should really be done if a number causes an overflow.

As a last aside, before providing the complete source, I need to mention the routine which prints error messages. Again I've isolated the code into a subroutine but I've used a table-orientated trick, based on the 68000's very useful indexed indirect addressing with displacement addressing scheme, which allows me to print appropriate text strings even though the program's internal error handling is done via error numbers.

This is how it works. Within the program a number of error type EQUates are defined:

```
NO_ERRORS          EQU  0
NO_ARGUMENTS       EQU  1
LONG_ARGUMENTS     EQU  2
NO_MATHS           EQU  3
NO_TRANS           EQU  4
OVERFLOW           EQU  5
```

At the end of the program a list of text strings corresponding to those errors are also defined:

```
error0    dc.b 'no errors',NULL
error1    dc.b 'no value supplied',NULL
```

```
error2    dc.b 'command string too long',NULL
error3    dc.b 'could not open maths library',NULL
error4    dc.b 'could not open mathtrans library',NULL
error5    dc.b 'result produced an overflow',NULL
```

In addition to this a table is set up containing a dc.l directive that specifies those string addresses like this:

```
error_table   dc.l error0,error1,error2,error3,error4,error5
```

The error message routine has to convert the numbers 0,1,2 etc, into the appropriate error messages and here's how it can be done. I clear register d0 and copy the error number to it. Shifting this value two places to the left effectively multiplies the value in d0 by four (try writing out some examples if you don't believe it) and this results in d0 holding offsets of either 0, 4, 8, 12, 16 or 20. If you think about the address of the error_table label and the four byte values which the assembler will generate references for, you'll see that error_table + 0, error_table + 4,error_table + 8, error_table + 12, error_table + 16 and error_table + 20, will in fact give the addresses of the six table entries and these locations hold the addresses of the error message text strings.

What is needed, given the base address that we've called error_table, is some way of adding the offset that we've calculated (by shifting the error number) to the base address and using that value as the address from which we get an operand. This is exactly what the 68000's indexed indirect addressing with displacement allows us to do because it lets us create an address by adding an index value, which may be stored in an address or data register, *and* a fixed displacement, to a base address stored in another address register. Using this addressing mode allows us, given N an error number, to retrieve the address of the corresponding N'th string.In fact the instruction:

```
move.l 0(a0, d0.l), -(sp)
```

allows us to retrieve it and push it onto the stack so it is just what is needed for the amiga.lib printf() call. Here then is the complete error message printing subroutine:

```
ErrorMsg  clr.l   d0                 could contain garbage!
          move.b  error_flag,d0      get error number
          lsl.l   #2,d0              multiply by 4
          move.l  #error_table,a0    load table base
                                     address
          move.l  0(a0,d0.l),-(sp)   push table entry
                                     contents
          pea     string_format      push format string
```

```
        jsr     _printf             print error message
        add.l   #8,sp               adjust stack
        rts
```

and to finish this chapter here's the complete source code that illustrates, within the context of a runable program, the *conditional subroutine call* approach that I've been talking about:

```
* ------------------------------------------------------------------
* Example CH12-8.s
* ------------------------------------------------------------------
; some system include files...
        include exec/types.i
        include exec/libraries.i
        include exec/exec_lib.i
* ------------------------------------------------------------------
; external reference declarations...
        XREF _printf
        XREF _afp
        XREF _fpa
        EXTERN_LIB SPExp
        XDEF _stdout
        XDEF _DOSBase
* ------------------------------------------------------------------
CALLSYS  MACRO
        LINKLIB _LVO\1,\2
        ENDM
; CALLSYS macro is used to extend LINKLIB and thus avoid
; the explicit use of the _LVO prefixes in the function
; names...
* ------------------------------------------------------------------
; general EQUate definitions...
_AbsExecBase        EQU  4
LF                  EQU  10
NULL                EQU  0
* ------------------------------------------------------------------
; error number EQUate definitions...
NO_ERRORS           EQU  0
NO_ARGUMENTS        EQU  1
```

```
LONG_ARGUMENTS      EQU  2
NO_MATHS            EQU  3
NO_TRANS            EQU  4
OVERFLOW            EQU  5
* ---------------------------------------------------------------
; program starts by checking size of CLI/Shell argument
; line...
         clr.b      error_flag
LBOUND   cmpi.b     #1,d0
         bne        UBOUND
         move.b     #NO_ARGUMENTS,error_flag
         bra        OPENDOS
UBOUND   cmpi.b     #number_SIZEOF,d0
         bls        COPYARGS
         move.b     #LONG_ARGUMENTS,error_flag
         bra        OPENDOS
COPYARGS lea        number,a1       destination pointer
         subq.b     #2,d0           disregard line terminator
LOOP     move.b     (a0)+,(a1)+     copy string
         dbra       d0,LOOP
         move.b     #NULL,(a1)      NULL terminate string
OPENDOS  move.l     _AbsExecBase,_SysBase    set up SysBase
         lea   dos_name,a1          and open DOS library
         moveq      #0,d0           any version will do
         CALLSYS    OpenLibrary,_SysBase     macro (see text
                                             for details)
         move.l     d0,_DOSBase     store returned value
         beq        EXIT            test result for success
; if we reach here then the DOS library is open and its
; functions can be safely used!
         CALLSYS    Output,_DOSBase      get default output
                                         handle
         move.l     d0,_stdout           store output handle
         beq        CLOSEDOS
; This next code is tricky unless you realize what is
; happening. The 68000 hasn't got conditional subroutine
; instructions so I create my own by pushing a return
; address on the stack and then conditionally BRANCHING
```

```
; to the appropriate subroutine.
DOS_OPEN  pea       CLOSEDOS
          tst.b     error_flag      command line error?
          beq       ARGS_OK         next subroutine level
          rts
CLOSEDOS  tst.b     error_flag      were there any errors?
          beq       CLOSEDOS1       skip error message if not
          jsr       ErrorMsg
CLOSEDOS1 move.l    _DOSBase,a1     base needed in a1
          CALLSYS   CloseLibrary, _SysBase
; all done so exit back to CLI/Shell...
EXIT      clr.l     d0
          rts                       logical end of program
* ------------------------------------------------------------------
; Remember that this diagram level is coded as a subroutine
ARGS_OK      pea    ARGS_OK1        push a return address
             jsr    OpenMaths       zero flag clear on failure
             beq    MATHS_OPEN      next subroutine level
ARGS_OK1     rts                    twin execution-see text
* ------------------------------------------------------------------
; another diagram level coded as a subroutine
MATHS_OPEN   pea    MATHS_OPEN1     push a return address
             jsr    OpenTrans       zero flag clear on failure
             beq    TRANS_OPEN      next subroutine level
             rts
MATHS_OPEN1  jsr    CloseMaths
             rts
* ------------------------------------------------------------------
; yet another diagram level coded as a subroutine and at
; this point the DOS, maths, and mathtrans libraries are
; open and useable...
TRANS_OPEN  pea      TRANS_OPEN1   push return address
            pea      number        push pointer
            jsr      _afp          data comes back in d0
            add.l    #4,sp         adjust stack
            CALLSYS  SPExp,_MathTransBase     values
                                              sent/returned
                                              in d0
```

```
            bvc     PRINT_DATA   check for overflow
            move.b  #OVERFLOW,error_flag
            rts
TRANS_OPEN1 jsr     CloseTrans
            rts
* ------------------------------------------------------------
; lowest diagram level coded again as a subroutine
PRINT_DATA  pea     result       result already in d0
            move.l  d0,-(sp)     push ffp value
            jsr     _fpa         convert back to ASCII
            addq.l  #8,sp        adjust stack
            pea     result       push sum string pointer
            pea     string_format      push format string
                                       address
            jsr     _printf      use amiga.lib printf()
            addq.l  #8,sp        shortcut way to adjust stack
            rts
* ------------------------------------------------------------
; If OpenMaths() routine fails the zero flag will be CLEAR
; on return!
OpenMaths   lea     math_name,a1  library name start in a1
            moveq   #0,d0         any version will do
            CALLSYS OpenLibrary,_SysBase     macro (see text
                                             for details)
            move.l  d0,_MathBase  store returned value
            beq     OpenMaths1    branch taken if open
                                  failed
            clr.l   d0            open OK so set zero flag
            rts
OpenMaths1  move.b  #NO_MATHS,error_flag     will CLEAR z
                                             flag
            rts
* ------------------------------------------------------------
; If OpenTrans() routine fails the zero flag will be
; CLEAR on return!
OpenTrans   lea     mathtrans_name,a1   library name start
                                        in a1
            moveq   #0,d0         any version will do
```

```
            CALLSYS  OpenLibrary,_SysBase     macro (see text
                                              for details)
            move.l   d0,_MathTransBase   store returned value
            beq      OpenTrans1   branch taken if open failed
            clr.l    d0           open OK so set zero flag
            rts
OpenTrans1  move.b   #NO_TRANS,error_flag     will CLEAR z
                                              flag
            rts
* ---------------------------------------------------------------
CloseMaths  move.l   _MathBase,a1 base needed in a1
            CALLSYS  CloseLibrary, _SysBase
            rts
* ---------------------------------------------------------------
CloseTrans  move.l   _MathTransBase,a1   base needed in a1
            CALLSYS  CloseLibrary, _SysBase
            rts
* ---------------------------------------------------------------
; following routine uses the value present in error_number
; to identify the n'th address in a table of error message
; pointers...
ErrorMsg    clr.l    d0                  could contain
                                         garbage!
            move.b   error_flag,d0       get error number
            lsl.l    #2,d0               multiply by 4
            move.l   #error_table,a0     load table base
                                         address
            move.l   0(a0,d0.l),-(sp)    push table entry
                                         contents
            pea      string_format       push format string
            jsr      _printf             print error message
            add.l    #8,sp               adjust stack
            rts
* ---------------------------------------------------------------
; variables and static data...
_stdout         ds.l   1
_SysBase        ds.l   1
_DOSBase        ds.l   1
_MathBase       ds.l   1
```

```
_MathTransBase  ds.l    1
error_flag      ds.b    1
dos_name        DOSNAME
math_name       dc.b 'mathffp.library',NULL
mathtrans_name  dc.b 'mathtrans.library',NULL
error0          dc.b 'no errors',NULL
error1          dc.b 'no value supplied',NULL
error2          dc.b 'command string too long',NULL
error3          dc.b 'could not open maths library',NULL
error4          dc.b 'could not open mathtrans library',NULL
error5          dc.b 'result produced an overflow',NULL
string_format   dc.b '%s',LF,NULL
                EVEN
number          ds.b 32
number_SIZEOF   EQU *-number
result          ds.b 16
error_table     dc.l
                error0,error1,error2,error3,error4,error5
* ------------------------------------------------------------
```

Last Words

I've covered quite a bit of ground in this chapter but by now some things should be becoming clear. For a start you should now be appreciating the usefulness of understandable variable names, macro facilities and the adoption of standardised code layouts (plus lots of remarks). You should also now be clear about the use of, and the differences between, the register based parameter passing methods used by the Amiga's run-time libraries, and the stack-based conventions used by amiga.lib. Along the way we've introduced CLI/Shell parameter collection, string copying, table access, error handling and hierarchical based nested subroutine coding techniques.

What should also now have been firmly driven home is the fact that a great many jobs which have to be done in an Amiga assembly language program are done by system library calls and this is, of course, why I have devoted a lot of time and space to these library related issues in the first place!

13: Exec Messages and Ports

Towards the end of this book I am going to be developing some fully fledged Intuition programs. Now this may present quite a challenge because an appreciation of a number of separate Amiga programming areas which, unfortunately, are all quite difficult to understand in their own right, is going to be needed. One of these areas concerns the Intuition IDCMP message system which is built upon far more general communications functions. In this chapter I want to look in more detail at these intertask communications arrangements and in fact the *intuimessages* structures that were discussed in Chapter Nine were deliberately introduced prior to these discussions so that some of the ideas had time to *settle* before the more difficult aspects were dealt with.

An Overview

The message system used on the Amiga is, at the grass roots level, an Exec facility. Information can be sent from one task to another by creating a data packet known as a Message structure and then transmitting it (sending it) to its destination. Messages pass between tasks using another Exec defined structure called a MsgPort, more commonly called a *message port* or just a *port*. Ports are basically software entities whose job, amongst other

things, is to act as a receiving station for messages. Before a program can receive a message it must have allocated and initialised a suitable message port. Here's the definition of the system's MP (message port) structure in terms of the STRUCTURE macro:

```
STRUCTURE  MP,LN_SIZE            size equivalent to an Exec Node
UBYTE      MP_FLAGS
UBYTE      MP_SIGBIT             signal bit number
APTR       MP_SIGTASK            task to be signalled
STRUCT     MP_MSGLIST,LH_SIZE    linked list of messages
LABEL      MP_SIZE
```

LN_SIZE reserves space equivalent to the size of a standard Exec Node structure and MP_MSGLIST represents an Exec list structure used to create a linked list of messages associated with the port. As new messages arrive they are added to the end of the list. As messages are read they are taken from the front (head) of the list. The MP_FLAGS field is used to indicate various message arrival actions and the MP_SIGTASK field identifies the task to be signalled as messages arrive. Bear in mind that the macro only calculates equivalent offsets but it is useful during these structure related discussions to talk about the fields that such offsets represent when the structure has been allocated and set up.

Messages themselves are based on an extensible length structure with the Exec defined fields being supplemented by additional user defined data. The structure has a system label MN and here's the basic layout:

```
STRUCTURE  MN, LN_SIZE     size equivalent to an Exec Node
APTR       MN_REPLYPORT    message reply port
UWORD      MN_LENGTH       message length
LABEL      MN_SIZE
```

The Node space at the front of the resulting structure is used for port linkage. The MN_REPLYPORT field indicates which port the reply will be sent to (see discussion which follows), and the MN_LENGTH field indicates the total length of the message. The real message data is always provided as an extension, usually by defining a new structure in terms of a message plus other data as can be seen in the case of the IntuiMessage definition repeated below:

```
STRUCTURE IntuiMessage,0
  STRUCT im_ExecMessage,MN_SIZE ◄── basic message structure
  LONG im_Class                     subsequent fields are
  WORD im_Code                      the extensions that
  WORD im_Qualifier                 provide the real data
  APTR im_IAddress                        ▼
  WORD im_MouseX
  WORD im_MouseY
  LONG im_Seconds
  LONG im_Micros
  APTR im_IDCMPWindow
  APTR im_SpecialLink
  LABEL im_SIZEOF
```

If, for example, you wished to create messages which just stored mouse coordinates you might define your own structure like this:

```
STRUCTURE MouseMessage,0
   STRUCT mm_ExecMessage,MN_SIZE
   UWORD  mm_MouseX
   UWORD  mm_MouseY
   LABEL  mm_SIZEOF
```

That explains what messages are in terms of physical blocks of memory, now let's look at how these structures are used. If program A sends program B a message, it does so by using an Exec system call known as PutMsg(). This adds the message into a linked list of messages which are tied to program B's port structure. The important point about this process is that the message is *not* copied. In other words it is the memory block associated with program A's message which is linked into the list of messages present at program B's message port. Technically this is known as *queuing by reference* and its main advantage is that the very substantial overhead of creating local copies of each and every message floating around the Amiga system is avoided. In a sense then, when program A allocates, initialises and then sends program B some message, what program A is really doing is giving program B a license to use part of its memory space.

Now this is all very well but the scheme presents a number of potential difficulties. Let's go over the program A —> program B message passing scenario once more to see what problems can occur.

Program A wants to send program B a message so it allocates some memory for a message, fills in the appropriate details and then *sends* the message to program B using Exec's PutMsg() function. Program A will need to know the address of program B's message port at this time but system calls are available for finding such information.

By the time program A's PutMsg() call has completed we've developed a quite dangerous situation because program A has allocated some message memory and at some stage program A is going to have to deallocate it, ie return it to the system free memory pool. *But*, once the PutMsg() function has *sent* the message the backward and forward pointing Node fields of the memory block containing the message will have been altered so that the message is linked into program B's messages list. If program A terminated, or decided for any other reason to deallocate its message unit, serious problems would arise. In short, program B's message list would become corrupt and the system would no doubt *guru* shortly afterwards!

What is needed is a convention which eliminates this type of problem. The method that Exec has adopted is as follows. Program A, in sending a message to program B, is effectively granting a temporary license to program B to use part of its memory space (that relating to the message). Once this license has been granted, program A should not interfere with the message until it is safe to do so. How does program A know when its message can be reused or discarded? Usually program B will send the message back to program A using Exec's ReplyMsg() function. This function links (with a suitable reply ID marker) program A's message into program A's message port. When program A reads this, it knows that program B has finished using its message and that it is then free to reuse that memory space as it sees fit.

From the above description you'll realise that in most cases both of the communicating programs will need their own message ports – even when, as in the above example, the passage of real information is only going one way.

Exec Message Functions

Here are the descriptions of Exec's PutMsg() and ReplyMsg() functions mentioned above.

Function:	**PutMsg()**
Description:	Send a message to a message port
Call Format:	PutMsg(port_p, message_p);
Registers:	a0 a1
Arguments:	port_p – pointer to a message port message_p – pointer to a message
Return Value:	None
Notes:	This function can signal tasks and cause software interrupts to occur. The action is dependent on the flags set in the MP_FLAGS field of the destination port (see RKM manuals for further details).

Function:	**ReplyMsg()**
Description:	Send a message back to its reply port
Call Format:	ReplyMsg(message_p);
Registers:	a1
Arguments:	message_p – pointer to a message
Return Value:	None
Notes:	This function is a bit like PutMsg() in that it links the message into a message port. To indicate that it is a reply however this function places the NT_REPLYMSG flag into the message's ln_Type field. More details can be found in the RKM system manuals.

Another function that is related to the above is the Exec GetMsg() function.

Function:	**GetMsg()**
Description:	Collect first message queued at message port
Call Format:	message_p=GetMsg(port_p);
Registers:	d0 a0
Arguments:	port_p – pointer to a message port
Return Value:	message_p – pointer to a message
Notes:	This function does not wait. If a message is not available it will return with a NULL value.

GetMsg() unlinks the first message from the port and after it has been used the associated message is essentially *free floating*, ie it is not pointer-link tied into the message chain of the port it came from. Now, if we add these details to the steps which occur as two programs communicate, we end up with this scheme:

Program A	Program B
1: Allocates memory for message	
2: Fills in details	
3: Sends Message using PutMsg()	
4:	Collects message using GetMsg()
5:	Extracts data from message
6:	Sends back message using ReplyMsg()
7: Receives reply using GetMsg()	
8: Reuses/deallocates message	

In Chapter 15 we are going to be communicating with Intuition and in terms of the above scenario Intuition is going to be program A and our applications examples, which will be carrying out actions 4, 5 and 6 above, are going to represent the actions of program B.

Signals

It's all very well saying that one program collects the message that another program sends but that still doesn't tell us how one program knows that another program has sent it a message. As might be expected, Exec also solves this problem very elegantly by adopting an inter-task signalling system.

For each task Exec allocates 32 bits for use as *signal bits*. Sixteen are used by Exec itself and 16 are available for use by the task in question. In most cases you will rarely need to worry about how these bits are allocated because both Intuition calls and amiga.lib calls such as CreatePort() handle the nitty gritty details for you (you can find the details in the RKM manuals).

What you will need to do however is to work out what signal bit is being used because there is an Exec function called Wait() available which allows you to put your program to sleep until specific signals are received.

Function:	**Wait()**
Description:	Wait for one or more signals
Call Format:	signals=Wait(signal_mask);
Registers:	d0 d0
Arguments:	signal_mask – 32 bit mask of signals to wait for
Return Value:	signals which caused the Wait() to be satisfied
Notes:	This is generally useful because it allows signals from different sources to be combined.

The important point with Wait() is that it uses a 32 bit mask value, not the 8 bit signal bit number as stored in the MsgPort structure. The difference between the two representations is easily seen by looking at an example:

```
                    bit 16                  This is the mask
                      |                     arrangement needed
                      |                     if MP_SIGBIT = 16
                      V
00000000 00000001 00000000 00000000
```

To convert the MP_SIGBIT value to a mask we simply leftshift the number 1 an appropriate number of times, namely MP_SIGBIT times and you'll see an example of this type of mask creation in Chapter 15.

Now, how does all this Exec stuff fit into the job we want to do, namely communicating with Intuition? Well, as mentioned earlier the easiest way to gain access to an IDCMP is to specify one or more of the IDCMP flags when you open a window. If Intuition sees that you've done this it will automatically create a pair of message ports for that window. One port, the Window Port, is used by Intuition. The other, referred to as the User Port, is for the program's use and the Intuition programmer needs to know the address of this port in order to collect messages from it. Fortunately this is simply a matter of looking into the Window structure and picking up the appropriate pointer.

Suppose that you have a system *close* gadget present in a window display and that you want this gadget to control the closedown operations that the program must perform. The window will have originally been opened by setting up a NewWindow structure with the CLOSEWINDOW flag set in the IDCMP flags field and so Intuition will provide the program with this class of messages. Take what is said about windows and flags at face value for the moment and concentrate only on the ideas concerning the message passing aspects.

I've already mentioned Exec's Wait() function which allows a program to *sleep* until a message from any one of a number of specified ports *wakes it up*. Often though you'll only have one port to look at and there is in fact a simpler function, called WaitPort(), available for use.

Function:	**WaitPort()**
Description:	Suspend program execution until port becomes nonempty
Call Format:	message_p=WaitPort(port_p);
Registers:	d0 a0
Arguments:	port_p – a pointer to a message port
Return Value:	message_p – a pointer to first message at the port
Notes:	When this call returns it means that one or more messages have arrived at the port. In most cases it is not necessary to collect the WaitPort() return value because a separate function, called GetMsg(), can subsequently be used to both identify and remove the message from the message port. Parts of the RKM official documentation seem to suggest that this function can return *without* a valid message address!

Waiting for messages to arrive may sound like a complicated process, and underneath the surface it is reasonably complex, but for the Intuition user all that is needed in order to wait for an IntuiMessage is a line of code which looks like this:

```
CALLSYS WaitPort,_SysBase
```

When the code generated by this macro is executed the program goes to sleep, ie becomes inactive, until an event occurs which results in a message being sent to the window's UserPort. When this situation occurs the program needs to do several things:

1. It must collect the first message by using the GetMsg() function.
2. It must extract the necessary information from the message.
3. It must tell Intuition that the message has been dealt with, which it does by using the ReplyMsg() function. The parameter needed in this case is a pointer to the message.
4. It must check for, and if necessary collect and reply to, any other messages that may also have arrived at the port.

My concern at the moment is to explain how to write the parts of a program which can handle the arrival of these messages and there is something which needs to be emphasised at this point: The signal that a *message has arrived* (which terminates the program's *sleeping state*) actually means that *one or more messages* have arrived. This being so, any loop arrangements used must be able to handle, or at least reply to, each and every message that comes along and it's this topic which provides the subject matter for the rest of this chapter.

Message Collection

To finish this chapter I want to create a subroutine that will monitor an IDCMP message stream and tell me when the user has hit a window's Close Window gadget. Essentially this means writing a WaitForExitMessage() routine and a good first step is to think about what the program is going to have to do.

Firstly we'll need to put the program to sleep until a message arrives. When the program comes to life again it must collect the message/s that caused the wake up signal. In the following fragment I simply assume that this can be done, that the routine will be able to determine that a CLOSEWINDOW message has been received, and that on finding such a message it will set an *exit flag*. Codewise I just insert a jsr GetMessage reference having made a mental note to write the code later on.

I was able to sketch the above ideas quite easily using a sort of 68000 pseudocode, ie 68000 code plus comments for the details about things I wasn't completely sure about yet. Here's the result:

```
                    Clear exit flag
WaitForExitMessage  Set registers up for a WaitPort() call
                    CALLSYS  WaitPort,_SysBase
                    jsr      GetMessage
                    Examine the exit flag to
                    see if it has been set
                    bne      WaitForExitMessage
                    rts
```

The routine needs to be able to check the exit flag to see if the user is ready to quit. My choice was to use register d2 as an exit flag because, being one of the designated *non-scratch* registers this meant that I was not going to have to worry about the system destroying its contents during the execution of a library function. Note: According to the Amiga's system documentation, the contents of registers a0/a1 and d0/d1 must be regarded as lost after a function call unless otherwise stated.

As far as the collecting of a message is concerned we'll need to try to get the message and, having checked that it really did exist, look to see if it is a CLOSEWINDOW class intuimessage. If it is, the exit flag must be set. If it isn't, the exit flag is left alone (ie kept clear). What I must ensure however is that *I reply to all messages that are received*. This can be done using Exec's ReplyMsg() function and since a wake up signal can mean that one or more messages have arrived at the port I've also got to loop repeatedly until all messages have been handled. Again it's not too difficult to produce

a 68000 style sketch of the code and, bearing in mind that indirect addressing with displacement can be used to extract class data from the intuimessage (see Chapter Nine) this was the general framework that I chose:

```
GetMessage      Set registers up for a GetMsg() call
                CALLSYS   GetMsg,_SysBase      get the message
                Check to see if the message existed
                beq       GetMessageExit       did it exist?
                Get message pointer in register a1
                cmpi.l    #CLOSEWINDOW,im_Class(a1)
                bne       GetMessage1
                move.l    #TRUE,d2     user hit close gadget
GetMessage1     Set registers up for a ReplyMsg() call
                CALLSYS   ReplyMsg,_SysBase
                bra       GetMessage   check for more messages
GetMessageExit  rts       d2 holds exit flag
```

Now comes the good news: If you put the above two fragments together, you'll see that the foundations are in place for a routine which does exactly what we require. Having said that, a certain amount of tidying up is clearly needed and of course there are a few details still to be filled in concerning the setting up of the system library calls.

The WaitPort() needs to be provided with a port address in a0 but I've decided that the main program will be expected to supply this parameter in register a2 because it will be needed throughout the routine and I wanted it in a nonscratch register. The function autodocs tell us that ReplyMsg() needs message pointers in register a1. These pointers will of course be supplied to the subroutine internally as the GetMsg() function is used but obviously I'll need to make sure that results are in the right register!

Additionally I've chosen to preserve all the registers that are going to be used and, bearing in mind our previous message passing scenarios, it is not too hard to produce the following code suggestion:

```
WaitForExitMessage   movem.l  d0-d2/a0-a2,(sp)     preserve
                                                   registers
                     clr.l    d2                   clear exit flag
WaitForExitMessage2  move.l   a2,a0                port address
                     CALLSYS  WaitPort,_SysBase
                     jsr      GetMessage
                     cmpi.l   #TRUE,d2             exit flag set?
                     bne      WaitForExitMessage2
                     movem.l  (sp)+,d0-d2/a0-a2    restore
                                                   registers
                     rts                  logical end of routine
GetMessage           move.l   a2,a0       get port address in a0
                     CALLSYS  GetMsg,_SysBase  get the message
                     tst.l    d0
                     beq      GetMessageExit       did it exist?
                     move.l   d0,a1       copy pointer to a1
                     cmpi.l   #CLOSEWINDOW,im_Class(a1)
                     bne      GetMessage1
                     move.l   #TRUE,d2    user hit close gadget
GetMessage1          CALLSYS  ReplyMsg,_SysBase
                     bra      GetMessage          check for more
                                                  messages
GetMessageExit       rts      d2 holds exit flag
```

You'll also see that within the GetMessage subroutine I move the returned GetMsg() value (which comes back in d0) to register a1. This serves two purposes. Firstly, it allows me to use a1 as the base for structure accessing using indirect addressing with displacement. Secondly, register a1 is automatically set up for the ReplyMsg() call (function needs the message address in a1). Remember that when moving to an address register the move instruction is actually a movea instruction which does *not* set the status flags – because of this a tst.l instruction is needed before the status byte flags truly represent the state of the value which the GetMsg() function returns in d0.

If we add a bit of internal documentation to the above code it's possible to produce a quite useful *IDCMP orientated* subroutine. Here's the final result:

```
* ------------------------------------------------------------------
; Example CH13-1.s
; Function name:     WaitForExitMessage()
; Purpose:           Wait until user hits window's close gadget
; Input Parameters:  Address of IDCMP userport should be in a2.
; Output parameters: None
; Register Usage:    a0: Used by WaitPort() and GetMsg()
;                    a1: Used by ReplyMsg()
;                    a2: Holds userport address
;                    d0: Used by WaitPort() and GetMsg()
;                    d1: Unused but possibly altered by system
                         functions
;                    d2: Used as an exit flag (quit when nonzero)
; Other Notes:       All registers are preserved
* ------------------------------------------------------------------
; subroutine specific EQUates.
TRUE                EQU      1
* ------------------------------------------------------------------
WaitForExitMessage  movem.l  d0-d2/a0-a2,(sp)  preserve regis-
ters
                    clr.l    d2                clear exit flag
WaitForExitMessage2 move.l   a2,a0             port address
                    CALLSYS  WaitPort,_SysBase
                    jsr      GetMessage
                    cmpi.l   #TRUE,d2          exit flag set?
                    bne      WaitForExitMessage2
                    movem.l  (sp)+,d0-d2/a0-a2 restore registers
                    rts                   logical end of routine
* ------------------------------------------------------------------
GetMessage          move.l   a2,a0         get port address in a0
                    CALLSYS  GetMsg,_SysBase   get the message
                    tst.l    d0
                    beq      GetMessageExit    did it exist?
                    move.l   d0,a1         copy pointer to a1
                    cmpi.l   #CLOSEWINDOW,im_Class(a1)
                    bne      GetMessage1
                    move.l   #TRUE,d2      user hit close gadget
```

```
GetMessage1         CALLSYS  ReplyMsg,_SysBase
                    bra      GetMessage        check for more
                                               messages
GetMessageExit      rts                    d2 holds exit flag
* ------------------------------------------------------------
```

Black Boxes Rule OK!

We've now produced a typical *utility routine* which may be used by a programmer without them knowing any more than these details.

Function:	**WaitForExitMsg()**
Description:	Wait until user sends CLOSEWINDOW message to port
Call Format:	WaitForExitMsg(port_p);
Registers:	a2
Arguments:	port_p – pointer to a window's IDCMP user port
Return Value:	None
Notes:	This routine can be used with any Intuition window that has been provided with a close gadget and which generates CLOSEWINDOW messages.

The routine is actually a very simple form of an IDCMP *event handler* and although it ignores all messages except those of class CLOSEWINDOW it can actually be expanded quite easily. To a certain extent however the sophistication, or otherwise, of the routine is neither here nor there – what is important is that we've encapsulated quite a complex set of operations in a *black box* type routine that can then be used without knowing how it works and this is quite a good example of the benefits of the *information hiding* approach that I discussed earlier in the book.

Before we can write an IDCMP example program we need to know how to open a window, and this of course means that some more preliminary Intuition material needs to be provided.

Windows

Amiga programs may open one or more windows in a screen and the method of doing this has much in common with the opening of screens themselves, some details of which were given in Chapter 8, and is based on the creation of a fairly complex structure known as a Window structure. Intuition provides help in this area by allowing windows structures to be created from a much simpler NewWindow structure. A program has therefore only to provide the bare minimum of window detail in this structure before using a call to the OpenWindow() Intuition routine which handles the more complicated setting up details. Again the important thing at the

Intuition level is to know a little about the fields present in the NewWindow structure. Before looking at this structure it is useful to know a little about the Intuition window attributes which are under the control of the programmer.

Window Types

Intuition provides a number of different window types. Borderless windows, as the name suggests, are drawn without the default edging, although they can be given edges if title bars or system gadgets have been specified. To get a borderless window you set the BORDERLESS flag in the NewWindow structure. GimmeZeroZero windows contain extra bitplanes which hold the window title, system gadgets and borders and these allow the program to draw freely over the inner surface of the window without trashing the graphics drawn by the system. Backdrop windows are opened behind normal windows and no amount of depth arranging will ever send a non-backdrop window behind a backdrop one. Perhaps surprisingly these windows are very useful and many programs open screen-sized borderless backdrop windows as a means of creating a full screen size display area which has Intuition window communications facilities. Another window type you'll read about in the Intuition manuals is the SuperBitMap window, which is used to display portions of a user supplied bitmap display.

Whether Workbench or custom screens are used all windows opening in a particular screen will inherit from that screen the definition of the colour palette to be used and the horizontal/vertical pixel resolution.

Window Gadgets

Two types of window gadgets are supported: User defined gadgets and system gadgets. System gadgets include the drag bar which allows users to move a window around, two depth arrangement gadgets which let users move windows in front of or behind other windows, and a sizing gadget which allows the user to close a window. Most of the movement/size window operations which the user may perform will be handled transparently by Intuition although there are occasions where Intuition might supply, or be asked to supply, a message to indicate some particular user action.

One special case, which is relevant to the code that we have developed so far in this chapter, is the closing of a window. Intuition will *never* close a window automatically – instead when the user hits the close gadget Intuition sends the program a message telling it what has been done and then leaves the actual shutdown operations to the program itself!

Window Redrawing

Intuition offers a number of different window redrawing schemes. With Simple Refresh Intuition leaves most of the redrawing of overlapped areas to the program itself. Smart Refresh buffers offscreen portions and general window status to provide faster refresh operations, at the expense of using more memory. There's also a method called SuperBitMap redrawing and this maintains a completely separate window bitmap, as opposed to keeping the window contents as part of the screen display data. The benefit here is that the applications program never has to worry about redrawing window information because the window display is always available for use by Intuitions redrawing operations.

Right, we've dealt with some of the options which Intuition provides. Now let's look at the details of the NewWindow structure used to pass window specifications to Intuition. Here's the structure itself:

```
STRUCTURE NewWindow,0
    WORD nw_LeftEdge              some general dimensions
    WORD nw_TopEdge
    WORD nw_Width
    WORD nw_Height
    BYTE nw_DetailPen
    BYTE nw_BlockPen
    LONG nw_IDCMPFlags            IDCMP flags
    LONG nw_Flags
    APTR nw_FirstGadget
    APTR nw_CheckMark
    APTR nw_Title                 title text for window
    APTR nw_Screen
    APTR nw_BitMap
    WORD nw_MinWidth
    WORD nw_MinHeight
    WORD nw_MaxWidth
    WORD nw_MaxHeight
    WORD nw_ Type;
    LABEL nw_SIZE
```

The header files predefine a great many flags which are used to specify the various options. Here are the field details and allowed flag definitions:

nw_LeftEdge

The initial x position of the window's top left corner.

nw_RightEdge

The initial y position of the window's top left corner.

nw_DetailPen

Similar function to the equivalent NewScreen field but if set to -1 the window will actually use the pens specified in the associated screen structure.

nw_BlockPen

Ditto DetailPen.

nw_IDCMPFlags

These, as already mentioned, are concerned with the specification of Intuition communications.

nw_Flags

These window flags fall into four categories:

System gadgets: You use these flags tell Intuition which system gadgets are needed in the window:

WINDOWSIZING	Asks for a sizing gadget
WINDOWDEPTH	Asks for depth arrangement gadgets
WINDOWCLOSE	Asks for close gadget
WINDOWDRAG	Asks for a drag bar

Window type: Use these flags to specify additional window characteristics:

BACKDROP

BORDERLESS

GIMMEZEROZERO

Refresh method: You *must* set one of these flags:

SIMPLE_REFRESH

SMART_REFRESH

SUPER_BITMAP

Message flags:

REPORTMOUSE	This flag tells Intuition that the window should receive mouse pointer movements
ACTIVATE	Window becomes active on opening
NOCAREREFRESH	Tells Intuition *not* to bother sending window refresh messages
RMBTRAP	Used to trap potential menu operations and instead just deliver right-mouse-button messages

nw_FirstGadget

Pointer to the start of a linked list of user defined gadgets.

nw_CheckMark

Pointer to an image to be used when menu items are checkmarked. Setting this field to NULL causes Intuition to use the default tick checkmark.

nw_Title

Pointer to window title text.

nw_Screen

If you have opened the window in a custom screen then this pointer should point to the screen's associated Screen structure.

nw_BitMap

If using SUPER_BITMAP refresh, this field must point to a BitMap structure.

nw_MinWidth	Minimum width of window
nw_MinHeight	Minimum height of window
nw_MaxWidth	Maximum width of window
nw_MaxHeight	Maximum height of window
nw_Type	Set to either WBENCHSCREEN or CUSTOMSCREEN

Opening and Closing Windows

Once a NewWindow structure has been set up it is possible to use these Intuition functions to do all the hard work.

Function:	**OpenWindow()**
Description:	Open an Intuition Window
Call Format:	window_p=OpenWindow(new_window_p);
Registers:	d0 a0
Arguments:	new_window_p – pointer to initialised NewWindow structure
Return Value:	window_p – pointer to an Intuition Window structure. If the window could not be opened a NULL pointer is returned.

Function:	**CloseWindow()**
Description:	Close an Intuition Window
Call Format:	CloseWindow(window_p);
Registers:	a0
Arguments:	window_p – pointer to an existing Window structure
Return Value:	None

At Last, A Message Handling Example

By now you should have learn't quite a bit about opening and closing libraries and getting data to and from structures using indirect addressing with displacement. Now that we've covered some message handling and window topics it's possible to create a program that ties all these ideas together. The following program uses this basic plan:

Open the Intuition library

Set up a NewWindow structure

Open a window with close and drag gadgets

Get user port address from real window structure

Call the 'WaitForExitMessage() routine

Close window

Close library

```
* ------------------------------------------------------------------
* Example CH13-2.s
* ------------------------------------------------------------------
; some system include files...
          include exec/types.i
          include exec/libraries.i
          include exec/exec_lib.i
          include intuition/intuition.i
          include intuition/screens.i
```

```
* ------------------------------------------------------------
; a macro to extend LINKLIB and thus avoid the explicit use of
; the _LVO prefixes in the function names.
CALLSYS    MACRO
           LINKLIB _LVO\1,\2
           ENDM
* ------------------------------------------------------------
; EQUate definitions.
_AbsExecBase          EQU  4
_LVOOpenWindow        EQU  204
_LVOCloseWindow       EQU  72
WIDTH                 EQU  600
HEIGHT                EQU  100
DETAIL_PEN            EQU  1
BLOCK_PEN             EQU  1
* ------------------------------------------------------------
; main program code.
               move.l   _AbsExecBase,_SysBase  store Exec
                                               library base
               lea      intuition_name,a1      library name start
                                               in a1
               moveq    #0,d0                  any version will do
               CALLSYS  OpenLibrary,_SysBase   macro (see text
                                               for details)
               move.l   d0,_IntuitionBase      store returned
                                               value
               beq      EXIT                   test result for
                                               success

OPEN_WINDOW    lea      new_window,a0          new_window base
                                               address
               move.w   #WIDTH,nw_Width(a0)
               move.w   #HEIGHT,nw_Height(a0)
               move.b   #DETAIL_PEN,nw_DetailPen(a0)
               move.b   #BLOCK_PEN,nw_BlockPen(a0)
               move.l   #CLOSEWINDOW,nw_IDCMPFlags(a0)
               move.l   #SMART_REFRESH+WINDOWDRAG+WINDOW
                        CLOSE,nw_Flags(a0)
```

```
                move.l   #window_title,nw_Title(a0)
                move.w   #WBENCHSCREEN,nw_Type(a0)
                CALLSYS  OpenWindow,_IntuitionBase
                move.l   d0,window_p
                beq      CLOSE_LIB
                move.l   d0,a1                  window base
                                                address
                move.l   wd_UserPort(a1),a2     user port
                jsr      WaitForExitMessage
CLOSE_WINDOW    move.l   window_p,a0
                CALLSYS  CloseWindow,_IntuitionBase
; now close the library and quit...
CLOSE_LIB       move.l   _IntuitionBase,a1   base needed in a1
                CALLSYS  CloseLibrary,_SysBase
EXIT            clr.l    d0
                rts                            logical end of
                                               program
* ------------------------------------------------------------
; Function name:     WaitForExitMessage()
; Purpose:           Wait until user hits window's close gadget
; Input Parameters:  Address of IDCMP userport should be in a2.
; Output parameters: None
; Register Usage:    a0: Used by WaitPort() and GetMsg()
;                    a1: Used by ReplyMsg()
;                    a2: Holds userport address
;                    d0: Used by WaitPort() and GetMsg()
;                    d1: Unused but possibly altered by system
                     functions
;                    d2: Used as an exit flag (quit when nonzero)
; Other Notes:       All registers are preserved
* ------------------------------------------------------------
; subroutine specific EQUates...
TRUE            EQU      1
* ------------------------------------------------------------
WaitForExitMessage  movem.l   d0-d2/a0-a2,(sp)       preserve
                                                     registers
                    clr.l     d2              clear exit flag
```

```
WaitForExitMessage2 move.l    a2,a0           port address
                    CALLSYS   WaitPort,_SysBase
                    jsr       GetMessage
                    cmpi.l    #TRUE,d2        exit flag set?
                    bne       WaitForExitMessage2
                    movem.l   (sp)+,d0-d2/a0-a2      restore
                                                     registers
                    rts                       logical end of
                                              routine
* ------------------------------------------------------------------
GetMessage          move.l    a2,a0           get port address in
                                              a0
                    CALLSYS   GetMsg,_SysBase   get the message
                    tst.l     d0
                    beq       GetMessageExitdid it exist?
                    move.l    d0,a1           copy pointer to a1
                    cmpi.l    #CLOSEWINDOW,im_Class(a1)
                    bne       GetMessage1
                    move.l    #TRUE,d2        user hit close gadget
GetMessage1         CALLSYS   ReplyMsg,_SysBase
                    bra       GetMessage        check for more
                                                messages
GetMessageExit      rts       d2 holds exit flag
* ------------------------------------------------------------------
; variables and static data...
_IntuitionBase      ds.l   1
_SysBase            ds.l   1
window_p            ds.l   1
new_window          ds.b   nw_SIZE
window_title        dc.b 'ExampleCH132 test window',0
intuition_name      dc.b 'intuition.library',0
* ------------------------------------------------------------------
```

More Esoteric Uses

As far as this book goes the use of messages and ports is limited to fairly straightforward examples. Things however are not always this straightforward in the messages/ports world but the flexibility and versatility of the underlying Exec options usually allows most difficulties to be tackled one way or the other. Here are two tips that may prove useful at a later stage.

Messages are queued in FIFO order regardless of importance and this can sometimes mean that a message of relatively minor importance (an INTUITICK message for instance) could be sitting, waiting for collection, whilst a far more important message concerning a requester, window movement or a window redrawing operation, was hidden behind it. Usually the delays in handling compound message streams can be kept low but on occasion it might be necessary to open a second, separate, port just for handling messages of importance.

Another area where message passing comes in useful is in minimising interrupt code time. Suppose you have a fairly long winded job which you'd like carried out when a certain interrupt signal occurs. To avoid overburdening the interrupt system you might decide to set up a separate task to handle the actual processing and just use the interrupt code to send a message to that task effectively telling it to start processing.

A Word of Encouragement

If you've suddenly found that things have got *technically tough* during this chapter don't worry too much – this material has a proven track record for causing brain damage amongst programmers and it is almost certain to be hard going if you are encountering it for the first time. To start with just try and develop a general appreciation of what is going on.

14: Making a Start with Intuition

At this stage in the proceedings, where a number of aspects of Intuition-related message handling and screen/window operations have been looked at, it is worthwhile examining some other Intuition tools. We'll start with a number of easy-to-use high-level functions based on units which the official documentation calls *illustration data types.*

Three such data types are described and these cover Intuition's text, line drawing and image display facilities. Here are the basic definitions:

- IntuiText strings – These are used to define text strings.
- Borders – These define sets of connected lines that define some arbitrary shape.
- Images – These are bitplane-orientated graphic definitions.

Intuition uses these objects to define the text, outline shapes, and graphical images associated with gadgets, menus, requesters etc. They can also be freely used in a direct way because Intuition provides three routines DrawImage(), DrawBorder() and PrintIText() which allow the programmer to draw complex graphics very easily indeed.

IntuiText Strings

The IntuiText structure looks like this:

```
STRUCTURE  IntuiText,0
    UBYTE  it_FrontPen        front pen colour for drawing
    UBYTE  it_BackPen         back pen colour for drawing
    UBYTE  it_DrawMode        Intuition 'drawmode'
    UBYTE  it_KludgeFill00    for word alignment
    WORD   it_LeftEdge
    WORD   it_TopEdge
    APTR   it_ITextFont       font to be used
    APTR   it_IText           pointer to null terminated text
    APTR   it_NextText        next IntuiText structure
    LABEL  it_SIZEOF
```

As can be seen from the above description, the IntuiText structure allows the position, drawing mode, colour and font style of the text to be specified. Here are some more details of the associated structure fields:

it_FrontPen and it_BackPen are colour register numbers.

it_DrawMode may be set to one of four flag values.

RP_JAM1	Front pen is used for rendering the text string.
RP_JAM2	Front pen is used for rendering the text string and the back pen is used for the background.
RP_COMPLEMENT	String is drawn in the complement of the background colour.
RP_INVERSID	With this flag set, the background is filled with the front pen colour.

it_LeftEdge/it_TopEdge specify the position (as pixel offsets) of the start of the string relative to the top-left of the display.

it_TextFont can be used to specify a font. If this field is set to NULL then the default font will be used.

it_IText is a pointer to the text string itself. The normal C style convention is followed, ie the string should be null terminated.

it_NextText is a pointer field which allows IntuiText structures to be linked together. It is very useful because it allows whole chains of such structures to be displayed using just one PrintIText() call. The field should be set to NULL for IntuiText structures which are the last (or the only) structure in such a chain.

Using an IntuiText structure is easy. Set up the IntuiText definition, and then make a call to the PrintIText() function described below.

Function:	**PrintIText()**
Description:	This is Intuition's high-level text printing routine
Call Format:	PrintIText(rastport_p, itext_p, left_offset, top_offset);
Registers:	a0 a1 d0 d1
Arguments:	rastport_p – pointer to a RastPort itext_p – pointer to an IntuiText structure left_offset – a general left offset which will be used with all of the linked IntuiText structures of a particular PrintIText() call. top_offset – a general top offset which will be used with all of the linked IntuiText structures of a particular PrintIText() call.
Return Value:	None
Notes:	If an IntuiText font field is NULL then this function will use the RastPort's font. If this is undefined then the default system font will be used. A RastPort incidentally is just another name for a drawing area. Screen and window RastPort pointers are, as you will see from the example code given later, easily obtained from the corresponding Screen or Window structures. It is convenient to have displacement offsets in the PrintIText() call itself because this allows a global offset to be applied to a whole chain of IntuiText structures. You may have a group of twenty or thirty separate text items on display but, if you so desire, will be able to reposition the whole group (keeping their relative positions the same) just by altering the PrintIText() global offsets.

Setting Up IntuiText Structures

There are a variety of options available for creating these units. You may use a general ds.b directive to provide space and then have the program set up the various fields using indirect addressing with displacement, much as was done with the NewWindow structure in the last chapter. Another possibility is to use the same initialisation approach but dynamically allocate the required memory, using the Exec memory allocation functions.

A more common method however is to set up static initialisation blocks using dc.x statements and this allows you to document the fields as well. In the example given later in this chapter you see this type of scheme used:

```
intuitext1
    dc.b    3,0,RP_JAM2,0    pens, drawmode and fill byte
    dc.w    60,20            XY origin
    dc.l    NULL             default font
```

```
    dc.l    ITextText1          text pointer
    dc.l    intuitext2          next IntuiText structure
                                ITextText1
    dc.b    'The border around this was drawn using
            DrawBorder()',0
    cnop 0,2
intuitext2
    dc.b    3,0,RP_JAM2,0       pens, drawmode and fill byte
    dc.w    40,40               XY origin
    dc.l    NULL                default font
    dc.l    ITextText2          text pointer
    dc.l    intuitext3          next IntuiText structure
ITextText2
    dc.b    'and all of the text written using
            PrintIText() function',0
    cnop 0,2
intuitext3
    dc.b    3,0,RP_JAM2,0       pens, drawmode and fill byte
    dc.w    20,60               XY origin
    dc.l    NULL                default font
    dc.l    ITextText3          text pointer
    dc.l    NULL                no next structure
ITextText3
    dc.b    'To quit just hit the CLOSE gadget at the top
            left of the window',0
```

Here I've linked three IntuiText structures together and this allows them to be printed with a single PrintIText() call. Notice also that the cnop directive is being used to ensure that each structure starts at an even address. If you forget this you'll get addressing error Gurus.

Borders

These Intuition structures, and associated drawing routines, got their name because they were originally used for drawing borders around things. They do however provide a quite general high-level multiple-line drawing mechanism based on this structure:

```
STRUCTURE Border,0
   WORD   bd_LeftEdge
   WORD   bd_TopEdge
```

```
BYTE   bd_FrontPen      front pen colour for drawing
BYTE   bd_BackPen       back pen colour for drawing
BYTE   bd_DrawMode      Intuition 'drawmode'
BYTE   bd_Count
APTR   bd_XY            pointer to data
APTR   bd_NextBorder    pointer to next Border structure
LABEL  bd_SIZEOF
```

bd_FrontPen and bd_BackPen are colour register numbers although at the present time the latter of these fields, bd_BackPen, is unused.

bd_DrawMode may be set to one of these flag values:

RP_JAM1	Front pen is used for rendering
RP_COMPLEMENT	Line is drawn in the complement of the background colour.

bd_LeftEdge/bd_TopEdge specify the position (as pixel offsets) of the start point relative to the top-left of the display.

bd_Count specifies the number of pairs in an array of co-ordinate points. The bd_XY field is a pointer to that array.

bd_NextBorder is a pointer field which allows Border structures to be linked together. Again it's useful because it allows whole chains of such structures to be displayed using just a *single* DrawBorder() call. The field should be set to NULL for Border structures which are the last (or the only) structure in such a chain.

Function:	**DrawBorder()**
Description:	This is Intuition's high-level line drawing routine
Call Format:	DrawBorder(rastport_p, border_p, left_offset, top_offset);
Registers:	a0 a1 d0 d1
Arguments:	rastport_p – pointer to a RastPort border_p – pointer to a Border structure left_offset – a general left offset which will be used with all of the linked Border structures of a particular DrawBorder() call top_offset – a general top offset which will be used with all of the linked Border structures of a particular DrawBorder() call.
Return Value:	None
Notes:	Again it is convenient to have displacement offsets in the DrawBorder() call itself because this allows a global offset to be applied to a whole chain of Border structures. You may have a group of twenty or thirty separate line sets on display but, if you so desire, will be able to reposition the whole group (keeping their relative positions the same) just by altering the global offsets.

In the example program given at the end of this chapter you will see I've adopted this type of dc.x style definition of the border structure:

```
border1
    dc.w   60-2,20-2        XY origin
    dc.b   3,0,RP_JAM1      front & back pens and drawmode
    dc.b   5                number of XY vectors
    dc.l   BorderVectors1   pointer to XY vectors
    dc.l   NULL             no next border
BorderVectors1
    dc.w   0,0
    dc.w   420,0
    dc.w   420,10
    dc.w   0,10
    dc.w   0,0
```

As with IntuiText and many other Intuition objects you will see this arrangement used in a great many programs!

Images

Intuition's arrangements for drawing graphics into multiple-bitplane screens and windows are, in terms of the underlying ideas, extremely complex. Intuition provides pre-written routines, based on a structure known as an Image structure, which simplifies the job of displaying graphics data.

The Intuition Image structure itself is easy to understand. Here's the layout:

```
STRUCTURE Image,0
    SHORT ig_LeftEdge
    WORD  ig_TopEdge
    SHORT ig_Width
    WORD  ig_Height
    WORD  ig_Depth
    APTR  ig_ImageData      pointer to real image data
    BYTE  ig_PlanePick
    BYTE  ig_PlaneOnOff
    APTR  ig_NextImage      pointer to next image structure
    LABEL ig_SIZEOF
```

ig_LeftEdge and ig_TopEdge are offsets from the top left of the display element. The ig_Width and ig_Height fields indicate the size of the image and ig_Depth tells the system how many bitplanes are in use. ig_PlanePick identifies the planes in the real display which have been picked to receive the defined image data, and ig_PlaneOnOff tells the system what to do with those planes that are not picked. ig_NextImage is a pointer which, in a similar fashion to the bd_NextBorder and it_NextText fields of the Border and IntuiText structures, allows any number of Image structures to be linked together and displayed with a single call to the Intuition DrawImage() routine.

Function:	**DrawImage()**
Description:	This is Intuition's high-level Image drawing routine
Call Format:	DrawImage(rastport_p, image_p, left_offset, top_offset);
Registers:	a0 a1 d0 d1
Arguments:	rastport_p – pointer to a RastPort
	image_p – pointer to an Image structure
	left_offset – a general left offset which will be used with all of the linked Image structures of a particular DrawImage() call.
	top_offset – a general top offset which will be used with all of the linked Image structures of a particular DrawImage() call.
Return Value:	None
Notes:	Again it is convenient to have displacement offsets in the DrawImage() call itself because this allows a global offset to be applied to a whole chain of Image structures. You may have a group of a couple of dozen separate images on display but, if you so desire, will be able to reposition the whole group (keeping their relative positions the same) just by altering the global offsets.

On the face of it this function call arrangement makes the display of graphics images very easy indeed. In practice things are not quite that simple because although using the Image structures and the DrawImage() function is easy enough, creating the associated Image data is not. In fact sitting down and working out from first principles exactly how to create the Image data for a particular object (whether it be a boat, a plane or some fancy backdrop display) turns out to be an absolutely monstrous task.

The good news is that you as a programmer will *never* have to do this because nowadays tools are available which make the task of creating complex graphic objects a piece of cake. Two things have helped produce this situation. Firstly, the existence of clear inter-program graphics definition guidelines (part of the now famous IFF standard) encouraged the creation of programs that can read and write graphics data using a common data-file format. Secondly, programs such as Electronic Art's *Deluxe Paint* have provided an

easy means of creating IFF picture files without requiring the programmer to be involved with the underlying complexities of bitplane data generation. More help has appeared and tools (such as Power Windows) that can convert IFF brushes into the equivalent Image data are nowadays readily available.

An example bit-by-bit plan for a small graphics object is provided in the Intuition sections of the Addison Wesley Libraries RKM manual. I'm not going to duplicate this material because, as I've already mentioned, you are unlikely to ever have to use this approach. The relationships between displays, bitplanes, Images etc, are dealt with very thoroughly in the RKM manuals and when you get to the point where you start to need in-depth information then the RKM manuals are without doubt the best place to look.

Getting Graphics into Code

As already mentioned, the task of creating and using graphics in your Amiga programs has been considerably eased by the development of some sophisticated graphics-support tools. First and foremost we should mention Electronic Art's Deluxe Paint.

No Amiga programming book would be complete without a mention of this classic Amiga drawing program. Deluxe Paint is powerful, robust, and best of all it can store as IFF files both complete pictures and small, user definable, graphic sections (brushes).

By switching on Deluxe Paint's X/Y co-ordinate display a user can easily create objects of a given size. If some graphic images 50 pixels by 20 pixels are needed then a suitable background area can be marked out, the images can be drawn, and the brush facility can then be used to save that particular area of the display.

So, how do you get a Deluxe Paint drawing into your program? As you probably know Deluxe Paint stores picture data using IFF format files. These can be used in two basic ways. Firstly, it is possible for a program to read in an IFF file and convert it into a suitable (Amiga displayable) form directly. The advantages of this particular approach are that you only need to read the picture into memory just prior to displaying it, so it becomes very easy to change the graphics without re-compiling the program (you just swap one IFF file for another). Secondly, you can take the IFF file and convert it to an Intuition Image structure. Having done that the Image structure and the associated Image data can be read into the source code of the program and displayed using one of the Intuition support functions, namely the DrawImage() function. This system call takes four parameters: the address of the RastPort

(drawing area), the address of the Image structure to be displayed, and the X and Y screen co-ordinates for the point identifying the top left of the Image.

How do you get from an IFF file to an Intuition Image structure? There are two ways. Firstly, there are a number of *brush to image* public domain utilities which can do this type of translation. Secondly, some commercial offerings are available which include facilities for this type of translation – here the Inovatronic's Power Windows is probably the most sophisticated. Power Windows is far more than just a brush image converter program (that is just an incidental extra), it is an object orientated Amiga front-end design package. The examples of Image creation given in the next chapter were actually converted using Power Windows.

Intuition's Gadgets

The following notes provide a brief tutorial introduction to the use of Intuition's gadgets, an important and useful group of Intuition objects.My objective is not to document all aspects of Intuition object use (that information could fill a book by itself), it is to illustrate how some of the more important ones interact not only with each other but with the general Amiga's program<->Intuition communication system. This, as we already know, is built upon Exec's message handling facilities.

I'll assume that you know, whether it be roughly or exactly, what a gadget is in Amiga-speak. Intuition provides a number of gadget types: Boolean gadgets for collecting yes/no, true/false type information, string and integer gadgets for collecting text and numbers. A more complex slider orientated unit, called a proportional gadget, is also supported and this enables positional information to be collected from the user.

Gadgets, from the users viewpoint, provide a convenient mouse-orientated way of inputting data. If as a programmer you had to devise a similar WIMP orientated icon system, define and program mouse movement and gadget selection procedures, and build a suitable gadget communications system you would rightly complain (it would be a massive task). Of course the Amiga programmer doesn't have to do this – Intuition has provided building blocks which simplify the construction of such WIMP orientated programs. All you the programmer need do is find out how to use these building blocks.

At the highest level Intuition recognises two main gadget classes: *system gadgets* and *custom gadgets*. Since system gadgets are easily dealt with I'll tackle these first.

System Gadgets

These, as the name suggests, have special system connotations and they are used to monitor window closing, sizing, depth arranging and dragging operations. All can be used with Intuition windows but the depth arrange and drag gadgets can also be placed in screens.

The important point about these types of gadget is that Intuition controls the imagery of the gadgets and they essentially come on a *take it or leave it* basis. You inform Intuition about the system gadgets to be used by setting appropriate flags. You'll remember in the Chapter 13 example a WINDOWCLOSE flag was used in the NewWindow structure to ask Intuition to install a *window close* system gadget.

With screens you will always get drag and depth-arrange gadgets if the screen's title bar is showing. Intuition does however allow a screen's title bar to be hidden.

Screen and window system gadgets are essentially handled transparently although one special case, the window close gadget, has to be handled in much the same way as the custom gadgets which we are about to look at. Basically Intuition detects the use of the gadgets, does all the graphic highlighting or alternate imagery operations, and then sends you (or rather your program) a message telling you what has been done. Intuition does not automatically send messages about each and every action the user performs and in fact it is your responsibility, as a programmer, to minimise the amount of information your program has to deal with. You do this by only asking to be kept informed about user events which are of real interest to you.

System gadgets are fine but much of the Amiga's interface magic has of course come from the fact that programmers have been able to use powerful Intuition building blocks to create their own *personalised* gadgets. These gadgets, known as custom gadgets, are infinitely flexible and well worth learning about.

Custom Gadgets

This is where the fun really starts because, other than the fact that these entities must be linked to a window (rather than a screen), there are almost no restrictions on their use.

Creating a custom gadget entails setting up a suitable, Intuition understandable, definition of the unit you require. Such a definition will contain a great many items including, for example, position and gadget size info, gadget type details, and highlighting information so that Intuition knows what should be done when the

gadget is selected by the user. It may also contain pointers to other units including Border, Image and IntuiText structures which specify graphics objects that should be associated with the gadget. You can of course also tell Intuition what sort of information you need to be kept informed about.

Needless to say this *gadget definition* involves another structure definition called, not surprisingly, a Gadget structure:

```
STRUCTURE Gadget,0
    APTR  gg_NextGadget     pointer to next gadget in list
    WORD  gg_LeftEdge       next four variables describe the
    WORD  gg_TopEdge        location/dimensions of the select
                            box
    WORD  gg_Width
    WORD  gg_Height
    WORD  gg_Flags;         highlighting/positioning/state
                            flags
    WORD  gg_Activation     flags determine gadget behaviour
    WORD  gg_GadgetType     identifies the gadget type
    APTR  gg_GadgetRender   pointer to 'unselected' Image
    APTR  gg_SelectRender   pointer to 'selected' Image
    APTR  gg_GadgetText     pointer to gadget text if any
    LONG  gg_MutualExclude
    APTR  gg_SpecialInfo
    WORD  gg_GadgetID       user-defined ID field
    APTR  gg_UserData       pointer to user data
    LABEL gg_SIZEOF
```

gg_NextGadget is a field which allows gadgets to be linked together. The programmer creates a suitable list of gadgets and then places a pointer to the first gadget (the head of the gadget chain) into the nw_FirstGadget field of the NewWindow structure. When Intuition opens the window it will read through the gadget list and both implement and monitor all of the gadgets you've asked for.

gg_LeftEdge, gg_TopEdge, gg_Width and gg_Height identify the position and dimensions of the gadget's select box.

The gg_Flags field is used to specify a number of gadget attributes based on Intuition defined flag values. Five commonly needed definitions are.

GADGHCOMP which selects highlighting by complementing all of the bits within the gadgets select box.

GADGHBOX which highlights by drawing a box around the gadgets select box.

GADGHIMAGE which tells Intuition that alternate graphics will be used.

GADGIMAGE which tells Intuition that Images, rather than Borders, are being used in the gg_GadgetRender/gg_SelectRender fields.

SELECTED which enables you to preselect the state of a toggle-selected gadget.

but flags are also available for specifying positional data as container edge offsets rather than absolute container positions and for specifying that gadget sizes should vary with the relative height and width of the window. The RKM manuals are the place to look for complete details.

Intuition also defines a set of Activation flags including the following:

TOGGLESELECT which tells Intuition that a Boolean gadget should change (toggle) from on to off (and vice versa) each time it is selected.

GADGIMMEDIATE which forces Intuition to send a GADGETDOWN IDCMP message as soon as a gadget is selected by a user.

Again many flags are available and as always it is to the RKM manuals that you should look for the most comprehensive information.

gg_GadgetType tells Intuition what type of gadget is being dealt with. Allowable values include the BOOLGADGET, STRGADGET and PROPGADGET flags used respectively to indicate a Boolean, string or proportional gadget.

The gg_GadgetRender field, if non-NULL, indicates that there are borders or images associated with the gadget. If a border is being used then the field will point to a border structure. If the field is used to point to an Image structure then it is necessary to tell Intuition that this is so by setting the GADGIMAGE flag in the Flags field.

gg_SelectRender allows alternate imagery to be used when Intuition highlights the gadget. To use it, put a pointer to the Border or Image structure to be used in this field and set the GADGHIMAGE flag in the gg_Flags field.

gg_GadgetText if non-NULL should point to an IntuiText structure which describes the text to be associated with the gadget.

gg_MutualExclude is a part-implemented, but reserved, field. You'll find details about the use of a BOOLEXTEND activation flag in the RKM Libraries manual.

gg_SpecialInfo is a field used to add additional structures to things like proportional gadgets.

gg_GadgetID and gg_UserData are fields available for the applications program to use. They are ignored by Intuition itself.

Custom gadgets can be placed anywhere in a window and the list of gadgets associated with any one window can be modified whilst the window remains open. New gadgets can be added, gadgets can be deleted or prevented from functioning and you will find a great many useful Intuition support functions documented in the RKM Includes & Autodocs manual.

It is worth mentioning at this point that even during use, various items in a Gadget structure may be altered. Flags can be changed, message requirements may be altered and so on. In order to do this safely however certain rules should be adhered to, the most important being that you should remove a gadget from the window's *gadget list before* you edit any characteristics that Intuition may be monitoring. Once the necessary changes have been made the gadget can be added back into the gadget list.

For example, one of the gadget flags that is monitored and adjusted by Intuition is the SELECTED flag. Sixteen bits are used in the gadget structure for such flags and the bit corresponding to 0080hex (C equivalent 0x0080) is the one that Intuition uses to tell whether the gadget is on or off. The intuition.i header file makes the appropriate definition of SELECTED and so to, safely, turn a gadget on or off this is the procedure which should be followed: remove the gadget from the list, adjust the SELECTED bit, add the gadget back into the list and finally up-date the gadget display.

Doing Things The Easy Way

Building NewScreen and NewWindow definitions, designing gadgets and working out suitable dimensions and characteristics etc, is not that difficult but it can be both time consuming and prone to error. Many programmers find it useful to use a WIMP interface code generator to create most (if not all) of these types of definitions and one particular program, called Power Windows, is well established and therefore clearly worth mentioning.

Inovatronic's Power Windows

Essentially Power Windows provides the programmer with a tool for creating and editing screens, windows, gadgets and menus using an *object orientated* approach.

It's a flexible program, screen definition is straightforward and both standard and custom screens are supported. You can set the colour palette directly or can incorporate a palette from any convenient IFF file. Windows are equally easily created and, once present on the display, can be moved around and resized using normal mouse operations. Adding gadgets to a window is just a matter of selecting the *Add A Gadget* menu option, adjusting the gadget's size and then moving it to the desired position. Menu generation is equally simple and although not often needed you can incorporate IFF brush imagery with the menu.

One of the more powerful features of Power Windows is the *Grab A Window* menu option. When you select this option you are offered a menu which provides details of all of the screens and windows for all applications which are currently running. To grab a window you just select its name to cause the window, plus all of the associated gadgets and menus, to be imported into Power Windows. Only the window, text, gadget imagery etc, which is directly *pointer linked* to the window will be imported, so sometimes you will be disappointed with the results. Nevertheless this is a very useful function. Power Windows can also help with IDCMP event handling.

Once you are happy with the display, Power Windows can do one of two things. Firstly it can generate an *intermediate* file which contains the display data in a form which can be read back into Power Windows itself, which enables you to edit the display at a later date. Secondly it can generate the source code that your own programs can use to produce an identical display. There are several options available for code generation (either commented or uncommented) to be used with 68K assembler, Lattice/SAS C, Manx's Aztec C, Benchmark Modula 2, TDI Modula 2, MultiFORTH, TrueBASIC, AmigaBASIC, and ACBASIC Compiler v1.3.

Full control of screen, window, gadget, menu, text and border characteristics coupled with many other extras such as gadget cloning, collision checking, colour re-mapping and image compression makes Power Windows an extremely useful tool for the serious Amiga programmer.

Code Generators

Using these types of code generator for handling the Intuition interface has many advantages. First and foremost it will save you time! Secondly you'll work with a display that can actually be seen

as it is created. Thirdly it is possible, by keeping the reloadable *intermediate files*, to go back at a later date and make changes, eg reposition gadgets. Once the changes have been incorporated, just generate the new code, recompile and the new version will be up and running in a very short space of time. You can of course also use these types of tool to produce prototype interfaces for testing ideas and producing *rough and ready* skeleton interfaces. When you have finished your program you can then go back and tidy up the initial efforts. Once this has been done it is a simple matter to generate the new interface code and just swap that for the preliminary version.

Whilst on the subject of code generators, don't forget that you can always *tweak* the source code that has been produced to suit your own purposes. There is nothing to stop you running the generated code through a text editor to change, eg globally prefix, the names of the structures.

Another good reason to *modify* the output code is to reduce its physical size. If, for example, you create a display with 48 identical gadgets, each having a border, then the generated code will have 48 identical border structures, one for each gadget. In such a case Intuition doesn't need 48 instances but it will happily manage with one. So the trick is to read the generated source into a text editor, remove 47 of the identical structures, and then change the border pointers in each of the 48 gadgets so that they all point to the single remaining border structure.

Intuition's Menu System

Menus are the last of the Intuition building blocks that I'm going to look at. Again the purpose of this section will be not to mention every feature but to discuss the general ideas. You'll see in the next chapter that the communications aspect of menu handling has much in common with gadget handling and many of the ideas that have already been dealt with can be expanded to provide generalised IDCMP-message based, event-driven, code loops.

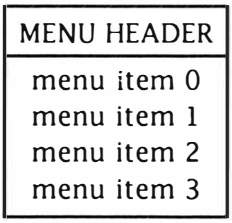
When a user presses the right hand mouse button on an Amiga the title bar at the top of the screen changes to a menu strip which displays along its length one or more category names. As these names are touched by the mouse pointer, sets of options appear below the category name and these, if selected, can cause either particular program actions to occur or can result in the appearance of further *sub-menu* items.

Menus have many benefits. If properly organised, they can hide much of the complexity of a program from a user. They do not encroach on screen space until the right hand mouse button is

pressed and even then their presence is almost completely transparent as far as things like use-detection, display saving and re-drawing are concerned.

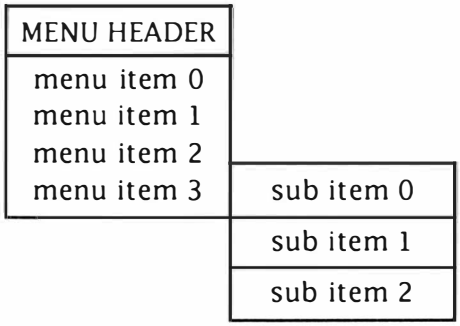
The Amiga menu system is also very flexible and there are few absolute rules to follow. The menu content, overall structure, and the actions which should be performed when particular menu items are selected, can all be defined by the programmer. Intuition will use these definitions to set up and monitor the necessary graphics objects on the screen so from that point onwards the nitty-gritty details associated with menu use are handled automatically. When the user has done something significant, ie made a proper menu selection, Intuition will send the program a message explaining what has been done – it is then up to the program to decide what actions should be taken.

A menu, and here I'm talking about a single header followed by a number of menu items, will look like this:



As far as positioning and size goes there are a number of constraints worth mentioning. The position/size of the item boxes must be such that they do not overlap the left or right sides of the header field. Item boxes should also be positioned so that they are directly adjacent, so that there are no spaces between menu item fields.

A menu item can itself invoke a sub-menu. From the programmer's viewpoint sub-menu items, as you will see later in the chapter, pose no particular additional difficulties:



To define a menu, Intuition uses a number of data sets, the first being the Menu structure itself:

```
STRUCTURE Menu,0
    APTR  mu_NextMenu
    WORD  mu_LeftEdge
    WORD  mu_TopEdge
    WORD  mu_Width
    WORD  mu_Height
    WORD  mu_Flags
    APTR  mu_MenuName
    APTR  mu_FirstItem
    WORD  mu_JazzX   remaining fields are for internal use
    WORD  mu_JazzY
    WORD  mu_BeatX
    WORD  mu_BeatY
    LABEL mu_Menu
```

mu_NextMenu provides a means of linking menus together. The next four fields describe the menu header's select box. At the current time values for mu_TopEdge and mu_Height are ignored and the screen's title bar values are used instead. mu_LeftEdge and mu_Width are then the fields which effectively size and position the menu header within the title bar framework.

The menu mu_Flags field contains two values. MENUENABLED indicates whether the menu is currently enabled or disabled so this flag should be set before asking Intuition to create the menu. Otherwise the user will be able to see the menu but will not be able to select anything. You should not directly alter this flag once Intuition has control of the menu – instead the OnMenu() and Offmenu() function calls can be used to enable or disable the menu as required. Another flag, MIDRAWN, is also defined. It is managed by Intuition and is used to indicate whether the menu items are currently visible or not.

mu_MenuName is simply a pointer to a null terminated string representing the menu's header name. mu_FirstItem is a pointer to the head of a chain of MenuItem structures used to describe the menu options themselves. As a STRUCTURE definition the format of a MenuItem looks like this:

```
STRUCTURE MenuItem,0
    APTR  mi_NextItem
    WORD  mi_LeftEdge
    WORD  mi_TopEdge
    WORD  mi_Width
    WORD  mi_Height
    WORD  mi_Flags
    LONG  mi_MutualExclude
    APTR  mi_ItemFill
    APTR  mi_SelectFill
    BYTE  mi_Command
    BYTE  mi_KludgeFill00
    APTR  mi_SubItem
    WORD  mi_NextSelect
    LABEL mi_SIZEOF
```

These structures hold quite a lot of data so here's the rundown on the most important MenuItem characteristics that you'll need to supply when building a menu:

mi_NextItem is a pointer to the next item in a chain of such items. As usual the last item in the chain should have this field set to NULL.

mi_LeftEdge, mi_TopEdge, mi_Width and mi_Height describe the select box of the menu item.

mi_Flags. There are quite a few flag values defined by Intuition.

CHECKED tells Intuition that a CHECKIT item should be displayed in the checkmarked *selected* state right from the start.

CHECKIT tells Intuition that a menu item is an attribute, ie something with a value or characteristic rather than some action which is to be carried out. Intuition will *checkmark* the field when it is selected and the checkmark/no-checkmark state will toggle on and off with alternate selections.

COMMSEQ informs Intuition that the menu item has an alternative command-key sequence that may be used instead of mouse/menu selection. Menu command-key sequences are combinations of the Right-Amiga key with some other alphanumeric character. If such a sequence is received, which corresponds to a defined menu selection, Intuition will send the program the equivalent menu selection event which the program would treat in the normal fashion.

HIGHBOX is another highlighting flag which results in a box being drawn around the item's select area.

HIGHCOMP is a select highlighting flag which complements the select box of the menu item.

HIGHIMAGE indicates alternate imagery based on either IntuiText or Image structures. If text items are being used, the ITEMTEXT flag should also be set.

HIGHITEM is an Intuition maintained flag which indicates the highlight state of an item.

HIGHNONE sets this flag and *no* highlighting will be done.

ISDRAWN is an Intuition maintained flag which indicates when subitems are on display.

ITEMENABLED should normally be set before submitting a menu to Intuition to ensure that the initial menu display is *active.* Once the menu is under Intuition's control the flag should not be altered except indirectly through the OnMenu() and OffMenu() function calls.

ITEMNEXT tells Intuition that the mi_ItemFill/mi_SelectFill fields point to IntuiText structures rather than images. The flag should be cleared, ie not set, when images are being used.

MENUTOGGLE must be set if a CHECKIT item is to be toggled.

mi_MutualExclude. This field allows the programmer to define fields as mutually exclusive. The purpose of this facility is to enable the programmer to prevent the user from making incompatible menu selections. If your program has menu options which support both low and high-resolution screen displays, it's pretty obvious that the user should not be able to select and turn on both options together so the solution is to make the two items mutually exclusive. By selecting high-res, the low-res option becomes de-selected and vice versa.

mi_ItemFill. This field is a pointer to either an IntuiText structure or an Image structure used to describe the data for rendering this item. If text is used, the ITEMTEXT flag should be set in the menu item's mi_Flags field.

mi_SelectFill. If alternate imagery is being used, ie if the HIGHIMAGE flag has been set, this field should point to the appropriate IntuiText or Image structure.

mi_Command. This field stores a single alphanumeric character used as a command-key shortcut. If the COMMSEQ flag has been set the user will be able to hold down the key, together with the Right-Amiga key, to select this item. Intuition senses the keypresses and transmits a menu event which looks as though the user selected the item via the normal mouse/pointer approach.

mi_SubItem. Points to the first subitem in a subitem list. SubItems are defined using the same MenuItem structure but they should NOT themselves have subitems!

mi_NextSelect. This field is maintained by Intuition and indicates when the item has been selected.

By the time the Menu and MenuItem definitions are complete most of the programmer's work is finished. All that remains is straightforward installation followed by management of the user<->program interactions. Intuition provides a number of function calls for this purpose.

Function:	**SetMenuStrip()**
Description:	Attach a menu to a window
Call Format:	result=SetMenuStrip(window_p, menu_p);
Registers:	d0 a0 a1
Arguments:	window_p – pointer to the window that menu is to be attached to.
	menu_p – pointer to the Menu structure
Return Value:	result – TRUE/FALSE success or failure indicator
Notes:	Any menu strip attached to a window should be removed before closing the window.

Function:	**ClearMenuStrip()**
Description:	Remove a menu strip from a window.
Call Format:	ClearMenuStrip(window_p);
Registers:	a0
Arguments:	window_p – pointer to a window structure
Return Value:	None
Notes:	If menu is in use this function will wait until user has completed their menu operations before removing the menu.

Function:	**OnMenu()**
Description:	Enable a menu or a specific menu item
Call Format:	OnMenu(window_p, menu_number);
Registers:	a0 d0
Arguments:	window_p – pointer to a Window structure
	menu_number – an unsigned 16 bit menu number value
Return Value:	None
Notes:	Menu numbers, and their internal arrangements are discussed in detail in the RKM Libraries & Devices manual.

Function:	**OffMenu()**
Description:	Disable a menu or a specific menu item
Call Format:	OffMenu(window_p, menu_number);
Registers:	a0 d0

Arguments:	window_p – pointer to a Window structure
	menu_number – an unsigned 16 bit menu number value
Return Value:	None
Notes:	Menu numbers, and their internal arrangements are discussed in detail in the RKM Libraries & Devices manual.

Function: ItemAddress()

Description:	This function returns the address of a specific menu item
Call Format:	item_p =ItemAddress(menu_p,menu_number);
Registers:	d0 a0 d0
Arguments:	menu_p – menu pointer
	menu_number – a 16 bit unsigned menu number
Return Value:	address of the menu item (NULL if no item was selected).
Notes:	

Menu Messages

The RKM manuals provide a lot of useful guidelines for menu design and menu use and it is best if these guidelines are followed because it ensures that any program you write will conform to the conventions that other Amiga programs use.

One of the main distinctions that is made concerns the fact that menu items can be either related to actions, ie operations which the program will perform, or to the selection of particular program attributes. In other words it suggests that the two basic divisions associated with menu items are that they either:

1. Cause the program to *do something*, eg copy a piece of text or delete the current project.

   or:

2. Cause a change in the program state, eg selecting a new background colour or a new screen resolution.

Basically this classification is provided for convenience and whilst facilities like the toggle select flag and mutual exclusion field do tend to be used with attribute items, the bottom line is this that your program can do whatever it wishes to when it receives menu-use notification.

When the user interacts with the menu system an Intuition input event of class MENUPICK will be generated and this is true even if the user decides not to make a selection. You'll get a MENUPICK message even if the only thing the user did was press the right mouse button. The number held in the MENUPICK message is a 16-bit value which contains 5 bits of menu number data, 6 bits of item

data, and 5-bits of sub-item data. These are easily unpacked with a bit of bit masking and bit shifting code and we'll look at an example in the next chapter.

A Runable Example

Image, gadget and menu examples are going to be given in the next chapter. For now though here's an example which is an extension of the Chapter 13 program (so a lot of the code will be familiar) modified to include IntuiText printing and Border drawing examples.

You'll notice that this time I've chosen to set up the NewWindow structure using dc.x statements. For static definitions this is normally the easiest approach and I only used the indirect addressing with displacement method in Chapter 13 so that you would be able to get some practice at relating the structure displacement names to the values being placed in the structures. The following code does however follow an identical pathway and essentially all that has been added to the program is the static text and border data:

```
*-------------------------------------------------------------
* Example CH14-1.s
*-------------------------------------------------------------
; some system include files.
         include exec/types.i
         include exec/libraries.i
         include exec/exec_lib.i
         include intuition/intuition.i
         include intuition/screens.i
*-------------------------------------------------------------
; a macro to extend LINKLIB and thus avoid the explicit use of
; the _LVO prefixes in the function names.
CALLSYS  MACRO
         LINKLIB _LVO\1,\2
         ENDM
*-------------------------------------------------------------
; EQUate definitions.
_AbsExecBase      EQU   4
_LVOOpenWindow    EQU   -204
_LVOCloseWindow   EQU   -72
```

```
_LVOPrintIText    EQU   -216
_LVODrawBorder    EQU   -108
WIDTH             EQU   600
HEIGHT            EQU   100
DETAIL_PEN        EQU   -1
BLOCK_PEN         EQU   -1
NULL              EQU   0
TRUE              EQU   1
* ------------------------------------------------------------------
; main program code.
            move.l  _AbsExecBase,_SysBase store Exec library
                                          base
            lea     intuition_name,a1     library name start in
                                          a1
            moveq   #0,d0                 any version will do
            CALLSYS OpenLibrary,_SysBase  macro (see text for
                                          details)
            move.l  d0,_IntuitionBase     store returned value
            beq     EXIT                  test result for
                                          success

OPEN_WINDOW lea     new_window,a0         new_window base
                                          address
            CALLSYS OpenWindow,_IntuitionBase
            move.l  d0,window_p
            beq     CLOSE_LIB
PRINT_ITEXT move.l  window_p,a1           get window address
            move.l  wd_RPort(a1),a0       get rastport address
            lea     intuitext1,a1
            move.l  #0,d0                 no additional offsets
            move.l  #0,d1
            CALLSYS PrintIText,_IntuitionBase
PRINT_BORDER move.l  window_p,a1          get window address
            move.l  wd_RPort(a1),a0       get rastport address
            lea     border1,a1
            move.l  #0,d0                 no additional offsets
            move.l  #0,d1
            CALLSYS DrawBorder,_IntuitionBase
```

```
SLEEP         move.l  window_p,a0           window base address
              move.l  wd_UserPort(a0),a2    user port
              jsr     WaitForExitMessage
CLOSE_WINDOW  move.l  window_p,a0
              CALLSYS CloseWindow,_IntuitionBase
; now close the library and quit...
CLOSE_LIB     move.l  _IntuitionBase,a1     base needed in a1
              CALLSYS CloseLibrary,_SysBase
EXIT          clr.l   d0
              rts                           logical end of
                                            program
*---------------------------------------------------------------
; Function name:      WaitForExitMessage()
; Purpose:            Wait until user hits window's close gadget
; Input Parameters:   Address of IDCMP user-port should be in
                      a2.
; Output parameters:  None
; Register Usage:     a0: Used by WaitPort() and GetMsg()
;                     a1: Used by ReplyMsg()
;                     a2: Holds user-port address
;                     d0: Used by WaitPort() and GetMsg()
;                     d1: Unused but possibly altered by system
                          functions
;                     d2: Used as an exit flag (quit when non-
                          zero)
; Other Notes:        All registers are preserved
*---------------------------------------------------------------
WaitForExitMessage    movem.l   d0-d2/a0-a2,-(sp)   preserve
                                                    registers
                      clr.l     d2                  clear exit flag
WaitForExitMessage2   move.l    a2,a0               port address
                      CALLSYS   WaitPort,_SysBase
                      jsr       GetMessage
                      cmpi.l    #TRUE,d2            exit flag set?
                      bne       WaitForExitMessage2
                      movem.l   (sp)+,d0-d2/a0-a2   restore
                                                    registers
                      rts       logical end of routine
```

```
* ------------------------------------------------------------------
GetMessage          move.l    a2,a0           get port address
                                                in a0
                    CALLSYS   GetMsg,_SysBase get the message
                    tst.l     d0
                    beq       GetMessageExit  did it exist?
                    move.l    d0,a1           copy pointer to
                                                a1
                    cmpi.l    #CLOSEWINDOW,im_Class(a1)
                    bne       GetMessage1
                    move.l    #TRUE,d2        user hit close
                                                gadget
GetMessage1         CALLSYS   ReplyMsg,_SysBase
                    bra       GetMessage      check for more
                                                messages
GetMessageExit      rts       d2 holds exit flag
* ------------------------------------------------------------------
; variables and static data...
_IntuitionBase ds.l   1
_SysBase       ds.l   1
window_p       ds.l   1
intuition_name dc.b 'intuition.library',0
          cnop 0,2
new_window
    dc.w   13,26                  window XY origin
    dc.w   610,115                width and height
    dc.b   DETAIL_PEN,BLOCK_PEN   pens
    dc.l   CLOSEWINDOW IDCMP      flags
    dc.l   WINDOWDRAG+WINDOWCLOSE+NOCAREREFRESH+
           SMART_REFRESH+RMBTRAP                    window flags
    dc.l   NULL                   no gadgets
    dc.l   NULL                   no CHECKMARK imagery
    dc.l   NewWindowName          window title
    dc.l   NULL                   no custom pointer
    dc.l   NULL                   no custom bitmap
    dc.w   0,0                    minimum width and height
    dc.w   0,0                    maximum width and height
    dc.w   WBENCHSCREEN           screen type
NewWindowName
```

```
    dc.b    'This window has been opened in the Workbench
            Screen',0
    cnop    0,2
border1
    dc.w    60-2,20-2               XY origin
    dc.b    3,0,RP_JAM1             front & back pens and drawmode
    dc.b    5                       number of XY vectors
    dc.l    BorderVectors1          pointer to XY vectors
    dc.l    NULL                    no next border
BorderVectors1
    dc.w    0,0
    dc.w    420,0
    dc.w    420,10
    dc.w    0,10
    dc.w    0,0
intuitext1
    dc.b    3,0,RP_JAM2,0           pens, drawmode and fill byte
    dc.w    60,20                   XY origin
    dc.l    NULL                    default font
    dc.l    ITextText1              text pointer
    dc.l    intuitext2              next IntuiText structure
ITextText1
    dc.b    'The border around this was drawn using
            DrawBorder()',0
    cnop 0,2
intuitext2
    dc.b    3,0,RP_JAM2,0           pens, drawmode and fill byte
    dc.w    40,40                   XY origin
    dc.l    NULL                    default font
    dc.l    ITextText2              text pointer
    dc.l    intuitext3              next IntuiText structure
ITextText2
    dc.b    'and all of the text written using PrintIText()
            function',0
    cnop 0,2
intuitext3
    dc.b    3,0,RP_JAM2,0           pens, drawmode and fill byte
```

```
    dc.w    20,60                   XY origin
    dc.l    NULL                    default font
    dc.l    ITextText3              text pointer
    dc.l    NULL                    no next structure
ITextText3
    dc.b    'To quit just hit the CLOSE gadget at the top left
            of the window',0
* ---------------------------------------------------------------
```

Further Down The Road

Before we look at some examples of gadget and menu code I ought to point something out concerning the material that's been covered over the last few chapters. As you will doubtless know Intuition is a big subject in its own right and it was never my intention to deal with all of aspects of gadget and menu use, let alone discuss Requesters, Alerts and so forth. What I have chosen to do instead is concentrate on some aspects that have clearly caused many new Amiga programmers a lot of problems including systematic, cleanly coded, message handling.

Once you've come to terms with some basic Intuition structures, and the ideas relating to the message passing environment, you'll realise something very important – all the structures and Intuition objects have very similar layouts and use arrangements and, best of all, once you can handle one type of IntuiMessage, you'll be able to handle *any* type of IntuiMessage. That, of course, goes a long way towards reducing the learning curve problems that we all have to face!

15: A Complete Intuition Example

The purpose of this chapter is to build on the material already discussed to create a simple, but nevertheless complete, Intuition based example program. For the Amiga newcomer, getting involved with Intuition based programming usually comes as a bit of a shock to the system because a lot of system-related material needs to be understood. For those venturing out into the world of 68000 assembler the shock is even greater especially since much of the available documentation has been written for the C programmer.

The good news however is that, if you've got this far into *Mastering Amiga Assembler*, and have coped with the material to date, or at least acquired an appreciation of the main ideas, then you are almost home and dry. I've looked at the Amiga environment, the header files, the use of some important system macros (which make 68000 programming easier), and the ideas related to the opening of libraries and making library calls. I've also talked about Exec message-based IDCMP issues and provided a routine for the easy collection of CLOSEWINDOW type IDCMP messages.

Chapter 14 put some of those ideas together and the first thing I want to do in this chapter is to build on those ideas by presenting a program that uses a custom Intuition screen. The basic plan then is as follows:

```
Open Intuition Library
   Open Graphics Library
      Open an Intuition Screen
      Set up screen's colour map
         Open an Intuition Window
            Print some Text, Borders and Images
            Go to sleep until user hits the CLOSE gadget
         Close Window
      Close Screen
   Close Graphics Library
Close Intuition Library
```

The good news is that you'll already recognise most of the program code (because it's based on the Workbench screen orientated Example CH14-1.s) so all that remains is to provide some notes about the additions that have been made.

Because the LoadRGB() function is going to be used to set up the screen colours I've had to open the graphics library, hence you'll see what should by now be a very familiar piece of additional code, namely:

```
    lea     graphics_name,a1      library name start in a1
    moveq   #0,d0                 any version will do
    CALLSYS OpenLibrary,_SysBase  macro (see text for
                                  details)
    move.l  d0,_GfxBase           store returned value
    beq     CLOSE_INTUITION       test result for success
```

To actually open the screen the custom screen routines, first discussed in Chapter 8, have been used. The following fragment makes use of the new_screen structure that you'll find in the source listing:

```
OPEN_SCREEN lea      new_screen,a0     new_screen base
                                       address
            CALLSYS  OpenScreen,_IntuitionBase
            move.l   d0,screen_p
            beq      CLOSE_GRAPHICS
```

One of the additions to the program is the display of an Intuition image using the DrawImage() function. Electronic Art's *Deluxe Paint* was used to create an IFF brush and, after conversion to a dc.w based Image definition, this was read into the program. The graphic is displayed with this straightforward call:

```
DRAW_IMAGE  move.l   window_p,a1        get window address
            move.l   wd_RPort(a1),a0    get rastport
                                        address
            lea      image1,a1
            move.l   #0,d0              no additional
                                        offsets
            move.l   #0,d1
            CALLSYS  DrawImage,_IntuitionBase
```

Notice incidentally how indirect addressing with displacement is used to get the window's rastport address.

Colour Map Creation

This is a topic that has been well covered by almost all Amiga magazines and reference books. A colour map is a suitably sized array of words where the lower 12 bits of each entry represents the Red, Green, and Blue (RGB) colour components of a given colour register. Example CH15-1.s is going to use a 3 bitplane screen and so it needs 2 to the power 3 (ie 8) entries in its table. Each RGB colour item can range from 0 hex to F hex and so an entry corresponding to $0000 would be black, $0FFF would be white, and so on. The definition you'll find in my source looks like this:

```
colour_table
    dc.w    $0000                   BLACK (background)
    dc.w    $0888                   GREY
    dc.w    $0FFF                   WHITE
    dc.w    $0F00                   RED
    dc.w    $00F0                   GREEN
    dc.w    $000F                   BLUE
    dc.w    $0FF0                   YELLOW
    dc.w    $0F0F                   MAUVE
colour_table_SIZEOF EQU *-colour_table
```

To ask the system to use such a map with a particular screen requires the use of a graphics routine called LoadRGB(). To use this call the screen's viewport address has to be retrieved from the screen structure that Intuition sets up. Load RGB() also expects the address of the colour map to be in register a1, and the colour map size in d0. Here's some code which performs the necessary magic:

```
LOAD_COLOURS  add.l   £sc_Viewport, d0      screen_p already in
                                            d0
              move.l  d0,a0                 viewport address now
                                            in a0
              lea     colour_table, a1      pointer to colour map
              move.w  £colour_table_SIZEOF,d0   colour map size
              CALLSYS LoadRGB,_GfxBase
```

The colour indirection scheme used on the Amiga means that we work not with absolute colours but with colour registers. With a given colour map definition however it is useful to define EQUate values which relate to the colours held in each register and in my program you'll find that I've included these definitions near the start:

```
BLACK       EQU   0
GREY        EQU   1
WHITE       EQU   2
RED         EQU   3
GREEN       EQU   4
BLUE        EQU   5
YELLOW      EQU   6
MAUVE       EQU   7
```

The other changes from the Chapter 14 example are minor. A new variable, _GfxBase, has been defined to store the graphics library pointer, an additional Intuitext item has been added, some changes to particular pen numbers have been made and extra LVO values for the new function calls are in place. Of course the image-related data has been added at the end of the example given in the previous chapter.

In fact the only new programming issue to contend with concerns the image data itself because on the Amiga image data needs to be placed in chip memory, so that it can be accessed by the custom chips. With programs which are to consist of a single source file, two options are available. Firstly, you can generate linkable code and then ask the linker to ensure that the *whole* program goes into

chip memory. Bearing in mind earlier remarks about chip memory as a precious resource this is not usually a good idea. Secondly, a *section* directive can be used within the source program so that data is marked as chip data. This is the approach used with the examples in this chapter and in the next example you'll see the directive written like this:

```
        SECTION IMAGE,DATA_C
ImageDatal
    dc.w  $0000,$0000,£0000,$0000,$0000,$0000,$01FF,$0000
    dc.w  $0000,$0000,£0000,$0000,$0000,$0000,$0000,$0000
    dc.w  $1FFC,$0000,£0000,$0000,$0000,$0FFF,$E000,$0000
    dc.w  $0000,$0000,£0000,$0000,$0000,$0000,$0001,$FFFF
    .
    .
    .
```

Note that I've deliberately steered clear of section issues and multiple-module programs within this book. For those who want the full gory details your assembler manuals will provide the necessary details.

Anyway that's quite enough of the techie stuff for the moment. Now that the additions have been dealt with, here's the source code for the program I've been discussing:

```
* ------------------------------------------------------------------
* Example CH15-1.s
* ------------------------------------------------------------------
; some system include files...
        include exec/types.i
        include exec/libraries.i
        include exec/exec_lib.i
        include intuition/intuition.i
        include intuition/screens.i
* ------------------------------------------------------------------
; a macro to extend LINKLIB and thus avoid the explicit use of
; the _LVO prefixes in the function names...
CALLSYS    MACRO
           LINKLIB_LVO\1,\2
           ENDM
```

```
* ------------------------------------------------------------------
; System EQUates...
_AbsExecBase          EQU       4
_LVOOpenScreen        EQU       -198
_LVOCloseScreen       EQU       -66
_LVOOpenWindow        EQU       -204
_LVOCloseWindow       EQU       -72
_LVOLoadRGB           EQU       -192
_LVOPrintIText        EQU       -216
_LVODrawBorder        EQU       -108
_LVODrawImage         EQU       -114

; Colour map EQUates...
BLACK                 EQU       0
GREY                  EQU       1
WHITE                 EQU       2
RED                   EQU       3
GREEN                 EQU       4
BLUE                  EQU       5
YELLOW                EQU       6
MAUVE                 EQU       7

; Screen EQUates..
SCREENWIDTH           EQU       320
SCREENHEIGHT          EQU       256
DEPTH                 EQU       3

; General EQUates...
Null                  EQU       0
True                  EQU       1
* ------------------------------------------------------------------
; main program code...
   move.l   _AbsExecBase,_SysBase    store Exec library base
   lea      intuition_name,a1        library name start in a1
   moveq    #0,d0                    any version will do
```

```
        CALLSYS  OpenLibrary,_SysBase     macro (see text for
                                          details)
        move.l   d0,_IntuitionBase        store returned value
        beq      EXIT                     test result for success
        lea      graphics_name,a1         library name start in a1
        moveq    #0,d0                    any version will do
        CALLSYS  OpenLibrary,_SysBase     macro (see text for
                                          details)
        move.l   d0,_GfxBase              store returned value
        beq      CLOSE_INTUITION          test result for success

OPEN_SCREEN lea      new_screen,a0   new_screen base address
            CALLSYS  OpenScreen,_IntuitionBase
            move.l   d0,screen_p
            beq      CLOSE_GRAPHICS

LOAD_COLOURS add.l   #sc_ViewPort,d0 screen_p already in d0
            move.l   d0,a0           viewport address now in a0
            lea      colour_table,a1 pointer to colour map
            move.w   #colour_table_SIZEOF,d0   colour map size
            CALLSYS  LoadRGB,_GfxBase

OPEN_WINDOW lea      new_window,a0   new_window base address
            move.l   screen_p,nw_Screen(a0)     set screen
                                                pointer
            CALLSYS  OpenWindow,_IntuitionBase
            move.l   d0,window_p
            beq      CLOSE_SCREEN

PRINT_ITEXT move.l   window_p,a1     get window address
            move.l   wd_RPort(a1),a0 get rastport address
            lea      intuitext1,a1
            move.l   #0,d0           no additional offsets
            move.l   #0,d1
            CALLSYS  PrintIText,_IntuitionBase

PRINT_BORDER move.l  window_p,a1     get window address
```

```
            move.l   wd_RPort(a1),a0 get rastport address
            lea      border1,a1
            move.l   #0,d0           no additional offsets
            move.l   #0,d1
            CALLSYS  DrawBorder,_IntuitionBase

DRAW_IMAGE  move.l   window_p,a1     get window address
            move.l   wd_RPort(a1),a0 get rastport address
            lea      image1,a1
            move.l   #0,d0           no additional offsets
            move.l   #0,d1
            CALLSYS  DrawImage,_IntuitionBase

SLEEP       move.l   window_p,a0     window base address
            move.l   wd_UserPort(a0),a2   user port
            jsr      WaitForExitMessage
CLOSE_WINDOWmove.l   window_p,a0
            CALLSYS  CloseWindow,_IntuitionBase

CLOSE_SCREENmove.l   screen_p,a0
            CALLSYS  CloseScreen,_IntuitionBase

; now close the libraries and quit...

CLOSE_GRAPHICS       move.l _GfxBase,a1   base needed in a1
            CALLSYS  CloseLibrary,_SysBase

CLOSE_INTUITION      move.l _IntuitionBase,a1  base needed in
                                               a1
            CALLSYS  CloseLibrary,_SysBase
EXIT        clr.l    d0
            rts                      logical end of program
*---------------------------------------------------------------
; Function name:     WaitForExitMessage()
; Purpose:           Wait until user hits window's close gadget
; Input Parameters:  Address of IDCMP user-port should be in a2.
```

```
; Output parameters: None
; Register Usage:    a0: Used by WaitPort() and GetMsg()
;                    a1: Used by ReplyMsg()
;                    a2: Holds user-port address
;                    d0: Used by WaitPort() and GetMsg()
;                    d1: Unused but possibly altered by system
                         functions
;                    d2: Used as an exit flag (quit when non-
                         zero)
; Other Notes:       All registers are preserved

* ------------------------------------------------------------

WaitForExitMessage   movem.l   d0-d2/a0-a2,-(sp)    preserve
                                                    registers
                     clr.l     d2          clear exit flag
WaitForExitMessage2  move.l    a2,a0       port address
                     CALLSYS   WaitPort,_SysBase
                     jsr       GetMessage
                     cmpi.l    #TRUE,d2    exit flag set?
                     bne       WaitForExitMessage2
                     movem.l   (sp)+,d0-d2/a0-a2    restore
                                                    registers
                     rts       logical end of routine
* ------------------------------------------------------------

GetMessage   move.l   a2,a0            get port address in a0
             CALLSYS  GetMsg,_SysBase  get the message
             tst.l    d0
             beq      GetMessageExit   did it exist?
             move.l   d0,a1            copy pointer to a1
             cmpi.l   #CLOSEWINDOW,im_Class(a1)
             bne      GetMessage1
             move.l   #TRUE,d2         user hit close gadget
GetMessage1  CALLSYS  ReplyMsg,_SysBase
             bra      GetMessage check for more messages
GetMessageExit       rts              d2 holds exit flag
* ------------------------------------------------------------

; variables and static data...
```

```
_GfxBase            ds.l      1
_IntuitionBase      ds.l1
_SysBase            ds.l      1
screen_p            ds.l      1
window_p            ds.l      1
intuition_name      dc.b 'intuition.library',0
graphics_name       dc.b 'graphics.library',0
     cnop 0,2
new_screen
   dc.w     0,0                        screen top left
   dc.w     CREENWIDTH,SCREENHEIGHT    screen width and height
   dc.w     DEPTH                      bitplane depth
   dc.b     WHITE,GREY                 detail and block pens
   dc.w     0                          no special view modes
   dc.w     CUSTOMSCREEN               screen type
   dc.l     NULL                       no special font
   dc.l     NULL                       no title
   dc.l     NULL                       no gadgets
   dc.l     NULL                       no custom bitmap
     cnop 0,2
new_window
   dc.w     0,0                        window XY origin
   dc.w     SCREENWIDTH,SCREENHEIGHT   width and height
   dc.b     WHITE,GREY                 detail and block pens
   dc.l     CLOSEWINDOW IDCMP          flags
   dc.l     SMART_REFRESH+WINDOWCLOSE+RMBTRAP  window flags
   dc.l     NULL                       no gadgets
   dc.l     NULL                       no CHECKMARK imagery
   dc.l     NewWindowName              window title
   dc.l     NULL                       screen set at run-time
   dc.l     NULL                       no custom bitmap
   dc.w     0,0                        minimum width and height
   dc.w     0,0                        maximum width and height
   dc.w     CUSTOMSCREEN               screen type
NewWindowName
   dc.b     'Screen-Sized Window In Custom Screen',0
```

```
    cnop      0,2
colour_table
    dc.w      $0000                    BLACK (background)
    dc.w      $0888                    GREY
    dc.w      $0FFF                    WHITE
    dc.w      $0F00                    RED
    dc.w      $00F0                    GREEN
    dc.w      $000F                    BLUE
    dc.w      $0FF0                    YELLOW
    dc.w      $0F0F                    MAUVE
colour_table_SIZEOF EQU *-colour_table
    cnop 0,2
border1
    dc.w      35-2,20-2                XY origin
    dc.b      WHITE,NULL,RP_JAM1       front & back pens and
                                       drawmode
    dc.b      5                        number of XY vectors
    dc.l      BorderVectors1           pointer to XY vectors
    dc.l      NULL                     no next border
BorderVectors1
    dc.w      0,0
    dc.w      250,0
    dc.w      250,10
    dc.w      0,10
    dc.w      0,0
intuitext1
    dc.b      WHITE,NULL,RP_JAM2,0     pens, drawmode and fill
                                       byte
    dc.w      35,20                    XY origin
    dc.l      NULL                     default font
    dc.l      ITextText1               text pointer
    dc.l      intuitext2               next IntuiText structure
ITextText1
    dc.b      'Border drawn using DrawBorder()',0
    cnop 0,2
intuitext2
```

```
    dc.b    BLUE,NULL,RP_JAM2,0     pens, drawmode and fill
                                    byte
    dc.w    35,40                   XY origin
    dc.l    NULL                    default font
    dc.l    ITextText2              text pointer
    dc.l    intuitext3              next IntuiText structure
ITextText2
    dc.b    'Text written using PrintIText()',0
    cnop 0,2
intuitext3
    dc.b    YELLOW,NULL,RP_JAM2,0   pens, drawmode and fill
                                    byte
    dc.w    35,60                   XY origin
    dc.l    NULL                    default font
    dc.l    ITextText3              text pointer
    dc.l    intuitext4              next structure
ITextText3
    dc.b    'Image drawn using DrawImage()',0
    cnop 0,2
intuitext4
    dc.b    MAUVE,NULL,RP_JAM2,0    pens, drawmode and fill
                                    byte
    dc.w    35,80                   XY origin
    dc.l    NULL                    default font
    dc.l    ITextText4              text pointer
    dc.l    NULL                    no next structure
ITextText4
    dc.b    'Just Hit CLOSE gadget to quit!',0
    cnop 0,2
image1
    dc.w    44,100                  XY origin
    dc.w    232,88                  image width and height
    dc.w    3                       depth
    dc.l    ImageData1              image data
    dc.b    $0007,$0000             plane configurations
    dc.l    NULL                    no next image
        SECTION IMAGE,DATA_C
```

```
ImageData1
    dc.w $0000,$0000,$0000,$0000,$0000,$0000,$01FF,$0000
    dc.w $0000,$0000,$0000,$0000,$0000,$0000,$0000,$0000
    dc.w $1FFC,$0000,$0000,$0000,$0000,$0FFF,$E000,$0000
    dc.w $0000,$0000,$0000,$0000,$0000,$0000,$0001,$FFFF
    .
    .
    .
    .
    .
    .
    dc.w $0000,$0000,$0000,$0000,$0000,$0002,$0000,$4000
    dc.w $0000,$0000,$0000,$0000,$0000,$0000,$0000,$0000
    dc.w $0000,$0000,$0000,$0000,$0000,$0000,$0000,$0000
    dc.w $0000,$0000,$0000,$0000,$0000,$0000,$0000,$0000
* ------------------------------------------------------------
```

An Alternative Exit

The next stage in our experiments is to re-write this first program so that it uses a menu style *quit* option rather than the system's close gadget.

To do this we have to create a menu structure and add it to our existing code. I've opted for the simplest example possible, one menu with a single menu item in it, and the data itself, which has been set up using the structures discussed in the last chapter, looks like this:

```
Menu1
    dc.l    NULL                    next menu
    dc.w    0,0                     XY origin
    dc.w    70,10                   hit box width and height
    dc.w    MENUENABLED             flags
    dc.l    MenuName                name
    dc.l    MenuItem1               menu items
    dc.w    0,0,0,0
MenuName
    dc.b    'Project',0
    cnop    0,2
```

```
MenuItem1
   dc.l    NULL                        no next menu item
   dc.w    0,0                         XY origin
   dc.w    40,8                        width and height
   dc.w    ITEMTEXT+ITEMENABLED+HIGHCOMP  flags
   dc.l    0
   dc.l    MenuIText1                  intuitext to be rendered
   dc.l    NULL
   dc.b    NULL
   dc.b    NULL
   dc.l    NULL                        no sub-items
   dc.w    MENUNULL
MenuIText1
   dc.b    RED,GREY,RP_COMPLEMENT,0    pens, drawmode and
                                       fill byte
   dc.w    0,0                         XY origin
   dc.l    NULL                        default font
   dc.l    MenuITextText1              text
   dc.l    NULL                        no next structure
MenuITextText1
   dc.b    'Quit',0
```

Having created the appropriate structures we need to tell Intuition to use the menu. This is done using the SetMenuStrip() and ClearMenuStrip() functions described in the last chapter and, as with so many of these system functions, the code is trivially simple once you've got the hang of library call use. Load the parameters needed by the function, and then use the CALLSYS macro.

Since setting the menu is the last job the program does before waiting to quit, removing the menu needs to be the first job to be done during program shutdown. Here's the code fragment you'll find in the Example CH15-2.s source:

```
ADD_MENU    move.l  window_p,a0
            lea     Menu1,a1
            CALLSYS SetMenuStrip,_IntuitionBase
SLEEP       move.l  window_p,a0     window base address
            move.l  wd_UserPort(a0),a2 user port
            jsr  WaitForMenuMessage
```

```
REMOVE_MENU  move.l window_p,a0
             CALLSYS ClearMenuStrip,_IntuitionBase
```

A few other changes have been made to the code from the first example. To start with I've removed the WINDOWCLOSE flag from the Flags field of the NewWindow structure, effectively telling Intuition that I no longer want a system *window close* gadget in the window. The CLOSEWINDOW flag has been removed from the IDCMP field. Obviously we will not get any of these messages because the close gadget is no longer present in the window.

The WaitForExitMessage() routine has been renamed WaitForMenuMessage() and where previously we checked for messages of class CLOSEWINDOW we now check instead for messages of class MENUPICK. Intuition makes this extremely easy to do and codewise all that is necessary is to change the comparison:

```
cmpi.l      #CLOSEWINDOW,im_Class(a1)
```

to:

```
cmpi.l      #MENUPICK,im_Class(a1)
```

Taken in isolation none of the above mentioned changes are particularly difficult but, with Intuition's help, we have nevertheless been able to completely change the exit procedure. Here's a listing of the revised code to examine:

```
* ------------------------------------------------------------------
* Example CH15-2.s
* ------------------------------------------------------------------
; some system include files...
       include exec/types.i
       include exec/libraries.i
       include exec/exec_lib.i
       include intuition/intuition.i
       include intuition/screens.i
* ------------------------------------------------------------------
; a macro to extend LINKLIB and thus avoid the explicit
; use of the _LVO prefixes in the function names.
CALLSYS     MACRO
            LINKLIB _LVO\1,\2
            ENDM
* ------------------------------------------------------------------
```

```
; System EQUates...
_AbsExecBase          EQU       4
_LVOOpenScreen        EQU       -198
_LVOCloseScreen       EQU       -66
_LVOOpenWindow        EQU       -204
_LVOCloseWindow       EQU       -72
_LVOLoadRGB           EQU       -192
_LVOPrintIText        EQU       -216
_LVODrawBorder        EQU       -108
_LVODrawImage         EQU       -114
_LVOSetMenuStrip      EQU       -264
_LVOClearMenuStrip    EQU       -54
; Colour map EQUates...
BLACK                 EQU       0
GREY                  EQU       1
WHITE                 EQU       2
RED                   EQU       3
GREEN                 EQU       4
BLUE                  EQU       5
YELLOW                EQU       6
MAUVE                 EQU       7
; Screen EQUates...
SCREENWIDTH           EQU       320
SCREENHEIGHT          EQU       256
DEPTH                 EQU       3
; General EQUates...
NULL                  EQU       0
TRUE                  EQU       1
*---------------------------------------------------------------
; main program code.
   move.l   _AbsExecBase,_SysBase    store Exec library base
   lea      intuition_name,a1        library name start in a1
   moveq    #0,d0                    any version will do
   CALLSYS  OpenLibrary,_SysBase     macro (see text for
                                     details)
   move.l   d0,_IntuitionBase        store returned value
```

```
        beq     EXIT                    test result for success
        lea     graphics_name,a1        library name start in a1
        moveq   #0,d0                   any version will do
        CALLSYS OpenLibrary,_SysBase    macro (see text for
                                        details)
        move.l  d0,_GfxBase             store returned value
        beq     CLOSE_INTUITION         test result for success
OPEN_SCREEN lea     new_screen,a0       new_screen base address
        CALLSYS OpenScreen,_IntuitionBase
        move.l  d0,screen_p
        beq     CLOSE_GRAPHICS
LOAD_COLOURS add.l  #sc_ViewPort,d0 screen_p already in d0
        move.l  d0,a0               viewport address now in a0
        lea     colour_table,a1 pointer to colour map
        move.w  #colour_table_SIZEOF,d0   colour map size
        CALLSYS LoadRGB,_GfxBase
OPEN_WINDOW lea     new_window,a0   new_window base address
        move.l  screen_p,nw_Screen(a0)    set screen
                                          pointer
        CALLSYS OpenWindow,_IntuitionBase
        move.l  d0,window_p
        beq     CLOSE_SCREEN
PRINT_ITEXT move.l  window_p,a1     get window address
        move.l  wd_RPort(a1),a0 get rastport address
        lea     intuitext1,a1
        move.l  #0,d0               no additional offsets
        move.l  #0,d1
        CALLSYS PrintIText,_IntuitionBase
PRINT_BORDER move.l  window_p,a1    get window address
        move.l  wd_RPort(a1),a0 get rastport address
        lea     border1,a1
        move.l  #0,d0               no additional offsets
        move.l  #0,d1
        CALLSYS DrawBorder,_IntuitionBase
DRAW_IMAGE  move.l  window_p,a1     get window address
        move.l  wd_RPort(a1),a0 get rastport address
        lea     image1,a1
```

```
            move.l   #0,d0          no additional offsets
            move.l   #0,d1
            CALLSYS  DrawImage,_IntuitionBase
ADD_MENU    move.l                  window_p,a0
            lea      Menu1,a1
            CALLSYS  SetMenuStrip,_IntuitionBase
SLEEP       move.l   window_p,a0         window base address
            move.l   wd_UserPort(a0),a2  user port
            jsr      WaitForMenuMessage
REMOVE_MENU move.l   window_p,a0
            CALLSYS  ClearMenuStrip,_IntuitionBase
CLOSE_WINDOWmove.l   window_p,a0
            CALLSYS  CloseWindow,_IntuitionBase
CLOSE_SCREENmove.l   screen_p,a0
            CALLSYS  CloseScreen,_IntuitionBase
; now close the libraries and quit...
CLOSE_GRAPHICS       move.l    _GfxBase,a1 base needed in a1
            CALLSYS  CloseLibrary,_SysBase
CLOSE_INTUITION      move.l    _IntuitionBase,a1    base needed
                                                    in a1
            CALLSYS  CloseLibrary,_SysBase
EXIT        clr.l    d0
            rts                     logical end of program
*---------------------------------------------------------------
; Function name:     WaitForMenuMessage()
; Purpose:           Wait until user selects quit from menu
; Input Parameters:  Address of IDCMP user-port should be in a2.
; Output parameters: None
; Register Usage:    a0:  Used by WaitPort() and GetMsg()
;                    a1:  Used by ReplyMsg()
;                    a2:  Holds user-port address
;                    d0:  Used by WaitPort() and GetMsg()
;                    d1:  Unused but possibly altered by system
                          functions
;                    d2:  Used as an exit flag (quit when non-
                          zero)
; Other Notes:       All registers are preserved
```

```
* ------------------------------------------------------------------
WaitForMenuMessage   movem.l   d0-d2/a0-a2,-(sp)     preserve
                                                     registers
                     clr.l     d2                    clear exit flag
WaitForExitMessage2  move.l    a2,a0                 port address
                     CALLSYS   WaitPort,_SysBase
                     jsr       GetMessage
                     cmpi.l    #TRUE,d2              exit flag set?
                     bne       WaitForExitMessage2
                     movem.l   (sp)+,d0-d2/a0-a2     restore
                                                     registers
                     rts                 logical end of routine
* ------------------------------------------------------------------
GetMessage           move.l    a2,a0       get port address in
                                           a0
                     CALLSYS   GetMsg,_SysBase       get the
                                                     message
                     tst.l     d0
                     beq       GetMessageExit  did it exist?
                     move.l    d0,a1       copy pointer to a1
                     cmpi.l    #MENUPICK,im_Class(a1)
                     bne       GetMessage1
                     move.l    #TRUE,d2              menu was used
 GetMessage1         CALLSYS   ReplyMsg,_SysBase
                     bra       GetMessage            check for more
                                                     messages
GetMessageExit       rts                     d2 holds exit flag
* ------------------------------------------------------------------
; variables and static data...
_GfxBase             ds.l      1
_IntuitionBase       ds.l      1
_SysBase             ds.l      1
screen_p             ds.l      1
window_p             ds.l      1
intuition_name       dc.b 'intuition.library',0
graphics_name        dc.b 'graphics.library',0
    cnop 0,2
new_screen
```

```
    dc.w    0,0                         screen top left
    dc.w    SCREENWIDTH,SCREENHEIGHT    screen width and height
    dc.w    DEPTH                       bitplane depth
    dc.b    WHITE,GREY                  detail and block pens
    dc.w    0                           no special view modes
    dc.w    CUSTOMSCREEN                screen type
    dc.l    NULL                        no special font
    dc.l    NULL                        no title
    dc.l    NULL                        no gadgets
    dc.l    NULL                        no custom bitmap
      cnop 0,2
new_window
    dc.w    0,0                         window XY origin
    dc.w    SCREENWIDTH,SCREENHEIGHT    width and height
    dc.b    WHITE,GREY                  detail and block pens
    dc.l    MENUPICK                    IDCMP flags
    dc.l    SMART_REFRESH               window flags
    dc.l    NULL                        no gadgets
    dc.l    NULL                        no CHECKMARK imagery
    dc.l    NewWindowName               window title
    dc.l    NULL                        screen set at run-time
    dc.l    NULL                        no custom bitmap
    dc.w    0,0                         minimum width and height
    dc.w    0,0                         maximum width and height
    dc.w    CUSTOMSCREEN                screen type
NewWindowName
    dc.b    '*** Select window to activate menu ***',0
    cnop 0,2
colour_table
    dc.w    $0000                       BLACK (background)
    dc.w    $0888                       GREY
    dc.w    $0FFF                       WHITE
    dc.w    $0F00                       RED
    dc.w    $00F0                       GREEN
    dc.w    $000F                       BLUE
    dc.w    $0FF0                       YELLOW
```

```
    dc.w      $0F0F                    MAUVE
colour_table_SIZEOF EQU *-colour_table
    cnop 0,2
border1
    dc.w      35-2,20-2                XY origin
    dc.b      WHITE,NULL,RP_JAM1       front & back pens and
                                       drawmode
    dc.b      5                        number of XY vectors
    dc.l      BorderVectors1           pointer to XY vectors
    dc.l      NULL                     no next border

BorderVectors1
    dc.w      0,0
    dc.w      250,0
    dc.w      250,10
    dc.w      0,10
    dc.w      0,0

intuitext1
    dc.b      WHITE,NULL,RP_JAM2,0     pens, drawmode and fill
                                       byte
    dc.w      35,20                    XY origin
    dc.l      NULL                     default font
    dc.l      ITextText1               text pointer
    dc.l      intuitext2               next IntuiText structure

ITextText1
    dc.b      'Border drawn using DrawBorder()',0
    cnop 0,2

intuitext2
    dc.b      BLUE,NULL,RP_JAM2,0      pens, drawmode and fill
                                       byte
    dc.w      35,40                    XY origin
    dc.l      NULL                     default font
    dc.l      ITextText2               text pointer
    dc.l      intuitext3               next IntuiText structure
```

```
ITextText2
   dc.b     'Text written using PrintIText()',0
   cnop 0,2

intuitext3
   dc.b     YELLOW,NULL,RP_JAM2,0     pens, drawmode and fill
                                      byte
   dc.w     35,60                     XY origin
   dc.l     NULL                      default font
   dc.l     ITextText3                text pointer
   dc.l     intuitext4                next structure

ITextText3
   dc.b     'Image drawn using DrawImage()',0
  cnop 0,2

intuitext4
   dc.b     MAUVE,NULL,RP_JAM2,0      pens, drawmode and fill
                                      byte
   dc.w     35,80                     XY origin
   dc.l     NULL                      default font
   dc.l     ITextText4                text pointer
   dc.l     NULL                      no next structure

ITextText4
   dc.b     'Use menu QUIT to exit!',0
  cnop 0,2
Menu1
   dc.l     NULL                      next menu
   dc.w     0,0                       XY origin
   dc.w     70,10                     hit box width and height
   dc.w     MENUENABLED               flags
   dc.l     MenuName                  name
   dc.l     MenuItem1                 menu items
   dc.w     0,0,0,0
```

```
MenuName
    dc.b      'Project',0
    cnop      0,2

MenuItem1
    dc.l      NULL                        no next menu item
    dc.w      0,0                         XY origin
    dc.w      40,8                        width and height
    dc.w      ITEMTEXT+ITEMENABLED+HIGHCOMP      flags
    dc.l      0
    dc.l      MenuIText1                  intuitext to be rendered
    dc.l      NULL
    dc.b      NULL
    dc.b      NULL
    dc.l      NULL                        no sub- items
    dc.w      MENUNULL

MenuIText1
    dc.b      RED,GREY,RP_COMPLEMENT,0 pens, drawmode and fill
                                          byte
    dc.w      0,0                         XY origin
    dc.l      NULL                        default font
    dc.l      MenuITextText1              text
    dc.l      NULL                        no next structure

MenuITextText1
    dc.b      'Quit',0
    cnop 0,2

image1
    dc.w      44,100                      XY origin
    dc.w      232,88                      image width and height
    dc.w      3                           depth
    dc.l      ImageData1                  image data
    dc.b      $0007,$0000                 plane configurations
    dc.l      NULL                        no next image
```

```
      SECTION IMAGE,DATA_C
ImageData1
   dc.w     $0000,$0000,$0000,$0000,$0000,$0000,$01FF,$0000
   dc.w     $0000,$0000,$0000,$0000,$0000,$0000,$0000,$0000
   dc.w     $1FFC,$0000,$0000,$0000,$0000,$0FFF,$E000,$0000
   dc.w     $0000,$0000,$0000,$0000,$0000,$0000,$0001,$FFFF
   .
   .
   .
   .
   dc.w     $0000,$0000,$0000,$0000,$0000,$0002,$0000,$4000
   dc.w     $0000,$0000,$0000,$0000,$0000,$0000,$0000,$0000
   dc.w     $0000,$0000,$0000,$0000,$0000,$0000,$0000,$0000
   dc.w     $0000,$0000,$0000,$0000,$0000,$0000,$0000,$0000
* ------------------------------------------------------------
```

A Minor Snag?

When you run the assembled version of Example CH15-2.s you'll notice that the program terminates even if you use the menu but decide not to make a menu selection. The reason stems from the fact that in this latter case Intuition sends a MENUPICK message whenever a menu is used regardless of whether a selection is made or not. To find out which items were selected it's necessary to analyse the menu number information provided in the im_Code field of the intuimessage.

In the case of the simple menu I've used there is only one item and so the program will either receive the code corresponding to that item, or it will receive a MENUNULL code to indicate that a selection was not made. I've opted for just checking that the message does not have a MENUNULL code before setting the menu routine's exit flag. In other words the fragment:

```
   cmpi.l   #MENUPICK,im_Class(a1)
   bne      GetMessage1
   move.l   #TRUE,d2 user wishes to quit
```

has been altered to:

```
   cmpi.l   #MENUPICK,im_Class(a1)
   bne      GetMessage1
   cmpi.w   #MENUNULL,im_Code(a1)
   beq      GetMessage1                false alarm?
   move.l   #TRUE,d2                   user wishes to quit
```

Since this is the only change made I'm not going to list the revised program (but you will find it on disk as ExampleCH15-3.s). Here though is the revised WaitForMenuMessage() routine so that you can see how the above changes fit into the general framework:

```
* ------------------------------------------------------------
; Function name:       WaitForMenuMessage()
; Purpose:             Wait until user selects quit from menu
; Input Parameters:    Address of IDCMP user-port should be in
                       a2.
; Output parameters:   None
; Register Usage:      a0: Used by WaitPort() and GetMsg()
;                      a1: Used by ReplyMsg()
;                      a2: Holds user-port address
;                      d0: Used by WaitPort() and GetMsg()
;                      d1: Unused but possibly altered by
                       system functions
;                      d2: Used as an exit flag (quit when
                           non-zero)
; Other Notes:         All registers are preserved
* ------------------------------------------------------------
WaitForMenuMessage     movem.l   d0-d2/a0-a2,-(sp)     preserve
                                                       registers
                       clr.l     d2          clear exit flag
WaitForExitMessage2    move.l    a2,a0       port address
                       CALLSYS   WaitPort,_SysBase
                       jsr       GetMessage
                       cmpi.l    #TRUE,d2    exit flag set?
                       bne       WaitForExitMessage2
                       movem.l   (sp)+,d0-d2/a0-a2     restore
                                                       registers
                       rts               logical end of routine
* ------------------------------------------------------------
GetMessage             move.l    a2,a0   get port address in a0
                       CALLSYS   GetMsg,_SysBase get the message
                       tst.l     d0
                       beq       GetMessageExit did it exist?
                       move.l    d0,a1       copy pointer to a1
                       cmpi.l    #MENUPICK,im_Class(a1)
```

```
                    bne       GetMessage1
                    cmpi.w    #MENUNULL,im_Code(a1)
                    beq       GetMessage1     false alarm?
                    move.l    #TRUE,d2  user wishes to quit
GetMessage1         CALLSYS   ReplyMsg,_SysBase
                    bra       GetMessage      check for more
                                              messages
GetMessageExit      rts                  d2 holds exit flag
*  ------------------------------------------------------------
```

A Final Excursion

This last example puts our existing experiments firmly into an Intuition based framework by making things happen as a user selects (or de-selects) various gadgets.

Some of the changes, such as using different text and positional data in the IntuiText structures, will be easily recognised as being of no special significance. Similarly the only noticeable changes in the early part of the program are that the calls to display border and image data have been eliminated because these operations will be dealt with as part of the gadget handling code. One additional library call, to set the colour of the primary graphics pen, was needed and the code for this is as follows:

```
SET_PEN_COLOUR   move.l    window_p,a1     get window address
                 move.l    wd_RPort(a1),a1 get rastport
                                           address
                 move.b    #BLACK,d0
                 CALLSYS   SetAPen,_GfxBase
```

The basic program framework is therefore still very similar to the previous example:

```
Open Intuition Library
  Open Graphics Library
     Open an Intuition Screen
     Set up screen's colour map
        Open an Intuition Window
           Add Menu
           Set Pen Colour
           Print some Text
           Go to sleep until user does something
           Remove menu
        Close Window
```

```
Close Screen
Close Graphics Library
Close Intuition Library
```

There are however two areas within this framework where things have changed quite dramatically. Firstly, a chain of three gadget definitions has been set up using the structure format outlined in Chapter 14. The setting up of gadget structures is just a matter of following the system guidelines. Once the definitions have been created, getting them displayed is easy because Intuition does most of the work – all the programmer needs to do is to place the address of the first gadget in the nw_FirstGadget field (see the source listing for details).

The second area where changes have occurred is the *event handling* section of the program. The good news here is that the ideas are still based on the message collection approach used with the WaitForExitMessage() and WaitForMenuMessage() functions. The routine has however been expanded to provide gadget handling facilities. The three gadgets are of the Boolean on/off variety and have Text, Border, and Image labels. When a gadget is selected a corresponding Intuition item gets displayed, when the gadget is turned off the item is removed from the screen.

The method I've chosen for this example is as follows: I store the gadget address (retrieved from the intuimessage) in a variable called gadget_p then, at the end of a possible stream of intuimessages, I look to see whether a valid address is present. If a gadget had not been used then my pointer would contain its initial value of zero.

Here's the code for the uppermost level of the handler:

```
MessageHandler   movem.l   d0-d4/a0-a2,-(sp)   preserve
                                               registers
                 clr.l     d4                  clear exit flag
MessageHandler2  clr.l     gadget_p            clear gadget pointer
                 move.l    a2,a0               port address
                 CALLSYS   WaitPort,_SysBase
                 jsr       GetMessage
                 cmpi.l    #TRUE,d4            exit flag set?
                 beq       MessageHandler3
                 tst.l     gadget_p            was a gadget hit?
                 beq       MessageHandler2
                 jsr       GadgetHandler       do gadget
                                               operations
```

```
                bra         MessageHandler2
MessageHandler3 movem.l     (sp)+,d0-d4/a0-a2   restore
                                                registers
                rts                 logical end of routine
```

You will notice that register a4 is now being used as the exit flag. This is because my original exit-flag register (d2) is needed by a RectFill() graphics function which is used to clear a displayed image from the window. A further extension is that, having checked to see if the IDCMP message is a MENUPICK message, a further check needs to be included for GADGETUP messages. It is here that, providing we've got the right type of message, that the gadget address is retrieved and stored in the gadget_p variable:

```
CheckGadgets    cmpi.l    #GADGETUP,im_Class(a1)
                bne       GetMessage1
                move.l    im_IAddress(a1),gadget_p
                                        save gadget address
```

With these fragments in place the second level of the message handling routine should still be comfortably familiar:

```
GetMessage      move.l    a2,a0         get port address in a0
                CALLSYS   GetMsg,_SysBase get the message
                tst.l     d0
                beq       GetMessageExit      did it exist?
                move.l    d0,a1             copy pointer to a1
                cmpi.l    #MENUPICK,im_Class(a1)
                bne       CheckGadgets
                cmpi.w    #MENUNULL,im_Code(a1)
                beq       GetMessage1         false alarm?
                move.l    #TRUE,d4     user wishes to quit
                bra       GetMessage1
CheckGadgets    cmpi.l    #GADGETUP,im_Class(a1)
                bne       GetMessage1
                move.l    im_IAddress(a1),gadget_p
                                        save gadget address
GetMessage1     CALLSYS   ReplyMsg,_SysBase
                bra       GetMessage        check for more
                                            messages
GetMessageExit  rts                       d4 holds exit flag
```

You will have noticed from the first level code that a jsr GadgetHandler call is made if gadget_p is non-zero. If it is non-zero it's because it contains the address of a gadget placed there by the above code. If you go back to Chapter 14 and look at the Gadget structure you'll see a field called gg_GadgetID. If you look at the gadget definitions given in the source code to Example CH15-4.s you will see that I've placed the values 1, 2 and 3 in the gg_GadgetID fields of Gadget1, Gadget2 and Gadget3 respectively.

To find out which gadget has been hit all we need to do, using our nowadays familiar structure accessing via indirect addressing approach, is to identify the gadget number and take some appropriate action. Here's a fragment that looks for gadget number 1 and, if found, executes a text printing routine:

```
GadgetHandler  move.l   gadget_p,a0
               cmpi.w   #1,gg_GadgetID(a0)  gadget 1 hit?
               bne      GadgetHandler1
               jsr      PrintText
               rts
```

Here's the fragment which checks for the second gadget:

```
GadgetHandler1 cmpi.w   #2,gg_GadgetID(a0)
               bne      GadgetHandler2  gadget 2 hit?
               jsr      DrawBorder
               rts
```

Since only three gadgets are in use, a gadget hit which turns out *not* to be gadgets 1 or 2, must be gadget 3. So the identity of gadget 3 doesn't need to be checked:

```
GadgetHandler2 jsr      DrawImage       must be gadget 3
               rts
```

Having recognised a gadget hit, stored the gadget address, and now reached the stage where we know the gadget's identity, all that remains code-wise is to do the various print/drawing operations. There's more good news here because these operations were done as part of the earlier program anyway and in two cases all that was needed was to move the routine from the original position to the gadget handling routine. This text print routine should therefore already be familiar:

```
PrintText      move.l   window_p,a1     get window address
```

```
                move.l   wd_RPort(a1),a0 get rastport
                                         address
                lea      intuitext2,a1
                move.l   #0,d0        no additional offsets
                move.l   #0,d1
                CALLSYS  PrintIText,_IntuitionBase
                rts
```

Similarly the border drawing code is identical to that in the previous program:

```
DrawBorder      move.l   window_p,a1     get window address
                move.l   wd_RPort(a1),a0 get rastport
                                         address
                lea      border1,a1
                move.l   #0,d0           no additional
                                         offsets
                move.l   #0,d1
                CALLSYS  DrawBorder,_IntuitionBase
                rts
```

Where they differ operationally however is that the RP_COMPLEMENT draw mode has been used so that the item is drawn and then un-drawn with successive calls to PrintText() and DrawBorder()!

Unfortunately the same approach cannot be used with the image drawing operation. Instead it is necessary to look at the gg_Flags field of the gadget structure to see whether it is selected or unselected and the easiest way to do this is to copy the gadget state into a data register like this:

```
   move.w       gg_Flags(a0),d0      get gadget state
```

and then exclusive OR the value with the system-defined SELECTED flag:

```
 eori.w         #SELECTED,d0         zero flag set =
                                     SELECTED
```

If the zero flag is set then this means that the SELECTED bit was set in the gg_Flags field. The following code does this and on the basis of the result it performs either a *Clear Image* routine or the Draw Image routine (as used in the previous program). For the example the image clearing was done by using the RectFill() graphics library function. The co-ordinate details need to be placed in d0-d3 and the window's rastport address in register a1 so the final image drawing/clearing section of the program ended up looking like this:

```
DrawImage       move.l  window_p,a1 get window address
                move.w  gg_Flags(a0),d0 get gadget state
                eori.w  #SELECTED,d0    zero flag set =
                                        SELECTED
                beq     DrawImage1
ClearImage      move.l  wd_RPort(a1),a1 get rastport
                                        address
                move.w  #44,d0          set image dimensions
                move.w  #130,d1
                move.w  #44+232-1,d2
                move.w  #130+88-1,d3
                CALLSYS RectFill,_GfxBase
                rts
DrawImage1      move.l  window_p,a1     get window address
                move.l  wd_RPort(a1),a0 get rastport
                                        address
                lea     image1,a1
                move.l  #0,d0           no additional offsets
                move.l  #0,d1
                CALLSYS DrawImage,_IntuitionBase
                rts
```

When all these fragments are placed together we end up with a routine that carries out the operations which we have deemed necessary for the menu and gadget events messages that could occur:

```
* ------------------------------------------------------------------
; Function name:MessageHandler()
; Purpose:              IDCMP menu and gadget message handler
; Input Parameters:     Address of IDCMP user-port should be in
a2.
; Output parameters:    None
; Register Usage:       a0-a1/d0-d3:    Used for system call
                                        parameters.
;                       a2:             Holds user-port address
;                       d4:             Used as exit flag (quit
when                                            non-zero)
; Other Notes:          All registers are preserved
* ------------------------------------------------------------------
```

```
MessageHandler   movem.l  d0-d4/a0-a2,-(sp)  preserve registers
                 clr.l    d4                 clear exit flag
MessageHandler2  clr.l    gadget_p           clear gadget
                                             pointer
                 move.l   a2,a0              port address
                 CALLSYS  WaitPort,_SysBase
                 jsr      GetMessage
                 cmpi.l   #TRUE,d4           exit flag set?
                 beq      MessageHandler3
                 tst.l    gadget_p           was a gadget hit?
                 beq      MessageHandler2
                 jsr      GadgetHandler      do gadget
                                             operations
                 bra      MessageHandler2
MessageHandler3  movem.l  (sp)+,d0-d4/a0-a2  restore registers
                 rts                         logical end of
                                             routine
* ---------------------------------------------------------------------
GetMessage       move.l   a2,a0              get port address in
                                             a0
                 CALLSYS  GetMsg,_SysBase    get the message
                 tst.l    d0
                 beq      GetMessageExit     did it exist?
                 move.l   d0,a1              copy pointer to a1
                 cmpi.l   #MENUPICK,im_Class(a1)
                 bne      CheckGadgets
                 cmpi.w   #MENUNULL,im_Code(a1)
                 beq      GetMessage1        false alarm?
                 move.l   #TRUE,d4           user wishes to
                                             quit
                 bra      GetMessage1
CheckGadgets     cmpi.l   #GADGETUP,im_Class(a1)
                 bne      GetMessage1
                 move.l   im_IAddress(a1),gadget_p
                                             save gadget address
GetMessage1      CALLSYS  ReplyMsg,_SysBase
                 bra      GetMessage         check for more
                                             messages
```

```
GetMessageExit   rts                          d4 holds exit flag
* ------------------------------------------------------------------
GadgetHandler    move.l   gadget_p,a0
                 cmpi.w   #1,gg_GadgetID(a0)  gadget 1 hit?
                 bne      GadgetHandler1
                 jsr      PrintText
                 rts
GadgetHandler1   cmpi.w   #2,gg_GadgetID(a0)
                 bne      GadgetHandler2      gadget 2 hit?
                 jsr      DrawBorder
                 rts
GadgetHandler2   jsr      DrawImage           must be gadget 3
                 rts
* ------------------------------------------------------------------
PrintText        move.l   window_p,a1         get window
                                              address
                 move.l   wd_RPort(a1),a0     get rastport
                                              address
                 lea      intuitext2,a1
                 move.l   #0,d0               no additional
                                              offsets
                 move.l   #0,d1
                 CALLSYS  PrintIText,_IntuitionBase
                 rts
* ------------------------------------------------------------------
DrawBorder       move.l   window_p,a1         get window
                                              address
                 move.l   wd_RPort(a1),a0     get rastport
                                              address
                 lea      border1,a1
                 move.l   #0,d0               no additional
                                              offsets
                 move.l   #0,d1
                 CALLSYS  DrawBorder,_IntuitionBase
                 rts
* ------------------------------------------------------------------
DrawImage        move.l   window_p,a1         get window
                                              address
```

```
                move.w   gg_Flags(a0),d0     get gadget state
                eori.w   #SELECTED,d0        zero flag set =
                                             SELECTED
                beq      DrawImage1
ClearImage      move.l   wd_RPort(a1),a1     get rastport
                                             address
                move.w   #44,d0              set image
                                             dimensions
                move.w   #130,d1
                move.w   #44+232-1,d2
                move.w   #130+88-1,d3
                CALLSYS  RectFill,_GfxBase
                rts

DrawImage1      move.l   window_p,a1         get window
                                             address
                move.l   wd_RPort(a1),a0     get rastport
                                             address
                lea      image1,a1
                move.l   #0,d0               no additional
                                             offsets
                move.l   #0,d1
                CALLSYS  DrawImage,_IntuitionBase
                rts
* ---------------------------------------------------------------
```

The End of The Road

The material covered in this chapter takes us to the end of our Intuition experiments. The final program, Example CH15-4.s, may not be earth shattering but it contains examples of a lot of things that real Intuition programs have to do. It opens libraries, screens and windows, draws text, borders and images, and it uses menus and gadgets via the Exec-based IDCMP message facilities. Once you've come to terms with this material you should be ready to choose your own pathways as far as Intuition is concerned and so, in a sense, this last program just gives you a place to start. Nevertheless, a lot of material has been covered in recent chapters and it seems a good idea to make sure that a hard copy of the results are available as a point of reference:

```
* ------------------------------------------------------------------
* Example CH15-4.s
* ------------------------------------------------------------------
; some system include files.
          include exec/types.i
          include exec/libraries.i
          include exec/exec_lib.i
          include intuition/intuition.i
          include intuition/screens.i
* ------------------------------------------------------------------
; a macro to extend LINKLIB and thus avoid the explicit use of
; the _LVO prefixes in the function names.
CALLSYS   MACRO
          LINKLIB _LVO\1,\2
          ENDM
* ------------------------------------------------------------------
; System EQUates...
_AbsExecBase         EQU  4
_LVOOpenScreen       EQU  -198
_LVOCloseScreen      EQU  -66
_LVOOpenWindow       EQU  -204
_LVOCloseWindow      EQU  -72
_LVOLoadRGB          EQU  -192
_LVOPrintIText       EQU  -216
_LVODrawBorder       EQU  -108
_LVODrawImage        EQU  -114
_LVOSetMenuStrip     EQU  -264
_LVOClearMenuStrip   EQU  -54
_LVORectFill         EQU  -306
_LVOSetAPen          EQU  -342
; Colour map EQUates...
BLACK                EQU  0
GREY                 EQU  1
WHITE                EQU  2
RED                  EQU  3
```

```
GREEN               EQU   4
BLUE                EQU   5
YELLOW              EQU   6
MAUVE               EQU   7
; Screen EQUates...
SCREENWIDTH         EQU   320
SCREENHEIGHT        EQU   256
DEPTH               EQU   3
; General EQUates...
NULL                EQU   0
TRUE                EQU   1
* ------------------------------------------------------------------
; main program code...
OPEN_INTUITION  move.l   _AbsExecBase,_SysBase    store Exec
                                                  library base
                lea      intuition_name,a1        library name start
                                                  in a1
                moveq    #0,d0            any version will do
                CALLSYS  OpenLibrary,_SysBase     macro (see text
                                                  for details)
                move.l   d0,_IntuitionBase        store returned
                                                  value
                beq      EXIT             test result for success
OPEN_GRAPHICS   lea      graphics_name,a1         library name start
                                                  in a1
                moveq    #0,d0            any version will do
                CALLSYS  OpenLibrary,_SysBase     macro (see text
                                                  for details)
                move.l   d0,_GfxBase      store returned value
                beq      CLOSE_INTUITION test result for success
OPEN_SCREEN     lea      new_screen,a0    new_screen base address
                CALLSYS  OpenScreen,_IntuitionBase
                move.l   d0,screen_p
                beq      CLOSE_GRAPHICS
LOAD_COLOURS    add.l    #sc_ViewPort,d0          screen_p already
                                                  in d0
                move.l   d0,a0       viewport address now in a0
                lea      colour_table,a1          pointer to colour
                                                  map
```

```
                move.w    #colour_table_SIZEOF,d0     colour
                                                      map size
                CALLSYS   LoadRGB,_GfxBase
OPEN_WINDOW     lea       new_window,a0   new_window base address
                move.l    screen_p,nw_Screen(a0)  set screen
                                                  pointer
                CALLSYS   OpenWindow,_IntuitionBase
                move.l    d0,window_p
                beq       CLOSE_SCREEN
ADD_MENU        move.l    window_p,a0
                lea       Menu1,a1
                CALLSYS   SetMenuStrip,_IntuitionBase
SET_PEN_COLOUR  move.l    window_p,a1     get window address
                move.l    wd_RPort(a1),a1 get rastport address
                move.b    #BLACK,d0
                CALLSYS   SetAPen,_GfxBase
PRINT_TEXT      move.l    window_p,a1     get window address
                move.l    wd_RPort(a1),a0 get rastport address
                lea       intuitext1,a1
                move.l    #0,d0       no additional offsets
                move.l    #0,d1
                CALLSYS   PrintIText,_IntuitionBase
SLEEP           move.l    window_p,a0     window base address
                move.l    wd_UserPort(a0),a2   user port
                jsr       MessageHandler
REMOVE_MENU     move.l    window_p,a0
                CALLSYS   ClearMenuStrip,_IntuitionBase
CLOSE_WINDOW    move.l    window_p,a0
                CALLSYS   CloseWindow,_IntuitionBase
CLOSE_SCREEN    move.l    screen_p,a0
                CALLSYS   CloseScreen,_IntuitionBase
CLOSE_GRAPHICS  move.l    _GfxBase,a1     base needed in a1
                CALLSYS   CloseLibrary,_SysBase
CLOSE_INTUITION move.l    _IntuitionBase,a1    base needed in a1
                CALLSYS   CloseLibrary,_SysBase
EXIT            clr.l     d0
                rts                       logical end of program
```

```
* ------------------------------------------------------------------
; Function name:      MessageHandler()
; Purpose:            IDCMP menu and gadget message handler
; Input Parameters:   Address of IDCMP user-port should be in a2.
; Output parameters:  None
; Register Usage:     a0-a1/d0-d3: Used for system call parameters.
;                     a2:          Holds user-port address
;                     d4:          Used as exit flag (quit when
                                     non-zero)
; Other Notes:        All registers are preserved
* ------------------------------------------------------------------
MessageHandler  movem.l  d0-d4/a0-a2,-(sp)    preserve registers
                clr.l    d4                   clear exit flag
MessageHandler2 clr.l    gadget_p             clear gadget pointer
                move.l   a2,a0                port address
                CALLSYS  WaitPort,_SysBase
                jsr      GetMessage
                cmpi.l   #TRUE,d4             exit flag set?
                beq      MessageHandler3
                tst.l    gadget_p             was a gadget hit?
                beq      MessageHandler2
                jsr      GadgetHandler        do gadget operations
                bra      MessageHandler2
MessageHandler3 movem.l  (sp)+,d0-d4/a0-a2    restore registers
                rts                          logical end of routine
* ------------------------------------------------------------------
GetMessage      move.l   a2,a0               get port address in a0
                CALLSYS  GetMsg,_SysBase     get the message
                tst.l    d0
                beq      GetMessageExit      did it exist?
                move.l   d0,a1               copy pointer to a1
                cmpi.l   #MENUPICK,im_Class(a1)
                bne      CheckGadgets
                cmpi.w   #MENUNULL,im_Code(a1)
                beq      GetMessage1                false alarm?
                move.l   #TRUE,d4            user wishes to quit
```

```
                bra       GetMessage1
CheckGadgets    cmpi.l    #GADGETUP,im_Class(a1)
                bne       GetMessage1
                move.l    im_IAddress(a1),gadget_p    save gadget
                                                      address
GetMessage1     CALLSYS   ReplyMsg,_SysBase
                bra       GetMessage      check for more messages
GetMessageExit  rts                       d4 holds exit flag
* ------------------------------------------------------------------
GadgetHandler   move.l    gadget_p,a0
                cmpi.w    #1,gg_GadgetID(a0)    gadget 1 hit?
                bne       GadgetHandler1
                jsr       PrintText
                rts
GadgetHandler1  cmpi.w    #2,gg_GadgetID(a0)
                bne       GadgetHandler2          gadget 2 hit?
                jsr       DrawBorder
                rts
GadgetHandler2  jsr       DrawImage             must be gadget 3
                rts
* ------------------------------------------------------------------
PrintText       move.l    window_p,a1     get window address
                move.l    wd_RPort(a1),a0 get rastport address
                lea       intuitext2,a1
                move.l    #0,d0           no additional offsets
                move.l    #0,d1
                CALLSYS   PrintIText,_IntuitionBase
                rts
* ------------------------------------------------------------------
DrawBorder      move.l    window_p,a1     get window address
                move.l    wd_RPort(a1),a0 get rastport address
                lea       border1,a1
                move.l    #0,d0           no additional offsets
                move.l    #0,d1
                CALLSYS   DrawBorder,_IntuitionBase
                rts
```

```
* ------------------------------------------------------------------
DrawImage       move.l   window_p,a1      get window address
                move.w   gg_Flags(a0),d0 get gadget state
                eori.w   #SELECTED,d0     zero flag set = SELECTED
                beq      DrawImage1
ClearImage      move.l   wd_RPort(a1),a1 get rastport address
                move.w   #44,d0           set image dimensions
                move.w   #130,d1
                move.w   #44+232-1,d2
                move.w   #130+88-1,d3
                CALLSYS  RectFill,_GfxBase
                rts
DrawImage1      move.l   window_p,a1      get window address
                move.l   wd_RPort(a1),a0 get rastport address
                lea      image1,a1
                move.l   #0,d0            no additional offsets
                move.l   #0,d1
                CALLSYS  DrawImage,_IntuitionBase
                rts
* ------------------------------------------------------------------
; variables and static data...
_GfxBase          ds.l    1
_IntuitionBase    ds.l    1
_SysBase          ds.l    1
screen_p          ds.l    1
window_p          ds.l    1
gadget_p          ds.l    1
intuition_name    dc.b 'intuition.library',0
graphics_name     dc.b 'graphics.library',0
* ------------------------------------------------------------------
; screen definition...
    cnop 0,2
new_screen
   dc.w   0,0                          screen top left
   dc.w   SCREENWIDTH,SCREENHEIGHT     screen width and height
   dc.w   DEPTH                        bitplane depth
```

```
    dc.b    WHITE,GREY                  detail and block pens
    dc.w    0                           no special view modes
    dc.w    CUSTOMSCREEN                screen type
    dc.l    NULL                        no special font
    dc.l    NULL                        no title
    dc.l    NULL                        no gadgets
    dc.l    NULL                        no custom bitmap
* ------------------------------------------------------------------
; window definition...
     cnop 0,2
new_window
    dc.w    0,0                         window XY origin
    dc.w    SCREENWIDTH,SCREENHEIGHT    width and height
    dc.b    WHITE,GREY                  detail and block pens
    dc.l    MENUPICK+GADGETUP           IDCMP flags
    dc.l    SMART_REFRESH               window flags
    dc.l    Gadget1                     first gadget
    dc.l    NULL                        no CHECKMARK imagery
    dc.l    NewWindowName               window title
    dc.l    NULL                        screen set at run-time
    dc.l    NULL                        no custom bitmap
    dc.w    0,0                         minimum width and height
    dc.w    0,0                         maximum width and height
    dc.w    CUSTOMSCREEN                screen type
NewWindowName
    dc.b    '*** Select window to activate menu ***',0
* ------------------------------------------------------------------
; screen colours definition...
    cnop    0,2
colour_table
    dc.w    $0000                       BLACK (background)
    dc.w    $0888                       GREY
    dc.w    $0FFF                       WHITE
    dc.w    $0F00                       RED
    dc.w    $00F0                       GREEN
    dc.w    $000F                       BLUE
```

```
    dc.w   $0FF0                          YELLOW
    dc.w   $0F0F                          MAUVE
colour_table_SIZEOF EQU  *-colour_table
* ---------------------------------------------------------------------
; border that appears when gadget is selected...
    cnop   0,2
border1
    dc.w   40-2,60-2                      XY origin
    dc.b   MAUVE,NULL,RP_COMPLEMENT       front & back pens and
                                          drawmode
    dc.b   5                              number of XY vectors
    dc.l   BorderVectors1                 pointer to XY vectors
    dc.l   NULL                           no next border
BorderVectors1
    dc.w   0,0
    dc.w   235,0
    dc.w   235,10
    dc.w   0,10
    dc.w   0,0
* ---------------------------------------------------------------------
; text that appears when gadget is selected...
intuitext1
    dc.b   WHITE,NULL,RP_JAM1,0           pens, drawmode and fill
                                          byte
    dc.w   40,60                          XY origin
    dc.l   NULL                           default font
    dc.l   ITextText1                     text pointer
    dc.l   NULL
ITextText1
    dc.b   'PLEASE SELECT ITEM TO DISPLAY',0
    cnop 0,2
intuitext2
    dc.b   MAUVE,NULL,RP_COMPLEMENT,0     pens, drawmode and fill
                                          byte
    dc.w   20,72                          XY origin
    dc.l   NULL                           default font
    dc.l   ITextText2                     text pointer
```

```
   dc.l   intuitext3                    next IntuiText structure
ITextText2
   dc.b   'As gadgets are selected an example',0
   cnop   0,2
intuitext3
   dc.b   MAUVE,NULL,RP_COMPLEMENT,0    pens, drawmode and fill
                                        byte
   dc.w   24,84                         XY origin
   dc.l   NULL                          default font
   dc.l   ITextText3                    text pointer
   dc.l   intuitext4                    next structure
ITextText3
   dc.b   'item will be displayed or removed',0
   cnop 0,2
intuitext4
   dc.b   MAUVE,NULL,RP_COMPLEMENT,0    pens, drawmode and fill
                                        byte
   dc.w   20,96                         XY origin
   dc.l   NULL                          default font
   dc.l   ITextText4                    text pointer
   dc.l   NULL                          no next structure
ITextText4
   dc.b   'To exit from program use menu QUIT!',0
   cnop 0,2
* ------------------------------------------------------------------
; menu definition...
Menu1
   dc.l   NULL                          next menu
   dc.w   0,0                           XY origin
   dc.w   70,10                         hit box width and height
   dc.w   MENUENABLED                   flags
   dc.l   MenuName                      name
   dc.l   MenuItem1                     menu items
   dc.w   0,0,0,0
 MenuName
   dc.b   'Project',0
   cnop   0,2
```

```
MenuItem1
    dc.l   NULL                              no next menu item
    dc.w   0,0                               XY origin
    dc.w   40,8                              width and height
    dc.w   ITEMTEXT+ITEMENABLED+HIGHCOMP flags
    dc.l   0
    dc.l   MenuIText1                        intuitext to be rendered
    dc.l   NULL
    dc.b   NULL
    dc.b   NULL
    dc.l   NULL                              no sub- items
    dc.w   MENUNULL
MenuIText1
    dc.b   RED,GREY,RP_COMPLEMENT,0          pens, drawmode and fill
                                             byte
    dc.w   0,0                               XY origin
    dc.l   NULL                              default font
    dc.l   MenuITextText1                    text
    dc.l   NULL                              no next structure
MenuITextText1
    dc.b   'Quit',0
    cnop 0,2
* ------------------------------------------------------------------
; gadget definitions...
Gadget1
    dc.l   Gadget2                           next gadget
    dc.w   18,24                             origin XY
    dc.w   77,21                             hit box width and height
    dc.w   NULL                              gadget flags
    dc.w   RELVERIFY+TOGGLESELECT            activation flags
    dc.w   BOOLGADGET                        type flags
    dc.l   GagdetBorder1                     gadget border
    dc.l   NULL                              no alternate imagery
    dc.l   GagdetIText1                      gadget text
    dc.l   NULL
    dc.l   NULL
```

```
    dc.w   1                          gadget ID
    dc.l   NULL
GagdetBorder1
    dc.w   -1,-1                      XY origin
    dc.b   BLUE,BLACK,RP_JAM1         pens and drawmode
    dc.b   5                          vector count
    dc.l   GagdetBorderVectors1       vector pointer
    dc.l   NULL                       no next border
GagdetBorderVectors1
    dc.w   0,0
    dc.w   78,0
    dc.w   78,22
    dc.w   0,22
    dc.w   0,0
GagdetIText1
    dc.b   WHITE,BLACK,RP_JAM2,0      pens, drawmode and fill
                                      byte
    dc.w   20,6                       XY origin
    dc.l   NULL                       default font
    dc.l   GagdetITextText1           text
    dc.l   NULL
GagdetITextText1
    dc.b   'Text',0
    cnop 0,2
Gadget2
    dc.l   Gadget3                    next gadget
    dc.w   124,24                     origin XY
    dc.w   77,21                      hit box width and height
    dc.w   NULL                       gadget flags
    dc.w   RELVERIFY+TOGGLESELECT     activation flags
    dc.w   BOOLGADGET                 gadget type
    dc.l   GagdetBorder2              gadget border
    dc.l   NULL
    dc.l   GagdetIText2               text
    dc.l   NULL
    dc.l   NULL
```

```
    dc.w   2                          gadget ID
    dc.l   NULL
GagdetBorder2
    dc.w   -1,-1                      XY origin
    dc.b   BLUE,BLACK,RP_JAM1         pens and drawmode
    dc.b   5                          vector count
    dc.l   GagdetBorderVectors2       vector pointer
    dc.l   NULL                       no next border
GagdetBorderVectors2
    dc.w   0,0
    dc.w   78,0
    dc.w   78,22
    dc.w   0,22
    dc.w   0,0
GagdetIText2
    dc.b   WHITE,BLACK,RP_JAM2,0      pens, drawmode and fill
                                      byte
    dc.w   14,6                       XY origin
    dc.l   NULL                       default font
    dc.l   GagdetITextText2           text
    dc.l   NULL
GagdetITextText2
    dc.b   'Border',0
    cnop 0,2
Gadget3
    dc.l   NULL                       no next gadget
    dc.w   230,24                     origin XY
    dc.w   77,21                      hit box width and height
    dc.w   NULL                       gadget flags
    dc.w   RELVERIFY+TOGGLESELECT     activation flags
    dc.w   BOOLGADGET                 gadget type
    dc.l   GagdetBorder3              gadget border
    dc.l   NULL
    dc.l   GagdetIText3               text
    dc.l   NULL
    dc.l   NULL
```

```
   dc.w   3                          gadget ID
   dc.l   NULL
GagdetBorder3
   dc.w   -1,-1                      XY origin
   dc.b   BLUE,BLACK,RP_JAM1         pens and drawmode
   dc.b   5                          vector count
   dc.l   GagdetBorderVectors3       vector pointer
   dc.l   NULL
 GagdetBorderVectors3
   dc.w   0,0
   dc.w   78,0
   dc.w   78,22
   dc.w   0,22
   dc.w   0,0
GagdetIText3
   dc.b   WHITE,BLACK,RP_JAM2,0      pens, drawmode and fill
                                     byte
   dc.w   17,6                       XY origin
   dc.l   NULL                       default font
   dc.l   GagdetITextText3           text
   dc.l   NULL
 GagdetITextText3
   dc.b   'Image',0
* ------------------------------------------------------------------
; image description.
       cnop 0,2
image1
   dc.w   44,130                     XY origin
   dc.w   232,88                     image width and height
   dc.w   3                          depth
   dc.l   ImageData1                 image data
   dc.b   $0007,$0000                plane configurations
   dc.l   NULL                       no next image
      SECTION IMAGE,DATA_C
ImageData1
   dc.w   $0000,$0000,$0000,$0000,$0000,$0000,$01FF,$0000
```

```
    dc.w   $0000,$0000,$0000,$0000,$0000,$0000,$0000,$0000
    dc.w   $1FFC,$0000,$0000,$0000,$0000,$0FFF,$E000,$0000
    dc.w   $0000,$0000,$0000,$0000,$0000,$0000,$0001,$FFFF
    .
    .
    .
    .
    .
    dc.w   $0000,$0000,$0000,$0000,$0000,$0002,$0000,$4000
    dc.w   $0000,$0000,$0000,$0000,$0000,$0000,$0000,$0000
    dc.w   $0000,$0000,$0000,$0000,$0000,$0000,$0000,$0000
    dc.w   $0000,$0000,$0000,$0000,$0000,$0000,$0000,$0000
* ------------------------------------------------------------------
```

So That's Assembler

By now it should be obvious that even simple 68000 Intuition programs can provide a few development headaches. When you see what needs to be done for more complex Intuition applications the whole Intuition thing can become quite frightening. Worse than that the *pure 68000* approach has another disadvantage – it can take a lot of time. There is however a solution that is increasingly favoured by many commercial developers and since no Amiga assembler book would be complete without some discussion of it, I've decided to finish my 68000 meanderings with some details.

16: Where To Go From Here

This chapter deals with issues which would not normally be regarded as suitable for the 68000 beginner. I've included it primarily because it could, if you have some C experience under your belt, enable you to get all the benefits of assembler programming without the disadvantage of having to code complete applications programs in assembler.

One of the problems that the programmer working solely in 68000 assembler has is time, or rather the lack of it. Large assembly language programs, as you now doubtless realise, take a long time to develop. This, coupled to the fact that 90% of most programs are not time critical, leads many programmers naturally to the conclusion that it is far quicker, and far easier, to develop a large program in a language like C and then fine tune it by rewriting the time critical parts using assembler. In that way you get the development speed of a high-level language coupled to the speed of assembler in the places where it counts.

This attitude isn't a cop out, nor an admission that assembler isn't up to the job when it comes to large applications programs. It is a practical solution which shortens development time but does not, in the end, sacrifice the efficiency gains which the Amiga assembler programmer can achieve.

In order to be able to write this type of *mixed code* you obviously need to know how to get from C to assembler code and back again. The good news is that once you have seen it done, you will realise that it's not actually that difficult. To be honest all decent C compiler manuals provide the necessary technical details although unfortunately the explanations are usually written in a way that only makes sense once you know a little about what's going on in the first place.

This chapter is designed to do three things. Firstly, to provide the necessary background information so that, if you decide to get into this very useful area of Amiga programming, the accounts you'll read in your compiler manuals will make more sense. Secondly, to provide details of the conventions used with the two most popular Amiga C compilers, Manx Aztec C and SAS/Lattice C. Thirdly, to offer some runable examples which will get you into *mixed code* programming in as painless a manner as possible. A general overview of the Amiga system programming issues has been provided but some system and RKM literacy is expected with the last example.

I mentioned early on in the book that there were a couple of places where some knowledge of C would be needed and it's for this reason that an appendix giving an overview of the language was provided. For the rest of this chapter then I'm going to assume that you know what a C function call is and at least a little about the C language itself.

Let us then make a start by talking a bit about the magic which occurs when you place a call to a routine, say Convert(), into a C source program. The compiler uses such source code statements to generate a reference to the named routine.

Under normal circumstances both the Manx Aztec and SAS/Lattice C compilers tag on an initial underscore to the function name. The call to the function Convert() therefore has the linker searching for a routine called _Convert and it is this routine, if the linker is going to successfully resolve the reference, that must be provided in the assembly language module!

The code which various C compilers produce when they encounter a function call does vary but the conventions to be followed will always be detailed in the compiler manual. To start with all you really need to be aware of is that the end result is usually that any parameters present in the function call get pushed onto the stack prior to a call being made to the appropriate subroutine. I say *usually* because there are some qualifying conditions with Lattice/SAS C because it allows register arguments to be used rather than the stack and in this case it is an @ character, rather than an underscore, which gets placed at the start of the function name.

From a practical viewpoint you, the mixed-code programmer, will have two tasks – writing the high-level C code which will take you out of C and into your assembler module, and writing the 68000 patch itself.

Writing the appropriate C code is easy – it simply involves placing suitably named function calls, with any required parameters, into the C source. This is done using normal C function conventions – you can even add your own ANSI C function prototypes to make sure that the compiler makes the appropriate usage and parameter-type checks!

The next step involves writing suitable assembly language code and assembling it to produce linkable object code. The assembler directives XDEF and XREF have to be used to get things running smoothly.

XDEF and XREF

We've already covered these assembler directives but let's go over the details once more for good measure. XDEF is used to define assembly language labels as being visible to other modules at link time. If you forget it, the assembly stage will go OK but you'll get errors when linking because the linker will be unable to resolve the corresponding function reference in the C code module.

XREF goes the other way, ie it tells the assembler that the information needed about the item in question will be imported when the assembly language module is linked. If you forget these then you'll get errors as soon as you try to assemble your code because the assembler will not realise that labels have been used whose values are unknown at assembly time.

Most assembler's place a limit on the number of characters within a label that will be regarded as significant and the ANSI C compiler standard actually only requires that the compiler caters for six characters with external references (although most handle more). The consequence of this is that you can, and it has happened to me many times, think you've got all of your inter-module references right but because a label gets truncated you end up with unexpected linker errors. Luckily this is never a serious problem and having, perhaps rather unwisely, used a variable such as:

```
my_variable_with_an_extremely_long_name
```

only to find that the linker tells you that it cannot resolve a reference called:

```
_my_variable_wi
```

it doesn't take too long to realise where the problem lies. The moral here is that it pays to be a pessimist. Either check the manuals first, or don't use long names for functions and variables whose references might need to be passed between modules. Manx's Aztec C incidentally offers #asm and #endasm statements which allow assembler code to be embedded within the C source. This can be useful on occasions but, in general, I believe it is safer to always place any assembler code into a separate module.

Specific SAS/Lattice C Conventions

These are the *Function Entry* rules. Upon entry to a function the stack, under conventional parameter passing conditions, contains the function arguments placed immediately above the long-word return address which register A7 (the stack pointer) points to. The arguments are pushed in right-to-left order and so it is the leftmost parameter which is the one immediately above the return address.

Here are some standard function entry steps which need to be carried out:

1. Save register a5, which contains the previous functions stack frame pointer. The best idea is to push it onto the stack!
2. Copy the contents of a7 into a5, thereby establishing a frame pointer for the current function which allows you to access the arguments indirectly using the a5 base value.
3. Subtract any stack work area needed from a7.

These steps can, if the work area required is less than 32K, be achieved with the 68000's link instruction. Lattice/SAS expects registers d2-d7,a2-a4 and a6 to be intact on return so, if any of these registers are to be used, they must be preserved. Again it is common practice to place them on the stack. The above stack orientated procedure forms the basis of a powerful general parameter passing technique which is well worth studying.

Function return values are passed back in one or more registers, depending on the data type declared for the function in question. Here are the return value details that must be adhered to:

Return Type	*Size*	*Pass Back Details*
char	8	low byte of d0
short	16	low word of d0
long	32	all of d0
float	32	all of d0
pointer	32	all of d0
double (IEEE)	64	passed in d0 and d1 with high bits in d0
double (FFP)	32	all of d0

If, incidentally, the function returns an instance of a structure or union (as opposed to a pointer to the object) then it must define a static work area, *not* on the stack, to temporarily hold the returned object. In these cases the function should return a pointer to the temporary copy in d0. Having set up the required return value the routine needs to reverse its entry steps, restoring the registers, advancing the a7 stack pointer past the work area, and restoring the previous frame pointer to a5, before exiting via a rts instruction. As mentioned in Chapter Four, the 68000 has an unlink (unlk) instruction specifically intended to simplify these operations. Note incidentally that it is the job of the *calling* function, and not the *called* function, to remove any arguments from the stack.

Aztec C Conventions

The Manx Aztec compiler exports the name of a function or variable by truncating the name to 31 characters and prefixing the underscore character as mentioned earlier. The function entry rules, which are similar to Lattice/SAS, are as follows. Upon entry to a function the stack again contains the function arguments placed immediately above the long-word return address, which register a7, the stack pointer, points to. The Aztec arguments appear in the same order as with Lattice/SAS C, ie the leftmost function argument will be the one immediately above the return address.

The Aztec technical manual says that register usage is implemented according to the Amiga guidelines so all used registers except for d0, d1, a0 and a1 must be stored and reinstated before the assembly language routine returns. However in the *Assembler* section, the manual states that registers d0-d3, a0, a1 and a6 are available as *work registers* and follows this statement by saying that "There is no need to preserve the values of work registers for other routines". I have not done much Aztec experimentation but I'd recommend sticking to the former, more restrictive convention, until you hear otherwise – it works and it is definitely safe!

In-line, ie embedded, assembler code must also preserve the contents of the non-scratch registers, ie all except d0, d1, a0 and a1, and in addition should of course *not* make any assumptions about the contents of the processor registers because the code that the compiler currently generates for particular C statements might well change in later releases. The Manx Aztec function return conventions, incidentally, again use the d0 and d1 data registers.

Some Examples

If all the references and directives in the above stages are correct the rest is easy. The C source is compiled, the assembly language code assembled, and then the modules are linked together with the startup-code to produce a runable program. Before discussing the 68000 code a short recap on the EOR function may be useful.

Exclusive-ORing, more commonly known as EOR, is a logical operation that is carried out on pairs of bits or bytes and works like this. The corresponding bits in each of the bit pattern are compared and if they are different then the result is a 0 value. If the bits are the same, ie either both bits are set to 0 or both are set to 1, then the result is a 1 value. The truth table for EOR operation therefore looks like Figure 16.1.

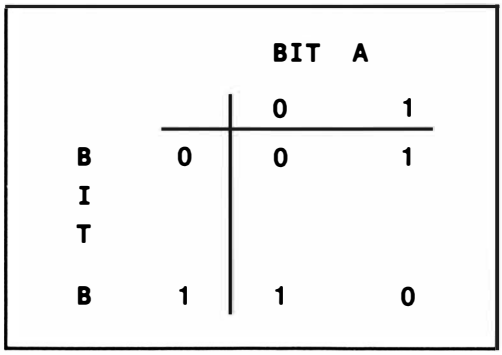


Figure 16.1. Exclusive-OR truth table.

For example: The result of exclusive-ORing 8F hex with 09 hex is 86 hex which is worked out as in Figure 16.2.

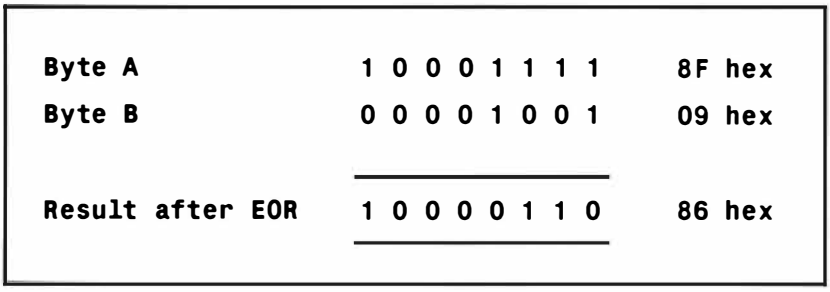


Figure 16.2. Exclusive-ORing 8F hex with 09 hex.

Exclusive-ORing is an operation which, when performed twice on a byte using the same EOR masking value, produces the original byte back again. Try it and see. This has led to the EOR operation being regularly used for simple encryption and decipher schemes. Take a piece of text, Exclusive-OR all the bytes with some mask value and the result will not be immediately obvious as a piece of text. Carry

out the same process again with the same encryption key, ie the same EOR mask, and the original text will be produced. Get the key wrong and it won't!

My initial CLI/Shell examples perform similar processes. Each asks the user to type in a string, and then calls an assembly language routine called Convert(). The assembler routine performs an Exclusive-ORing (EOR) of all bytes in the string which are neither the NULL terminator nor equal to the mask value itself, thus protecting C's definition of a string by ensuring that we don't produce any NULL values within the body of the string. Having done that the program prints the modified string, repeats the Convert() process and prints it again. The second EORing process does of course result in the original input string being produced.

Where the coding differs is that in the first example the assembler routine is directly accessing the global variables g_input_string and g_EOR_mask present in the C source code. In the second example these variables are *not* global, and both the start of the string and the EORmask value are given to the assembler routine as parameters, ie the values are provided as arguments during the Convert() call. This means that in the second example we have to get those arguments from the stack. Here's the run down on what has happened just prior to entering our assembly language patch. The arguments will have been pushed onto the stack followed by the return address. My second assembler patch uses a LINK a5,#0 instruction which pushes the contents of a5 onto the stack as well. The result? To access the two arguments of the C function we've had to use positive offsets of 8 and 12 respectively. See Chapter Four for details of link/unlk instruction usage.

Before you examine the source listings some points should be made. To start with you will notice in the pieces of assembler code provided that only the scratch registers a0 and d0 are used. This means that, for the examples, it is not necessary to preserve register contents on the stack. Despite this, in the second of the assembler patches I have included some movem instructions to save and restore data registers d2-d7. Why? It's just so that you can see exactly whereabouts in the code those push/pull operations would be carried out had registers d2-d7 actually been in use.

```
/* ------------------------------------------------------------ */
/* Example 16-1.c - uses Exclusive ORing patch via GLOBAL
                                                    variables */
#include <exec/types.h>
#include <stdio.h>
#define MESSAGE1   "Please enter a string\n"
#define MESSAGE2   "Converted string is..........."
#define MESSAGE3   "String after 2nd conversion..."
#define LINEFEED   10
#define MAX_CHARS  80
#define EOR_MASK   0x1F
TEXT g_input_string[MAX_CHARS+1]; /* space for the user's
                                                    string */
UBYTE g_EOR_mask=EOR_MASK; /* Exclusive-ORing conversion mask */
main()
{
WORD keyboard_character; UBYTE count=0;
printf(MESSAGE1);
while ((keyboard_character=getchar())!=LINEFEED)
     {
     if (count<=MAX_CHARS) g_input_string[count++]=
                                        keyboard_character;
     };
g_input_string[count]=NULL;          /* add terminal NULL */
Convert();                           /* EOR the string */
printf("%s %s \n",MESSAGE2,g_input_string);   /* show user
                                                 converted string */
Convert();                           /* 2nd EOR operation */
printf("%s %s \n",MESSAGE3, g_input_string); /* show string
                                                 again */
}
/* ------------------------------------------------------------ */


*  ------------------------------------------------------------  *
* Example 16-1.s assembler patch without argument passing      *
*  ------------------------------------------------------------  *
*a0 is loaded with the starting address of the input string
     XDEF _Convert
```

```
     XREF _g_input_string
     XREF _g_EOR_mask
* ------------------------------------------------------------ *
_Convert       move.l    #_g_input_string,a0   start of string
               move.b    _g_EOR_mask,d0        get mask value
               subq.l    #1,a0
* ------------------------------------------------------------ *
CONVERT_LOOP:  addq.l    #1,a0                 move to next byte
               tst.b     (a0)                  check it
               beq       FINISH      quit if NULL terminator
               cmp.b     (a0),d0          will it EOR to NULL ?
               beq       CONVERT_LOOP     if YES don't EOR it
               eor.b     d0,(a0)          safe to convert
               bra       CONVERT_LOOP          keep going
* ------------------------------------------------------------ *
FINISH         rts                             back to C
* ------------------------------------------------------------ *

/* ------------------------------------------------------------ */
/* Example 16-2.c - with parameter driven Exclusive ORing patch */
#include <exec/types.h>
#include <stdio.h>
#define MESSAGE1 "Please enter a string\n"
#define MESSAGE2 "Converted string is....."
#define MESSAGE3 "String after 2nd conversion..."
#define LINEFEED 10
#define MAX_CHARS 80
#define EOR_MASK 0x1F

main()
{
TEXT input_string[MAX_CHARS+1]; /* space for the user's string */
UBYTE EOR_mask=EOR_MASK; /* Exclusive-ORing conversion mask */
WORD keyboard_character; UBYTE count=0;
printf(MESSAGE1);
while ((keyboard_character=getchar())!=LINEFEED)
```

```
    {
    if (count<=MAX_CHARS) input_string[count++]=
                                          keyboard_character;
    };
input_string[count]=NULL;       /* add terminal NULL */
Convert(input_string, EOR_mask);     /* EOR the string */
printf("%s %s \n",MESSAGE2,input_string); /* show user
                                        converted string */
Convert(input_string, EOR_mask);     /* 2nd EOR operation */
printf("%s %s \n",MESSAGE3, input_string); /* show string again */
}
/* ------------------------------------------------------------  */

*  ------------------------------------------------------------  *
* Example 16-2.s assembler patch with argument passing          *
      XDEF   _Convert
*  ------------------------------------------------------------  *
_Convert     link a5,#0              don't need any workspace
             movem.l  d2-d7,-(sp)    normally where we save
             move.l   12(a5),d0      retrieve mask value
             move.l   8(a5),a0       retrieve string pointer
             subq.l   #1,a0
*  ------------------------------------------------------------  *
CONVERT_LOOP: addq.l  #1,a0          move to next byte
              tst.b   (a0)           check it
              beq     FINISH         quit if NULL terminator
              cmp.b   (a0),d0        will it EOR to NULL ?
              beq     CONVERT_LOOP   if YES don't EOR it
              eor.b   d0,(a0)        safe to convert
              bra     CONVERT_LOOP   keep going
*  ------------------------------------------------------------  *
FINISH        movem.l (sp)+,d2-d7    normally where we restore
              unlk    a5
              rts                    back to C
*  ------------------------------------------------------------  *
```

A Flashy Example

This last example is more advanced and has really only been included so that you can see something of the tricks that can be done with mixed code programming. It involves creating a pair of 68000 patches to create messages which flash, like the famous Amiga Guru alert. Creating flashing text on the Amiga is a relatively simple job because of the Amiga's colour indirection scheme. As you already probably know the screen *colours* present on a display aren't colours at all, they are references to colour registers, which is where the *indirection* comes in. By changing the values in these registers the effective, ie visible, colours present on the display can be changed without any additional screen manipulation effort. What we need to do therefore to create a flashing colour is to arrange to alternate the value in some particular colour register.

Now a program using such flashing facilities would not, or certainly should not, want to get involved with the task of continuously changing values in a colour register itself. The best idea, since it is not a particularly time consuming task, is to create a piece of code which is executed automatically and one way of doing this is via the interrupts.

Interrupt processing on the Amiga is a bit of a grey area especially since a lot of the early Amiga technical information verged on the misleading. At the Exec system level, two types of arrangements are available: interrupt handlers, and interrupt servers. Exec servers allow particular interrupt signals to be shared, so a number of quite independent routines can be tied to the same interrupt. In the case of my assembler code example, I am using the Exec server mechanism to modify a colour register value during selected vertical blanking intervals.

The Exec library offers a couple of system routines, called AddIntServer() and RemIntServer(), which allow sections of code to be added or removed from the interrupt chain in a system compatible fashion. These routines, which are documented in the Addison Wesley *Includes and Autodocs* RKM manual, take this form:

```
AddIntServer(interrupt_number, interrupt_pointer)
RemIntServer(interrupt_number, interrupt_pointer)
register usage      d0                  a0
```

The interrupt number for the vertical blank interrupt is 5, but for clarity it's best to use the include file symbolic value INTB_VERTB.The second parameter is a pointer to a system Interrupt structure, which to a C programmer looks like this:

```
struct Interrupt
       {
       struct Node     is_Node;
       APTR            is_Data;
       VOID            (* is_Code)();
       };
```

The equivalent assembler include file definition uses a value LN_SIZE to provide an offset equivalent to an Exec Node structure:

```
 STRUCTURE  IS,LN_SIZE
   APTR     IS_DATA
   APTR     IS_CODE
   LABEL    IS_SIZE
```

Exec uses these types of data blocks to provide a list of jobs which must be done when the interrupt occurs. As can be seen from the above fragments, part of the Interrupt structure includes a Node structure. In C this looks like this:

```
struct Node
      {
      struct Node *ln_Succ;  /* pointer to successor node */
      struct Node *ln_Pred;  /* pointer to predecessor node */
      UBYTE  ln_Type;        /* set this to NT_INTERRUPT */
      BYTE   ln_Pri;         /* can be set from +128 to -127 */
      char   *ln_Name;       /* NULL terminated string pointer */
      };
```

But for the assembler programmer the system STRUCTURE macro again comes to the rescue and allows this definition to be created:

```
 STRUCTURE  LN,0
   APTR     LN_SUCC
   APTR     LN_PRED
   UBYTE    LN_TYPE
   BYTE     LN_PRI
   APTR     LN_NAME
   LABEL    LN_SIZE
```

Several points are worth mentioning. Firstly, the Node's type, priority and name fields have to be provided. Secondly, the IS_CODE pointer must contain the address of your interrupt routine. Another rather important point is that you do *not* use rte instructions at the end of the routine – server chain interrupt code sections need to be written as subroutines ending in a rts! One last point concerns the IS_DATA field; this is available for convenience and Exec will pass anything you place in this field directly to the interrupt routine. How? It copies the field into the 68000's a1 address register so it is ready and waiting as the interrupt code is entered.

Given a suitable piece of code, and the properly initialised Interrupt node structure, the installation is surprisingly easy and just involves using the AddIntServer() routine. Before exiting the program can use a RemIntServer() call to take the job out of the vertical blanking server chain.

For this example I've put three pieces of code on disk. Firstly, there is the assembler source code which handles the setting up and closing down of the flashing interrupt. This is just a short example which modifies the contents of colour register 7. Depending on your needs, it shouldn't be too difficult to modify the routine to suit your own purposes. Secondly, I've included the source code for a skeleton C program which handles all the mundane Intuition screen/window opening, menu creation etc. Within this code you'll see a couple of calls to my assembly language routines. FlashOn() installs my interrupt job in the server chain, FlashOff() does the opposite, ie it removes it. Lastly, I have included a Workbench/CLI runable example which allows you to turn a *flashing text* display on and off via a menu.

Here to finish with is a listing of the assembler code. Since it was written using HiSoft's Devpac assembler I've left it in Devpac form to illustrate the use of the CALLEXEC and CALLGRAF (Devpac specific) macros. Users without Devpac will need to convert those macro calls by inserting the equivalent CALLSYS macro and specifying the appropriate library base. For instance the macro expression CALLGRAF SetRGB4, should be changed to CALLSYS SetRGB4, GfxBase:

```
* ------------------------------------------------------------------
* Example CH16-3.s Flashing assembler patch (written with Devpac)
* ------------------------------------------------------------------

            include   exec/types.i
            include   exec/exec_lib.i
            include   exec/interrupts.i
            include   hardware/intbits.i
            include   graphics/graphics_lib.i
DELAY       EQU       8
PRIORITY    EQU       0
            XDEF      _FlashOn
            XDEF      _FlashOff
            XREF      _GfxBase
            XREF      _g_viewport_p
            XREF      _colourtable
* ------------------------------------------------------------------
* Preserve a6, get colours and then set up the interrupt server
* node before adding to existing vertical blanking jobs.
* Structure is already defined in include files, so we can use
* the pre-calculated offsets...
_FlashOn:   movem.l   a6,-(a7)          preserve
            move.l    #_colourtable,a1
            move.w    14(a1),d0         get colour
            move.w    d0,d1             copy colour
            andi.w    #$0F00,d1         isolate red
            lsr.w     #8,d1
            move.b    d1,red
            move.b    d0,d1             copy colour
            andi.b    #$00F0,d1         isolate green
            lsr.b     #4,d1
            move.b    d1,green
            move.b    d0,d1             copy colour
            andi.b    #$000F,d1         isolate blue
            move.b    d1,blue
            move.l    #server_node,a1   base address
```

```
            move.b   #NT_INTERRUPT,LN_TYPE(a1)
            move.b   #PRIORITY,LN_PRI(a1)
            move.l   #_colourtable,IS_DATA(a1)
            move.l   #FLASH_CODE,IS_CODE(a1)
            moveq.l  #INTB_VERTB,d0     server node already in a1
            CALLEXEC AddIntServer       install
            movem.l  (a7)+,a6           restore
            rts                         quit
* ---------------------------------------------------------------------
            cnop     0,4
_FlashOff:  movem.l  a6,-(a7)           preserve
            move.l   #server_node,a1
            moveq.l  #INTB_VERTB,d0
            CALLEXEC RemIntServer

            movem.l  (a7)+,a6           restore
            rts                         quit
* ---------------------------------------------------------------------
FLASH_CODE: movem.l  d2-d3/a6,-(a7)     preserve registers
            subq.b   #1,count
            bne      FC1
            move.b   #DELAY,count
            bchg     #0,switch          alternate value
            beq      CLEAR_REG

SET_REG:    move.b   red,d1             prepare colours
            move.b   green,d2           for RGB4() call
            move.b   blue,d3
            bra      FC0
CLEAR_REG:  clr      d1                 clear colours
            clr      d2                 for RGB4() call
            clr      d3
FC0:        move.l   #7,d0              colour reg 7
            move.l   _g_viewport_p,a0
            CALLGRAF SetRGB4            reset colour
FC1:        movem.l  (a7)+,d2-d3/a6     restore registers
```

```
            moveq.l  #0,d0              set Z flag
            rts
*  ------------------------------------------------------------------
server_node ds.l     IS_SIZE            static declaration
count       dc.b     DELAY
red         ds.b     1                  space for storing
green       ds.b     1                  separated colour
blue        ds.b     1                  values
switch      ds.b     1                  boolean flash switch
*  ------------------------------------------------------------------
```

Complexity Threshold

By the time you have got to this part of the book you will doubtless have had quite a bit of Amiga programming experience and, if you are anything like the rest of us, you may be feeling a little technologically *punch drunk*. This isn't that surprising because the Amiga system and its documentation, both in physical size and complexity, stops many would-be Amiga programmers dead in their tracks. The fact of the matter is that complexity-wise the Amiga presents a whole new ball game and one look at the contents of the official Addison Wesley Amiga reference manuals is more than enough to tell you that things have changed considerably from the good old *eight bit* days.

Coping with thousands of pages of documentation, especially since they are coupled to complex hardware and very sophisticated O/S ideas, is quite a daunting prospect even to the pros. The important point to bear in mind is, of course, that you do not have to learn about everything at once!

The best idea is to adopt the same principles as the programmers who work with mainframes – they don't memorise everything, they just develop an understanding of (some would say a sympathy with) the system they use. Having said that, most will still spend as much time as they can reading the manuals, but what they are primarily trying to do is build up an overview, ie a general picture, of the system as a whole. It is this familiarity with both the general working of the system as a whole, and with the documentation, that makes it easy for them to get hold of information as and when they need it.

If you ask the average professional Amiga programmer what an AmigaDOS Process structure looks like, or what numerical value is assigned to Intuition's GADGETUP flag, they are unlikely to know, or particularly care in the latter case. But one thing is certain: they *will*

know where to find out! Many programmers will specialise in graphics, sound, comms etc, and if you ask a graphics specialist how you set up the Amiga's serial port for high-speed MIDI transmission the chances are odds on that they won't be able to tell you. Given some time and the necessary documentation however they will come across with the goods. Experience with the machine is important but all professional Amiga programmers will tell you the same thing, that access to decent technical information comes extremely high on the list of priorities. The first piece of parting advice is simply this: Do not even think about trying to enter the world of serious Amiga programming without getting the official documentation – it really is worth its weight in gold. What you may also need, because the official manuals are written primarily for professional programmers, are other books (such as this one) which attempt to explain some of the issues using a softer, tutorial style, approach.

I've had the chance to see a lot of Amiga code that has been written by programmers in their *early Amiga system days*, and of course I also have walked into many *technical snags* as I became Amiga system literate. As far as common pitfalls are concerned however, two things have stuck in my mind.

Firstly, a lot of programmers have come up via the route which involved hacking the eight bit Commodore 64, Sinclair ZX81 and the like and have tried to adopt the same *suck it and see whilst you type* approach on the Amiga. Basically it's not possible to just sit down at the keyboard and start writing Amiga programs because they tend to be too large and too complex to tackle in that way. You have to decide what you want to do, plan, design, code and then test your program carefully. You also have to implement your ideas in a way which follows the rules which the multi-tasking Exec imposes on all Amiga programs, except those which take over the machine completely. This means you will need to take an interest in program design as an integral part of code preparation. For the Amiga programmer such ideas are not useful extras – a systematic approach is a necessity. This book was not the place to deal with program design issues but I was at least able to outline the sort of techniques I use.

Secondly, the complexity issues themselves, as always, are relative not absolute. If you have studied computer science at school or college, or have worked with a multi-tasking computer system before, then you will have less to learn because many concepts will already be familiar. Similarly, if you've used languages like Pascal (which uses records in much the same sort of way that C uses structures) some language transition problems will be less troublesome. If, because of prior experience, the Amiga road seems

relatively straightforward then be thankful. If you are still struggling then be patient and don't worry – almost everyone who has ever sat down to learn about the Amiga system will have had, at some time or other, to cope with exactly the same difficulties.

With a system as complex as the Amiga we are getting to the point where even the professionals will admit that they'll never learn all there is to know about the Amiga. My advice? Don't worry about the amount of material that needs to be understood – at any one time concentrate only on those aspects related to the project which you are currently involved with. In other words adopt a *need to know* policy to guide your path through the system documentation. Above all, enjoy the challenge because, as I've said before, it is undoubtedly good for the soul!

17: The 68000 Instruction Set

The complete range of 68000 instructions can be roughly divided into the following classes:

- Data Movement instructions
- Flow Control (Jump, branch type) instructions
- Logical, shift and rotate type instructions
- Bit manipulation instructions
- Arithmetic instructions.

I mentioned right at the beginning of the book that just to list the full details of the 68000 instruction set would take a book in itself. This being so the details that follow are just a summary of the main instructions with a few notes about their uses, the addressing mode restrictions, flag effects and so on. Some examples are provided but in most cases you will find the most complete discussions of usage in the main text of the book.

Many 68000 instructions can work with byte, word and long word operands. Byte size values will not however be allowed if the destination or source operand is an address register. There are incidentally a number of instructions which can only be used in 68000 Supervisor mode. You'll see a number of these mentioned (mainly for completeness) but for full details of these instructions, and discussions of other

issues such as 68000 trap handling which have not been dealt with in this book, you are referred to the references given in the bibliography.

Effective Address

Motorola 68000 literature uses the term *effective address* to refer to the address that the processor ultimately uses and of course for instructions which identify an operand, do something, and then store a result, there will be an effective source address and an effective destination address. Usually the context of the instruction will make it easy to identify these separate entities. When a general effective address needs to be stated, as opposed to a specific addressing mode description, it is common practice to use the term <ea>.

Op-Codes

The part of the binary machine code instructions which holds the real *68000 understandable* information as to what operation the processor should perform, is known as the operation code or *op-code* part of the instruction.

Sign Extension

Some 68000 instructions sign-extend byte or word data, ie they propagate the sign bit (bit 7 in the case of byte data or bit 15 for word sized operands) to produce a 32 bit value.

Notes on An/Dn Name Conventions

When talking generally about address registers and data registers it is common practice to use the terms An and Dn to indicate *any* address register or *any* data register.

68000 Addressing Modes

One of the most powerful features of the Motorola 68000 device is the rich variety of addressing modes that is available. Most processor instructions work on a piece of data, called the operand, and this data has to be stored somewhere. Many instructions will use some real or implied source address (the effective source address), do something, and then transfer the result to some destination address (the effective destination address). In short, the processor's addressing modes enable these source and destination addresses to be specified. Here's the rundown on the basic 68000 addressing schemes.

Inherent Addressing

This is one of the addressing modes which does not involve the specifying of memory locations because the processor will know from the instruction op-code which addresses it should use. The 68000's return-from-subroutine, rts, instruction for instance *inherently knows* that the stack pointer register is to be used to move data to and from memory. The details are built into the instruction itself. This is why the programmer does not need to specify an addressing mode for rts, and why none are listed.

Register Addressing

This is perfectly straightforward to explain. Register addressing simply means that the operands reside in the processor's register and so no memory address information is needed. The 68000's exchange, EXG, instruction is one example of register addressing. The official documentation splits register addressing into data and address register addressing but for most practical purposes the distinction is neither here nor there.

Immediate Addressing

Another straightforward mode where the data in question, ie the operand itself, is placed immediately after the instruction op-code in memory. In other words the effective address will be the value of the program counter after the op-code part of the instruction has been fetched. The Motorola 68000 has long word, word and byte orientated immediate instructions but in the latter case the immediate data still gets stored as a word. The byte data is placed in the low-order part of the word and the upper byte is set to all zeros.

Absolute Addressing

This mode is also called direct addressing and actually consists of two schemes. With absolute long addressing the effective address used by the processor is the address contained in the four bytes (ie the long word) which follows the op-code and so this scheme can be used to address any memory location within a 32 bit addressing range.

A word (two-byte) addressing scheme known as absolute short addressing is also available and here only the lower 16 bits of an address need be specified – the upper half of the address is obtained by sign-extending bit 15 of the specified short address. This mode is quicker and more memory efficient than absolute long addressing but of course only addresses in the lower and upper 32K of address space (0000000 hex to 00007FFF hex and FFFF8000 hex to FFFFFFFF hex) can be specified in this way.

Address Register Indirect Addressing

Here the address of the operand is held in an address register and so this scheme is not the same as conventional *indirect addressing*, where the address of the operand is held in a memory location. Register indirect addressing is nevertheless a very powerful addressing mode and is indicated by placing parentheses around the register name. For example the instruction move.b (a2), d0 will copy the contents of the byte whose address is in register a2 into register d0.

Address Register Indirect with Displacement

This mode allows a fixed, but programmer defined, constant value to be added to the indirectly specified address. The displacement itself gets stored immediately after the op-code in memory and the effective address used by the processor will be the sum of the contents of the address register and the specified displacement. For example the instruction move.b 20(a2), d0 will copy the contents of the byte whose address is formed by *adding 20 to the address in register a2* into register d0.You will find a great many examples of this addressing mode within this book especially for storing and retrieving items from Amiga system defined structures.

Address Register Indirect with Postincrement

This mode provides for the automatic incrementing of a specified address *after* it has been used. Byte, word and long word sizes may be specified and the processor will increment the address by 1, 2 or 4 accordingly. The mode is specified by placing a plus sign after the normal indirect addressing scheme. For example, the instruction move.b (a2)+, d0 will copy the contents of the byte whose address is in register a2 into register d0 and, having done that, the contents of address register a2 will automatically be incremented by 1. This mode is convenient for handling lists of byte, word and long word values.

Address Register Indirect with Predecrement

This mode is similar to the above but it provides for the automatic decrementing of a specified address *before* it has been used. Again byte, word and long word sizes may be specified and the processor will decrement the address by 1, 2 or 4 accordingly. The mode is specified by placing a minus sign before the normal indirect addressing scheme. For example, the instruction move.b -(a2), d0 will copy the contents of the byte whose address is in register a2 into register d0 and, having done that, the contents of address register a2 will automatically be decreased by 1. This mode is convenient for handling lists of byte, word and long word values. Chapter Four outlines the reasons why the addresses are decremented before use and, in the case of the previous mode, incremented after use.

Address Register Indirect with Index and Displacement

This is another useful, but initially confusing, 68000 addressing mode. The effective address is the sum of three separate addresses. An address register specified indirect address, an *index* value held in an address or data register (long or word values may be specified), and a programmer defined constant displacement. The Motorola assembly language syntax for this addressing mode requires that the displacement is specified as with the basic register indirect addressing scheme but that the address register itself, and the index register, be enclosed within parentheses. The address register should be specified first, and the two enclosed items must be comma delimited. This is best illustrated by example and the instruction:

```
move.l 20(a0,d0.l), d2
```

for instance, forms an effective source address by taking the contents of register a0, adding the full 32 bit contents of register d0, and then adding 20 to the resulting address. In the case of the example statement the operand is retrieved from that address and placed in register d2.

Program Counter Relative with Displacement

Addressing modes that use offsets from the program counter, as opposed to absolute addresses are known as relative addressing modes. It's the microprocessor equivalent of you giving someone a friend's address by saying *they live six doors further up* rather than saying *they live at number 230*. The 68000 branch instructions automatically use relative addressing but many instructions allow explicit use of relative addressing with the option to include a displacement value. This mode, which we've not been too concerned with in this book, is equivalent to the *address register indirect with displacement* mode except for the fact that the program counter is used as the base register. It becomes useful when it is necessary to write truly position-independent 68000 code.

Program Counter Relative with Index and Displacement

Another addressing mode that has not concerned us in this book. In this case the basic relative addressing scheme is supplemented by both an address register or data register index value and a programmer-specified constant displacement. This mode is equivalent to the *address register indirect with index and displacement* mode except for the fact that the program counter is used as the base register. Again it becomes useful when it is necessary to write truly position-independent 68000 code.

Data Movement Instructions

Mnemonic: EXG – Exchange Registers		
Purpose: Exchanges the contents of two registers		
Addressing Modes:	Source	Destination
Data register direct	X	X
Address register direct	X	X
Flags affected: X N Z V C – – – – –		

Notes: This instruction does exactly what you'd expect – it swaps the contents of two registers.

Example:

	Before	After
`exg a1,d2`	**d1=00000001**	**d1=44445555**
	a1=44445555	**d1=0000001**

Mnemonic: LINK – Link and Allocate
Purpose: Creates temporary space on the stack
Flags affected: X N Z V C – – – – –

Notes: The source address register is pushed onto the stack, the stack-pointer (a7) is copied into the source and the destination is added to the stack-pointer. The destination-operand needs to be negative because the 68000-stack grows downward in memory. This instruction is dealt with in Chapter 4.

Mnemonic: UNLK – Unlink
Purpose: This reverses the link process
Flags affected: X N Z V C – – – – –

Notes: See Chapter Four for a discussion of how the unlk instruction is used.

Mnemonic: LEA – Load Effective Address		
Purpose: Loads an address register with a processor determined effective address.		
Addressing Modes:	Source	Destination
Data register direct		
Address register direct		X
Address register indirect	X	
Postincrement register indirect		
Predecrement register indirect		
Register indirect with displacement	X	
Register indirect with index	X	
Absolute Short	X	
Absolute Long	X	
PC relative with displacement	X	
PC relative with index	X	
Immediate		
Flags affected: X N Z V C – – – – –		

Notes: This instruction allows you to load an address register with an effective source address, ie the source address specified by virtue of a chosen addressing mode.

Example: The effective source address for the instruction:

```
lea new_window,a0
```

is the address of the location which has been labelled new_window. This is an example of absolute addressing.

Mnemonic: MOVE – Move Data from Source to Destination		
Purpose: Copies a source operand to specified destination		
Addressing Modes:	Source	Destination
Data register direct	X	X
Address register direct	X*	
Address register indirect	X	X
Postincrement register indirect	X	X
Predecrement register indirect	X	X
Register indirect with displacement	X	X
Register indirect with index	X	X
Absolute Short	X	X
Absolute Long	X	X
PC relative with displacement		
PC relative with index		
Immediate	X	
Flags affected: X N Z V C – Y Y 0 0		

Notes: You will find plenty of examples of move instructions within the chapters of this book. See the notes about the movea instruction and also be aware that address register direct addressing is *not* allowed if specified data size is byte!

There are a number of specialised move instructions which allow reading from and writing data to the whole status register or just the lower byte that holds the condition codes, allowing you to forcibly clear/set the N, Z, V, C and X flags. Some of these instructions are privileged in one or more members of the 680x0 family and you should consult the official 680x0 documentation for details.

Mnemonic: MOVEA – Move Address		
Purpose: Loads an address register with a value		
Addressing Modes:	Source	Destination
Data register direct	X	
Address register direct	X	X
Address register indirect	X	
Postincrement register indirect	X	
Predecrement register indirect	X	
Register indirect with displacement	X	
Register indirect with index	X	
Absolute Short	X	
Absolute Long	X	
PC relative with displacement	X	
PC relative with index	X	
Immediate	X	
Flags affected: X N Z V C – – – – –		

Notes: Only word or long word operands can be specified and if the operation is word-sized then the address is sign-extended. Most 68000 assemblers will accept move <ea>,An as well and the latter convention has been adopted in this book. You do however need to remember that when move is used to load an address register it is really a movea instruction and the flags are *not* affected.

Mnemonic: MOVEM – Move Multiple Registers to Memory		
Purpose: Copies multiple registers to memory		
Addressing Modes:	Source	Destination
Data register direct		
Address register direct		
Address register indirect		X
Postincrement register indirect		
Predecrement register indirect		X
Register indirect with displacement		X
Register indirect with index		X
Absolute Short		X
Absolute Long		X
PC relative with displacement		
PC relative with index		
Immediate		
Flags affected: X N Z V C – – – – –		

Notes: The main use of the instruction in this book has been for storing registers on the stack. For example:

```
movem.l d0-d7/a0-a6,-(a7)    push all registers onto the stack.
```

Mnemonic: MOVEM – Move Multiple Registers From Memory		
Purpose: Copies multiple registers from memory		
Addressing Modes:	Source	Destination
Data register direct		
Address register direct		
Address register indirect	X	
Postincrement register indirect	X	
Predecrement register indirect		
Register indirect with displacement	X	
Register indirect with index	X	
Absolute Short	X	
Absolute Long	X	
PC relative with displacement		
PC relative with index		
Immediate		
Flags affected: X N Z V C – – – – –		

Notes: The main use of the instruction in this book has been for retrieving registers from stack. For example:

```
movem.l (a7)+,d0-d7/a0-a6 pull    all registers from the stack.
```

Mnemonic: MOVEP – Move Peripheral Data
Purpose: To transfer data to or from a peripheral
Flags affected: X N Z V C – – – – –

Notes: This instruction has been specially designed for communication with devices which have been originally designed to work with 8-bit microprocessors.

Mnemonic: MOVEQ – Move Quick					
Purpose:	Copies immediate data to a specified data register				
Flags affected:	X	N	Z	V	C
	–	Y	Y	0	0

Notes: This instruction provides a quick (efficient) way to set a data register to a particular value which can be from -128 to +127 decimal. Most 68000 assemblers, given an immediate addressing move instruction, will generate moveq instructions where possible. For example:

	Before	After
`moveq #$58,d0`	`d0=ffffffff`	`d0=00000058`

Mnemonic: PEA – Push Effective Address		
Purpose: Pushes an address onto the stack		
Addressing Modes:	Source	Destination
Data register direct		
Address register direct	X	
Address register indirect		
Postincrement register indirect		
Predecrement register indirect		
Register indirect with displacement	X	
Register indirect with index	X	
Absolute Short	X	
Absolute Long	X	
PC relative with displacement	X	
PC relative with index	X	
Immediate		

Flags affected:	X	N	Z	V	C
	–	–	–	–	–

Notes: This instruction is often used to write position independent code. It provides a function similar to move.l <ea>,-(a7).

For example:

	Before	After
pea (a6)	**a6=12345678**	**a6=12345678**
	a7=44444444	**a7=44444448**

Mnemonic:	**SWAP – Swap Register Halves**
Purpose:	Exchanges upper and lower halves of a data register
Flags affected:	X N Z V C – Y Y 0 0

Notes: This instruction does exactly what you'd expect. For example:

	Before	After
swap d0	**d0=12345678**	**d0=56781234**

Flow Control Instructions

These instructions, as you will see from the main text, enable a programmer to create loops, if-then-else and case structure decisions and subroutines. They work by altering the contents of the program counter.

Mnemonic:	**Bcc – Branch Conditionally**
Purpose:	Transfers program control using relative addressing
Flags affected:	X N Z V C – – – – –

Notes: The branch data sizes may be byte or word so these instructions can branch in an area of 32K. When using a branch with a byte offset you can in fact put a .s (for short) suffix behind the instruction (eg beq.s HERE). Similarly when using a branch with a word offset you can use a .w suffix (eg beq.w HERE). Most assemblers will determine if the short or word form is needed automatically and will optimise word-branches to byte-branches whenever it is possible.

These instructions test a combination of the NZVC flags in the status register and conditionally perform a branch to another address. If the testing of the condition codes is true, then the branch is taken, otherwise the instruction immediately following the bcc instruction is executed.

Fourteen variations of this instruction are available and a related bra (branch always) instruction adds another condition to the testable set :

bcc: where cc stands for carry clear. The branch is taken if the carry (C) bit is 0. This instruction is often used in combination with shift and rotate operations.

bcs: where cs stands for carry set. The branch is taken if the carry (C) bit is 1.

beq: where eq stand for equal. The branch is taken if the zero (Z) bit is 1. This instruction, as we've seen many times within this book, is frequently used after tst and cmp type instructions.

bne: where ne stands for not equal. The branch is taken if the zero (Z) bit is 0. This instruction is of course the opposite of beq.

bpl: where pl stands for plus. The branch is taken if the negative (N) bit is 0.

bmi: where mi stands for minus. The branch is taken if the negative (N) bit is 1.

bvc: where vc stands for overflow clear. The branch is taken if the overflow (V) bit is 0. This instruction is often used in conjunction with arithmetic instructions like add, mul, and so on.

bvs: where vs stands for overflow set. The branch is taken if the overflow (V) bit is 1.

bge: where ge stands for greater or equal. The branch is taken when the negative (N) and overflow (V) bits contain the same value.

bgt: where gt stands for greater than. The branch is taken in cases where either N=1, V=1 and Z=0 or N=V=Z=0.

ble: where le stands for lower or equal. This branch is taken in cases where Z=1 or the N and V bits contain different values.

blt: where lt stands for less than. This branch is taken if the negative (N) and overflow (V) bits contain different values.

bhi: where hi stands for higher. This branch is taken if the negative (N) and overflow (V) bits contain the same value.

bls: where ls stands for lower or same. This branch is taken if the carry (C) and zezo (Z) bits contain different values.

bra: branch always – this instruction is commonly seen at the end of a loop to force control back to the top of the loop.

Mnemonic:	**DBcc – Test Condition, Decrement and Branch**
Purpose:	An automated decrement and branch loop instruction
Flags affected:	X N Z V C – – – – –

Notes: First the condition is tested and if satisfied the branch is not taken. Otherwise the specified data register is decremented and the branch only taken if Dn is -1. Data sizes may be byte or word so the instructions will branch in an area of up to 32K, thus providing an efficient way of creating many loops. There are 16 possible condition variations of this instruction and these are as per the bcc instructions except for the following two additions.

dbf or **dbra:**
An unsatisfiable condition allows the programmer to force a loop to only be terminated when the count value reaches -1.

dbt: Only performs a decrement on the specified data register. It *never* branches.

Chapter Three contains a discussion of this group of instructions.

Mnemonic:	**BSR – Branch to Subroutine**
Purpose:	Transfers program control to a subroutine
Flags affected:	X N Z V C – – – – –

Notes: See jsr notes below

Mnemonic: JSR – Jump to Subroutine		
Purpose: Transfers program control to a subroutine		
Addressing Modes:	Source	Destination
Data register direct		
Address register direct		
Address register indirect		X
Postincrement register indirect		
Predecrement register indirect		
Register indirect with displacement		X
Register indirect with index		X
Absolute Short		X
Absolute Long		X
PC relative with displacement		X
PC relative with index		X
Immediate		
Flags affected: X N Z V C – – – – –		

Notes: The bsr (branch to subroutine) and jsr (jump to subroutine) instructions are used for calling subroutines. The bsr form is a relative branch with a range of 32K. For subroutine calls beyond this range the jsr instruction should be used but, having said that, most assemblers would optimise jsr to bsr when possible because bsr is more efficient. When executing a bsr/jsr instruction, the 68000 pushes the program counter on the stack and then reloads it with the target address.

Mnemonic: RTS – Return From Subroutine					
Purpose:	Transfers control to a stack-retrieved address				
Flags affected:	X	N	Z	V	C
	–	–	–	–	–

Notes: In a sense this is the counterpart of the bsr/jsr instructions because it reloads the program counter register with the value on top of the stack. This value will usually have been put there by a bsr or jsr instruction.

Mnemonic: JMP – Jump		
Purpose: Transfers program control to a specified address		
Addressing Modes:	Source	Destination
Data register direct		
Address register direct		
Address register indirect		X
Postincrement register indirect		
Predecrement register indirect		
Register indirect with displacement		X
Register indirect with index		X
Absolute Short		X
Absolute Long		X
PC relative with displacement		X
PC relative with index		X
Immediate		

Flags affected:	X	N	Z	V	C
	–	–	–	–	–

Notes: This instruction is a variant of the move instruction but in this case the destination register, namely the program counter, is inherently defined. You could therefore just as easily use move.l (ea>,PC instead of jmp <ea>.

Mnemonic:	RTR – Return and Restore Condition Codes
Purpose:	Retrieves condition codes from stack and then transfers control to a stack-retrieved address
Flags affected:	X N Z V C Y Y Y Y Y

Notes: Similar to RTS but with rtr the condition codes are reloaded from the stack. This instruction comes in handy when the programmer doesn't want a subroutine to influence the condition codes. Before the jsr instruction you need to do a move.b ccr,-(a7) which pushes the ccr on the stack.

Logical Operations

Mnemonic:	AND – AND Logical	
Purpose:	Performs a boolean bitwise AND from source to destination and stores result in destination	
Addressing Modes:	Source	Destination
Data register direct	X	X
Address register direct		
Address register indirect	X	
Postincrement register indirect	X	
Predecrement register indirect	X	
Register indirect with displacement	X	
Register indirect with index	X	
Absolute Short	X	
Absolute Long	X	
PC relative with displacement	X	
PC relative with index	X	
Immediate	X	
Flags affected:	X N Z V C – Y Y 0 0	

Notes: There are two forms of this instruction. The above version uses a data register as the destination and all addressing modes except address register direct are allowed for the source. The second form uses a data register as the source. For example:

	Before	After
`and.b d0,d1`	`d0=33333333`	`d0=33333333`
	`d1=ffffffff`	`d1=ffffffcc`

Mnemonic: AND – AND Logical		
Purpose: Performs bitwise AND from a data register to a destination storing result in the destination		
Addressing Modes:	Source	Destination
Data register direct	X	X
Address register direct		
Address register indirect		X
Postincrement register indirect		X
Predecrement register indirect		X
Register indirect with displacement		X
Register indirect with index		X
Absolute Short		X
Absolute Long		X
PC relative with displacement		
PC relative with index		
Immediate		

Flags affected:	X	N	Z	V	C
	–	Y	Y	0	0

Mnemonic: ANDI – AND Immediate		
Purpose: Bitwise AND of immediate data source with destination		
Addressing Modes:	Source	Destination
Data register direct		X
Address register direct		
Address register indirect		X
Postincrement register indirect		X
Predecrement register indirect		X
Register indirect with displacement		X
Register indirect with index		X
Absolute Short		X
Absolute Long		X
PC relative with displacement		
PC relative with index		
Immediate	X	
Status register		X

Flags affected:	X	N	Z	V	C
	–	Y	Y	0	0

Notes: In addition to the more conventional register and memory usage the destination may be the condition codes or the whole of the 68000 status register. In the latter case the instruction is privileged. For example:

	Before	After
`andi.b #7,d0`	`d0=9999aaaa`	`d0=9999aaa0`

Mnemonic: EOR – Exclusive OR Logical		
Purpose: Performs bitwise Exclusive-OR from a data register to a destination storing result in the destination		
Addressing Modes:	Source	Destination
Data register direct	X	X
Address register direct		
Address register indirect		X
Postincrement register indirect		X
Predecrement register indirect		X
Register indirect with displacement		X
Register indirect with index		X
Absolute Short		X
Absolute Long		X
PC relative with displacement		
PC relative with index		
Immediate		

Flags affected:	X	N	Z	V	C
	–	Y	Y	0	0

Notes: This instruction, unlike the AND and OR instructions, can only take a data register as the source. For example:

	Before	After
`eor.l d4,d5`	`d4=ffffffff`	`d4=ffffffff`
	`d5=f0f0f0f0`	`d5=0f0f0f0f`

Mnemonic: EORI – Exclusive OR Immediate		
Purpose: Bitwise Exclusive-OR of immediate data source with destination		
Addressing Modes:	Source	Destination
Data register direct		X
Address register direct		
Address register indirect		X
Postincrement register indirect		X
Predecrement register indirect		X
Register indirect with displacement		X
Register indirect with index		X
Absolute Short		X
Absolute Long		X
PC relative with displacement		
PC relative with index		
Immediate	X	
Status register		X
Flags affected: X N Z V C – Y Y 0 0		

Notes: Destination may be condition codes or the whole of the 68000 status register. In the latter case the instruction is privileged. For example:

	Before	After
`eori.b #$ff,d6`	`d6=eeeeee30`	`d6=eeeeeecf`

Mnemonic: NOT – Logical Complement		
Purpose: Performs a bitwise complement of an operand		
Addressing Modes:	Source	Destination
Data register direct		X
Address register direct		
Address register indirect		X
Postincrement register indirect		X
Predecrement register indirect		X
Register indirect with displacement		X
Register indirect with index		X
Absolute Short		X
Absolute Long		X
PC relative with displacement		
PC relative with index		
Immediate		
Flags affected: X N Z V C – Y Y 0 0		

Notes: The instruction not.w An has the same effect as:

```
eori.w #$ffff,An.
```

Mnemonic: OR – Inclusive OR Logical		
Purpose: Performs bitwise OR from source to a data register		
Addressing Modes:	Source	Destination
Data register direct	X	X
Address register direct		
Address register indirect	X	
Postincrement register indirect	X	
Predecrement register indirect	X	
Register indirect with displacement	X	
Register indirect with index	X	
Absolute Short	X	
Absolute Long	X	
PC relative with displacement	X	
PC relative with index	X	
Immediate	X	
Flags affected: X N Z V C – Y Y 0 0		

Notes: There are two forms of this instruction. The above version uses a data register as the destination and all addressing modes except address register direct are allowed for the source. For example:

	Before	After
`or.l d0,d1`	`d0=ffffffff`	`d0=ffffffff`
	`d1=33333333`	`d1=ffffffff`

Mnemonic: OR – Inclusive OR Logical		
Purpose: Performs bitwise OR from data register to destination		
Addressing Modes:	Source	Destination
Data register direct	X	X
Address register direct		
Address register indirect		X
Postincrement register indirect		X
Predecrement register indirect		X
Register indirect with displacement		X
Register indirect with index		X
Absolute Short		X
Absolute Long		X
PC relative with displacement		
PC relative with index		
Immediate		

Flags affected:	X	N	Z	V	C
	–	Y	Y	0	0

Mnemonic: ORI – Inclusive OR Immediate		
Purpose: Performs bitwise OR using immediate data source		
Addressing Modes:	Source	Destination
Data register direct		X
Address register direct		
Address register indirect		X
Postincrement register indirect		X
Predecrement register indirect		X
Register indirect with displacement		X
Register indirect with index		X
Absolute Short		X
Absolute Long		X
PC relative with displacement		
PC relative with index		
Immediate	X	
Status register		X

Flags affected:	X	N	Z	V	C
	–	Y	Y	0	0

Notes: Destination may be condition codes or the whole of the 68000 status register. In the latter case the instruction is privileged. For example:

```
                    Before          After
ori.b #ff,d0        d0=efefefef     d0=efefefff
```

Shift and Rotate Operations

A whole range of logical and arithmetic shifts and rotate instructions are available on the 68000 processor. The following examples are just a selection.

Mnemonic:	**ASL – Arithmetic Shift Left in Data Register**				
Purpose:	Left shifts the contents of a data register				
Flags affected:	X	N	Z	V	C
	Y	Y	Y	Y	Y

Notes: This instruction arithmetically left shifts the contents of the data register so that the carry (C) and extend (X) flags receive the last bit shifted out. The shift count may be specified either by another data register or by immediate data and, in the latter case, a shift count in the range 1-8 may be specified. When a data register is used, counts in the range 0-63 are allowed.

ASL instructions can be used as a fast form of multiplying an operand by a power of two. The lower bit of the destination is always set to zero. For example:

	Before	After
`asl.l #4,d1`	`d1=0000000f`	`d1=000000f0`

Mnemonic: ASL – Arithmetic Shift Left in Memory		
Purpose: Left shifts the contents of a memory location		
Addressing Modes:	Source	Destination
Data register direct		
Address register direct		
Address register indirect		X
Postincrement register indirect		X
Predecrement register indirect		X
Register indirect with displacement		X
Register indirect with index		X
Absolute Short		X
Absolute Long		X
PC relative with displacement		
PC relative with index		
Immediate		
Flags affected: X N Z V C Y Y Y Y Y		

Notes: This form of the instruction is restricted to a one-bit shift and can only be used for word sized operands.

Mnemonic: ASR – Arithmetic Shift Right
Purpose: Right shift contents of data register or memory
Addressing Modes: Two versions as per ASL
Flags affected: X N Z V C Y Y Y Y Y

Notes: This instruction arithmetically shifts the bits of the operand to the right and, as with the ASL instruction, two forms exist. One version allows an operand in a data register to be shifted by a count

value specified either in a data register or as immediate data, the second version allows a one-bit shift of a word operand contained in memory.The shifted out low-order bit goes into the carry (C) and extend (X) flags and, at the other end of the operand, the sign bit is always repeated. ASR can be used as a fast form of dividing an operand by a power of two.

Mnemonic:	**LSL – Logical Shift Left**				
Purpose:	Left shift contents of data register or memory				
Addressing Modes:	Two versions as per ASL				
Flags affected:	X	N	Z	V	C
	Y	Y	Y	Y	Y

Notes: This instruction is identical to ASL and likewise exists in two forms.

Mnemonic:	**LSR – Logical Shift Right**				
Purpose:	Right shift contents of data register or memory				
Addressing Modes:	Two versions as per ASL				
Flags affected:	X	N	Z	V	C
	Y	Y	Y	Y	Y

Notes: This instruction also exists and is similar to ASR except for the fact that the high-order bit is always cleared, so zeros are fed in rather than the sign bit being duplicated.

Bit Manipulation Instructions

Mnemonic: BTST – Test a Bit		
Purpose: Tests an operand bit and sets zero flag accordingly		
Addressing Modes	Source	Destination
Data register direct	X	X
Address register direct		
Address register indirect		X
Postincrement register indirect		X
Predecrement register indirect		X
Register indirect with displacement		X
Register indirect with index		X
Absolute Short		X
Absolute Long		X
PC relative with displacement		X
PC relative with index		X
Immediate	X	
Flags affected: X N Z V C – – Y – –		

Mnemonic: BCLR – Test a Bit and Clear		
Purpose: Tests bit, sets Z flag accordingly, and then clears bit		
Addressing Modes:	Source	Destination
Data register direct	X	X
Address register direct		
Address register indirect		X
Postincrement register indirect		X
Predecrement register indirect		X
Register indirect with displacement		X
Register indirect with index		X
Absolute Short		X
Absolute Long		X
PC relative with displacement		
PC relative with index		
Immediate	X	
Flags affected: X N Z V C – – Y – –		

Mnemonic: BSET – Test a Bit and Set		
Purpose: Tests bit, sets Z flag accordingly, and then sets bit		
Addressing Modes:	Source	Destination
Data register direct	X	X
Address register direct		
Address register indirect		X
Postincrement register indirect		X
Predecrement register indirect		X
Register indirect with displacement		X
Register indirect with index		X
Absolute Short		X
Absolute Long		X
PC relative with displacement		
PC relative with index		
Immediate	X	

Flags affected:	X	N	Z	V	C
	–	–	Y	–	–

Mnemonic: BCHG – Test a Bit and Change		
Purpose: Tests bit, sets Z flag accordingly, then inverts bit		
Addressing Modes:	Source	Destination
Data register direct	X	X
Address register direct		
Address register indirect	X	
Postincrement register indirect	X	
Predecrement register indirect		X
Register indirect with displacement		X
Register indirect with index		X
Absolute Short		X
Absolute Long		X
PC relative with displacement		
PC relative with index		
Immediate	X	
Flags affected: X N Z V C – – Y – –		

Arithmetic Instructions

Mnemonic: ADD – Add Binary		
Purpose: Add source operand to data register destination		
Addressing Modes:	Source	Destination
Data register direct	X	X
Address register direct	X*	
Address register indirect	X	
Postincrement register indirect	X	
Predecrement register indirect	X	
Register indirect with displacement	X	
Register indirect with index	X	
Absolute Short	X	
Absolute Long	X	
PC relative with displacement	X	
PC relative with index	X	
Immediate	X	
Flags affected: X N Z V C Y Y Y Y Y		

Notes: Address register direct addressing is not allowed for byte size operations. Two forms of the instruction are available. For example:

```
                    Before          After
add.w d0,d2         d0=00000011     d0=00000011
                    d2=0000FFFA     d2=0000000B
                    XNZVC=00000     XNZVC=11001
```

Mnemonic: ADD – Add Binary		
Purpose: Add data register to destination operand		
Addressing Modes:	Source	Destination
Data register direct	X	X
Address register direct		
Address register indirect		X
Postincrement register indirect		X
Predecrement register indirect		X
Register indirect with displacement		X
Register indirect with index		X
Absolute Short		X
Absolute Long		X
PC relative with displacement		
PC relative with index		
Immediate		

Flags affected:	X	N	Z	V	C
	Y	Y	Y	Y	Y

Mnemonic: ADDA – Add Address		
Purpose: Add source operand to an address register		
Addressing Modes:	Source	Destination
Data register direct	X	
Address register direct	X	X
Address register indirect	X	
Postincrement register indirect	X	
Predecrement register indirect	X	
Register indirect with displacement	X	
Register indirect with index	X	
Absolute Short	X	
Absolute Long	X	
PC relative with displacement	X	
PC relative with index	X	
Immediate	X	
Flags affected: X N Z V C – – – – –		

Notes: This operation does not change any of the condition code values. For example:

	Before	After
`adda.l a3,a3`	**a3=00000002**	**a3=00000004**

Mnemonic: ADDI – Add Immediate
Purpose: Add immediate data to specified operand
Flags affected: X N Z V C Y Y Y Y Y

Notes: This instruction has exactly the same characteristics as the ADD using a data register source instruction, except that immediate addressing is used to specify the source (ie the source must be a constant).

Mnemonic:	**ADDQ – Add Quick**					
Purpose:	Add data specified in instruction code to operand					
Flags affected:	X	N	Z	V	C	
	Y	Y	Y	Y	Y	

Notes: Similar in effect to ADDI but the value is built into the instruction code itself. The immediate values in the source field are restricted to the range 1 to 8. This instruction is the fastest way to add a number between 1 to 8 to a destination operand.

Additional notes on ADD, ADDI, ADDQ: Most assemblers will optimise your code automatically and so if, for example, you write:

```
add  #1,Dn
```

the assembler will translate it automatically to:

```
addq #1,Dn
```

thus reducing the size of the object code and saving a few clock cycles of execution time.

Mnemonic: CLR – Clear and Operand		
Purpose: Sets specified register or memory location to zero		
Addressing Modes:	Source	Destination
Data register direct		X
Address register direct		
Address register indirect		X
Postincrement register indirect		X
Predecrement register indirect		X
Register indirect with displacement		X
Register indirect with index		X
Absolute Short		X
Absolute Long		X
PC relative with displacement		
PC relative with index		
Immediate		
Flags affected: X N Z V C – 0 1 0 0		

Notes: You cannot use clr to clear an address register but most assemblers allow instructions like clr a0 to be written and then substitute a sub.l instruction which has the same effect (sub.l a0,a0 in the case of clr a0). For example:

	Before	After
`clr.w d0`	`d0=bbbbbbbb`	`d0=00000000`
	`NZVC=1011`	`NZVC=0100`

Mnemonic: CMP – Compare		
Purpose: Compares operand with a data register and sets flags		
Addressing Modes:	Source	Destination
Data register direct	X	X
Address register direct	X	
Address register indirect	X	
Postincrement register indirect	X	
Predecrement register indirect	X	
Register indirect with displacement	X	
Register indirect with index	X	
Absolute Short	X	
Absolute Long	X	
PC relative with displacement	X	
PC relative with index	X	
Immediate	X	

Flags affected:	X	N	Z	V	C
	–	Y	Y	Y	Y

Notes: CMP is a subtraction instruction which affects only the condition codes. For example:

	Before	After
`cmp.l d2,d3`	`d2=00000001`	`d2=00000001`
	`d3=00000002`	`d3=00000002`
	`NZVC=1111`	`NZVC=0000`

Mnemonic:	CMPA – Compare Address
Purpose:	As CMP but uses an address register as destination
Flags affected:	X N Z V C – Y Y Y Y

Notes: This instruction differs only from CMP in that the second operand is an address register and that the data size cannot be byte.

Mnemonic:	CMPI – Compare Immediate
Purpose:	As CMP but compares against immediate data
Flags affected:	X N Z V C – Y Y Y Y

Mnemonic:	CMPM – Compare Memory
Purpose:	Compares contents of two memory locations
Flags affected:	X N Z V C – Y Y Y Y

Notes: Similar to CMP, but both the source and destination operands must use postincrement addressing. This instruction is used to compare areas of memory.

Additional note on all CMPx instructions. Most assemblers accept instructions like:

```
cmp.w (a0)+,(a1)+
```

and:

```
cmp.l #3,d0
```

Mnemonic:	DIVS – Signed Divide
Purpose:	Divides a 32 bit destination by a 16 bit source
Flags affected:	X N Z V C – Y Y Y 0

Notes: This instruction performs a division between two signed numbers. The destination register is always a long word and the source operand is always a word. After the division, the destination

operand contains the result. The quotient is always in the lower word and the remainder is always in the high order word of the data register!

Mnemonic:	**DIVU – Unsigned Divide**
Purpose:	Divides a 32 bit destination by a 16 bit source
Flags affected:	X N Z V C – Y Y Y 0

Notes: Nearly exactly the same as DIVS, only this time both operands are assumed to be unsigned.

Mnemonic:	**EXT – Sign Extend**
Purpose:	Propagates the upper bit of a byte, word or long word
Flags affected:	X N Z V C – Y Y Y 0

Notes: This instruction provides a convenient way to turn a word into a long word. If the high order bit of the data register is 0, so the data register is positive, zeros are padded in, otherwise ones are padded in. For example:

	Before	After
`ext.w d5`	`d5=000000ff`	`d5=0000ffff`

Mnemonic:	**MULS – Signed Multiply**
Purpose:	Multiplies two 16 bit operands
Flags affected:	X N Z V C – Y Y 0 0

Notes: This instruction performs a multiplication of the source and destination operand, putting the result in the destination operand.

Mnemonic:	**MULU – Unsigned Multiply**
Purpose:	Multiplies two 16 bit operands
Flags affected:	X N Z V C – Y Y 0 0

Notes: Similar to MULS, only both operands are assumed to be unsigned.

Mnemonic:	NEG – Negate				
Purpose:	Subtract from zero using two's complement arithmetic				
Flags affected:	X	N	Z	V	C
	Y	Y	Y	Y	Y

Notes: Negate an effective address operand. In a high level language this might look like this:

```
X = -X.
```

For example:

	Before	After
`neg.l d5`	`d5=00000001`	`d5=ffffffff`

Mnemonic:	SUBQ – Subtract Quick				
Purpose:	Subtract data specified in instruction code				
Flags affected:	X	N	Z	V	C
	Y	Y	Y	Y	Y

Notes: Similar in effect to SUBI but the value is built into the instruction code itself. The immediate values in the source field are restricted to the range 1 to 8. This instruction is the fastest way to subtract a number between 1 to 8 from a destination operand.

Additional notes on SUB, SUBI, SUBQ: Most assemblers will optimise your code automatically and if, for example, you write:

```
sub #1,Dn
```

the assembler will translate it automatically to:

```
subq #1,Dn
```

thus reducing the size of the object code and saving a few clock cycles of execution time.

Mnemonic: SUB – Subtract Binary		
Purpose: Subtract source operand from data register destination		
Addressing Modes:	Source	Destination
Data register direct	X	X
Address register direct	X*	
Address register indirect	X	
Postincrement register indirect	X	
Predecrement register indirect	X	
Register indirect with displacement	X	
Register indirect with index	X	
Absolute Short	X	
Absolute Long	X	
PC relative with displacement	X	
PC relative with index	X	
Immediate	X	
Flags affected: X N Z V C Y Y Y Y Y		

Notes: Address register direct addressing is not allowed for byte size operations. Two forms of this instruction exist.

Mnemonic: SUB – Subtract Binary		
Purpose: Subtract data register from destination operand		
Addressing Modes:	Source	Destination
Data register direct	X	
Address register direct		
Address register indirect		X
Postincrement register indirect		X
Predecrement register indirect		X
Register indirect with displacement		X
Register indirect with index		X
Absolute Short		X
Absolute Long		X
PC relative with displacement		
PC relative with index		
Immediate		
Flags affected: X N Z V C Y Y Y Y Y		

Mnemonic: SUBI – Subtract Immediate
Purpose: Subtract immediate data from specified operand
Flags affected: X N Z V C Y Y Y Y Y

Notes: This instruction, except for the fact that subtraction is involved, has exactly the same characteristics as the ADDI instruction.

Mnemonic: SUBA – Subtract Address		
Purpose: Subtract source operand from an address register		
Addressing Modes:	Source	Destination
Data register direct	X	
Address register direct	X	X
Address register indirect	X	
Postincrement register indirect	X	
Predecrement register indirect	X	
Register indirect with displacement	X	
Register indirect with index	X	
Absolute Short	X	
Absolute Long	X	
PC relative with displacement	X	
PC relative with index	X	
Immediate	X	
Flags affected: X N Z V C – – – – –		

Notes: This operation does not change any of the condition code values.

Mnemonic: TAS – Indivisible Test and Set					
Purpose: Test operand, set flags, then set the high-order bit					
Flags affected:	X	N	Z	V	C
	–	Y	Y	0	0

Notes: This instruction should *not* be used in Amiga programs because it can conflict with the Amiga's DMA (direct memory access) operations.

Mnemonic: TST – Test an Operand		
Purpose: Test an operand and set status flags accordingly		
Addressing Modes:	Source	Destination
Data register direct		X
Address register direct		
Address register indirect		X
Postincrement register indirect		X
Predecrement register indirect		X
Register indirect with displacement		X
Register indirect with index		X
Absolute Short		X
Absolute Long		X
PC relative with displacement		
PC relative with index		
Immediate		

Flags affected:	X	N	Z	V	C
	–	Y	Y	0	0

Other Instructions

In addition to the instructions outlined in this chapter the 68000 includes many other specialist instructions including binary coded decimal (BCD) operations, a range of supervisor-mode-only commands(privileged instructions) and trap generating and handling instructions. Please consult the official 68000 literature for details.

A: The C Language

C is an important language on the Amiga and in fact much of the Amiga's operating system has been written in C. Perhaps more important from the assembler programmer's viewpoint is that, because much of the official Amiga documentation has been written with the C programmer in mind, it is almost impossible to get by on the Amiga without some knowledge of the language. This appendix is not meant to teach you C but it is however meant to cover control constructs and characteristics of the language so, if you are not yet a C programmer, you'll still be able to appreciate something of the facilities that the language offers. You should note that in recent years C has undergone some significant changes and that an ANSI standard form now exists (this is the form discussed in this appendix). You should however be aware that the older style code, called K&R C, also exists and is still used. Details on C and ANSI/K&R differences can be found in most recently written C books!

Functions

Functions are the subprogram units which form the essential building blocks of all C programs. You don't have to write functions for everything you need to do in C – many functions come pre-written with the compiler or as part of the computer's operating system.

C functions, when properly written, make ideal program building blocks. They behave in many ways just like a black box – the user provides some input, called parameters or arguments, and the function carries out its job, possibly returning some information. The basic C syntax for a function call looks like this:

```
return-type  function-name ( parameter list )
      {
      variable declarations
      C statements which specify what the function does
      }
```

Here's a simple example which calculates the area of a rectangular box:

```
int  BoxArea(int width, int length)
    {
    int result;
    result=width*length;
    return(result);
    }
```

You wouldn't normally write such a trivial calculation as a function, but if you were going to, this shortcut form would also be allowed:

```
int  BoxArea(int width, int length)
    {
    return(width*length)
    }
```

Functions can call other functions and, if suitably written, can also call themselves. In other words, C supports recursion!

Decisions Using If Statements

In C *if* conditional testing takes this form:

```
if (expression)
    statement
```

The statement which gets executed can either be a single C statement or a group of statements enclosed within braces like this:

```
if (expression)
    {
```

```
    any number of statements
    }
```

Both syntax forms operate in the same way – the expression enclosed in parenthesis is evaluated and, if it's true, the statement or statements which follow are executed. For example the statement:

```
if (exit_flag==TRUE) closedown();
```

has this effect. The variable exit_flag is tested and if the condition is true, which in C means it has evaluated to a non-zero value, then the function closedown() is called.

C also provides an *if-else* extension whose formal syntax is:

```
if (expression)
    statement 1
else
    statement 2
```

Again the statement parts may be either single statements or blocks of statements placed in braces, for example:

```
if (keypress==ESCAPE) /* user wants some help */
    {
      PreserveScreen(); DisplayMesage();
      GetCharacter(); RestoreScreen();
    }
else
    {
    HandleCharacter(keypress);
    }
```

C's switch Statement

C provides the case structure construct, although it calls it a switch statement. This allows you to test an expression and then, on the basis of the result, carry out any number of code sections. The general form looks like this:

```
switch (expression)
        {
            case1 constant-expression: statement
```

```
            case2 constant-expression: statement
            case3 constant-expression: statement
            .
            .
            .
            caseN constant-expression: statement
            default: statement
        }
```

Again the sections of code can be either a single statement or a bracketed block of statements. The only limitation is that the expressions used to identify the individual cases must be integers.

As written the switch statement does not execute a particular set of statements and then return control to the program, execution falls through to other case sets. The way to avoid this is to use C's *break* statement which effects an immediate exit from the switch statement. So, although not specified in the syntax, the most useful description of the switch construct is this:

```
  switch (expression)
        {
            case1 constant-expression: statement
                                       break;
            case2 constant-expression: statement
                                       break;
            case3 constant-expression: statement
                                       break;
            .
            .
            .
            caseN constant-expression: statement
                                       break;
            default: statement
                     break;
        }
```

While and For Loops

The while loop uses this type of format:

```
while (expression)
    statement
```

As before the statement part may consist of either a single C statement or a block of statements enclosed in braces:

```
while (expression)
      {
      any number of statements
      }
```

C's equivalent of the common *for loop* adopts a most useful arrangement:

```
for (entry-expression; exit-expression; continuation-expression)
    statement
```

Again the statement part may consist of either a single C statement or a block of statements enclosed in braces. The parenthesised conditions are most usually assignment statements and conditional tests. The first part specifies the entry conditions, the second (commonly a conditional test) is evaluated before the body statements are executed, and the third part is usually an assignment which controls (increments or decrements) a loop variable.

An alternative C construct, a *do-while* loop, is also supported. Here the condition test is made at the end of the loop. As before braces are unnecessary for the single statement form, so the following two versions are acceptable:

```
do
 statement
 while (expression);
```

and:

```
do
 {
 any number of statements
 } while (expression);
```

Notice that, unlike the control statements mentioned earlier, a semicolon must follow the parenthesised expression.

Data Items

Data items used within a C program fall into two basic categories – constants and variables. C allows four fundamental type specifiers:

char	a single byte capable of holding one character.
int	an integer, usually reflecting the natural size of an integer on a given computer/processor.
float	a single precision floating point number.
double	a double precision floating point number.

And to these a number of qualifiers can be applied:

short	applies to int type only.
long	applies to int type only.
unsigned	applies to int or char types.
signed	applies to int or char type.

The exact number of bits which must be used to represent particular data types aren't specified by the language, they are determined by the underlying hardware of the machine and are therefore hardware dependent. On the Amiga for instance a long int is a 32-bit number, a short only 16-bits. Character char variables contain 8-bits.

The intention is that these qualifiers offer additional flexibility. If, for instance, we were dealing with a variable that we were certain would never hold values greater than 255 we could declare it as an unsigned char and the compiler would realise that the item will never require more than 8 bits of storage and would allocate memory accordingly.

Integer Constants

An integer constant is a whole number which may be positive, zero or negative. In C they may be specified using decimal, octal or hexadecimal (hex) notation.

The only restriction which C places on decimal integer constants is that they must not start with a 0 (zero). 999 and -126 are decimal constants. 016 is not! Why the restriction? It's because numbers which start with zeros are regarded as octal numbers, ie they're assumed to be base 8 numbers. Octal numbers must of course only contain the digits 0-7.

Numbers which start with the characters 0x (or 0X) signify a hexadecimal, ie base 16, number. These may consist of the digits 0-9 and the letters A-F (or a-f) inclusive. Hex numbers are very useful as a concise way of representing bit patterns, masks for logical operations etc.

Integer constants can be written with a qualifier. A decimal, octal or hex number followed by L, indicates a long integer, U indicates an unsigned int.

Floating Point Constants

In C floating point constants can be written in one of two ways – as decimals or in scientific, exponential, form. The latter scheme involves writing the number as either a floating point number or integer, adding the letter E, and then following that with an integer representing the appropriate power of 10.

Character Constants

Character constants in C are single characters written within single quote marks, 'B', 'd', '7','%' etc. The value of the constant is the numeric value of the character in the machine's character set. These are not to be confused with the equivalent integer numbers. The ASCII character 0 (zero) for instance, which can be written as as the constant '0', is represented internally by the numerical value 48, not by a zero value. Equally important is the fact that, on a machine which used a different character set, '0' would (as represented internally) be yet a different value again.

C allows a number of *escape sequences* to be used:

```
\a   alert (bell)
\b   backspace
\f   formfeed
\n   newline
\r   carriage return
\t   horizontal tab
\v   vertical tab
\\   backslash
\?   question mark
\'   single quote
\"   double quote
```

As well as the above sequences, byte-sized bit patterns can also be specified, \ooo, where ooo is an octal number x\hh is the hexadecimal equivalent. The ASCII space character could therefore be defined using the definition:

```
#define BELL '\x20'
```

One constant that crops up very frequently is the '\0' character. Its internal numerical value is zero and it is commonly known as the null character.

String Constants

A string constant is written as a sequence of characters enclosed in double quotes thus:

```
"some string"
```

Such constants can be concatenated at the time the program is compiled so it is legal to spread such strings over a number of lines if necessary. Internally all strings terminate with a null character, ie with '\0'. This is a C language requirement and it means that if, for instance, you write an eleven character string "some string" it will be stored using 12 locations.

Identifiers

C requires that various quantities, such as variables and constants, are given names in order that they can be referenced within the program. These names, which are called identifiers, can be made up of letters, digits and _ the underscore character. The only proviso is that the name must *not* start with a number. Identifiers are case sensitive and C programmers, because of a long established convention, tend to write all symbolic constants in uppercase. It is worthwhile maintaining this convention.

Arithmetic Operators

C supports all of the normal arithmetic operations, addition (+), subtraction (-), multiplication (*) and division (/). C also provides the % operator which is a modulus function. The expression x % z for instance gives the remainder after x has been divided by z.

Relational Operators

C offers the following relational operators:

```
>    greater than
>=   greater than or equal to
<    less than
```

```
==   equal to
!=   not equal to
```

Notice that equality uses a double == sign.

Assignment and the Assignment Operators

Assignment itself, as we've just mentioned, uses a single = sign. Its simplest use is in statements which take the following form:

```
variable = some expression or value
```

For assignments such as:

```
area = area + 40;
```

C allows a shortcut . The above expression can be written as:

```
area += 40;
```

Most binary operands, namely +, -, *, /, %, <<, >>, &, ^, and | can be used in this way.

C's Increment and Decrement Operators

C provides two very useful operators for incrementing and decrementing variables. Operations such as y = y + 1 can be written as:

```
y++; /* this means add 1 to the value of y */
```

Similarly y = y - 1 can be written:

```
y--;
```

It's also possible to control when the increment/decrement operation will occur. There are post-increment and pre-increment modes available:

```
y = x++;    x is incremented after the righthand
            side expression is evaluated and
            assigned.

y = ++x;    x is incremented before the righthand
            side expression is evaluated and
            assigned.
```

Type Conversions

If an operator like * or + is used with operands of different types then the less precise operand will usually be promoted to the same type as the most exact operand for the purposes of the calculation.

The above type of conversion is called implicit type conversion. C also allows the programmer to explicitly change types, providing of course that it is sensible to do so.

Bit Manipulation Operators

C was originally designed as a systems programming language and because of this, it was given quite a few operators that can act on the individual bits of an integer operand.

Category	Symbol	Name
Bitwise Operators		
	~	unary one's complement
	&	bitwise AND
	|	bitwise inclusive OR
	^	bitwise exclusive OR
Shift Operators		
	<<	left shift
	>>	right shift

The unary one's complement operator will turn all the 1s present in the binary form of an integer into 0s, and all positions that were originally 0s are converted to 1s.

Bitwise AND is most often used to mask out a particular bit pattern, ie to turn off certain bits of the number. If, for instance, the #define statement defines a constant called BITMASK as:

```
#define BITMASK 0x7FFF
```

then the expression:

```
x = x & BITMASK;
```

results in the most significant bit of the x variable being set to zero.

Similarly bitwise OR can be used to turn bits on. For instance, the expression:

```
x = x | BITMASK;
```

is an assignment which will set to 1 all of the bit positions in x which are set to one in the constant called BITMASK.

These types of operations, particularly in systems programming, are very common so the shortcut notation which C's assignment operators provide are very useful. The expression x = x & BITMASK for instance can simply be written more concisely as:

```
x & = BITMASK;
```

The bitwise exclusive OR operator ^ performs the standard exclusive OR operation. Every bit position where the two operands have different values will be set to 1, bits in other positions are set to zero.

Shift operators perform left and right shifts of their specified operands by a number of bits specified on the right of the operand, The expression:

```
x = x << 4;
```

shifts the contents of x four positions to the left.

Logical Operators

The operators && and || are known as C's AND and OR logical operators. Expressions connected by these operators are evaluated from left to right to see whether they are true or not. By definition the numeric value of a relational or logical expression is unity if the expression is true, and zero if it is false. A unary negation operator ! is also available which converts a non-zero operand into a zero operand and vice versa.

Precedence

The C language gives operators a precedence and in cases where operators of equal precedence have to be resolved it defines whether evaluation occurs on a left to right or a right to left basis. The following table gives the details of all of the C operators:

PRECEDENCE TABLE

Operators	Associativity
() [] -> .	left to right
! ~ ++ -- + - * & (type) sizeof	right to left
* / %	left to right
+ -	left to right
<< >>	left to right
< <= > >=	left to right
== !=	left to right
&	left to right
^	left to right
|	left to right
&&	left to right
||	left to right

```
? :                                                    right to left
=  +=  -=  *=  /=  %=  &=  ^=  |=  <<=  >>=           right to left
,                                                      left to right
```

The C Preprocessor

One of C's greatest strengths is that it offers a user programmable pre-processing stage. Prior to the start of compilation proper the source file is scanned for special preprocessor directives and these can be used to modify the source code. In general the preprocessor can perform three basic jobs: file inclusion, macro substitution and conditional compilation. The syntax of the preprocessor is quite separate from C. To start with, all preprocessor directives (ie preprocessor commands) must start with a hash # sign. The restrictions on the layout are also stricter than the C language itself.

Pointers and Address Related Operators

C allows you to work with pointers which represent memory addresses. The declaration:

```
char *buffer_p;
```

declares a variable called buffer_p as being a pointer to a char type item. An address of operator & is also available.

Complex Variables

The C language supports arrays of all types using separate square brackets for individual dimensions. It also allows variables of different types to be collected together into a unit known as a structure. For instance:

```
struct Date {
                long int Day;
                long int Month;
                long int Year;
              };
```

Such structures may be copied or assigned as complete units, their addresses may be taken and their individual members can be accessed, copied and assigned. ANSII C allows a structure to be passed to a function as a complete unit, and it allows the function to return a complete structure.

C has a special notation for working with structure pointers, the -> operator.

If p is a pointer to a structure then one of its members can be accessed with this type of statement:

```
p->MemberName;
```

If date_p is a pointer which has been declared as a pointer to the Date structure described earlier, ie as:

```
struct Date *date_p;
```

then the individual structure members could be initialised to represent 1st January 1992 using the statements:

```
date_p->Day=1;
date_p->Month=1;
date_p->Year=92;
```

Standard Input and Output (I/O) Functions

The C language itself doesn't actually have any inbuilt I/O facilities. What it does have is a standard library which provides a set of functions that, amongst other things, offer I/O and string handling. Nowadays ANSI C defines this library quite precisely so no matter what compiler, machine or operating system you are using you'll find these functions available.

As far as I/O goes, the C library adopts a very simple model for character I/O based on the idea of a text stream. A text stream is essentially a sequence of text lines, each of which ends in a newline character. If the system uses some other end-of-line character then, during I/O operations, the appropriate conversions are made transparently.

Associated with such operations is the idea of a standard input and standard output, places from which input can be received and output sent. On the Amiga for instance a CLI program, unless otherwise directed, receives its input from the keyboard and returns its output back to the CLI. This happens because C's standard I/O handles, called stdin and stdout, have been set up to achieve this.

getchar()

This routine reads one character from the standard input device. Since it collects single characters you might expect it to be used like this:

```
unsigned char keypress; /* DON'T COPY - THIS IS WRONG */
keypress=getchar();
```

Somewhat surprisingly this isn't the case. As well as returning all 256 possible eight bit characters getchar(), since it may be reading from a file, also has to be able to return an end-of-file (EOF) indicator. On the Amiga this is defined like this:

```
#define EOF (-1).
```

The net result is that we need a type larger than char and so int is used. The prototype for getchar() is therefore:

```
int getchar(void);
```

which just says that the function works without you specifying any parameters and that it provides you with an int sized object. Its correct use therefore would be as in:

```
int keypress;
keypress=getchar();
```

In many environments, including the Amiga, it is possible to re-direct these I/O streams. If a program is getting its data using getchar() then typing something like:

```
test <RAM:inputfile
```

will tell the test program to collect its input from a ram file called inputfile. This switching occurs via AmigaDOS's re-direction options and is totally transparent to the program itself.

Although getchar() is always called a function it is, like many library *functions* actually a macro. The compiler inserts the necessary code in-line rather than generating conventional function call code. The getchar() implementation, which we are not going to discuss, is actually made in terms of a lower-level macro called getc().

putchar()

This is the corresponding single character standard output routine. It's another macro and, like getchar(), is defined in terms of a lower-level function. The function prototype looks like this:

```
int putchar(int);
```

so you have to supply an int value. If you don't you will find that the compiler complains bitterly.

Programs using getchar() can, incidentally, also use re-direction.

printf()

We have already come across a printf() type function in Chapter 12 so now we can fill in some extra details. To start with the function uses this general arrangement:

```
printf(pointer-to-format-string, argument1, argument2,...
argumentN)
```

The format string can contain two types of objects: ordinary characters, which are sent to the standard output unchanged, and special control fields which are groups of characters starting with the % sign.

This arrangement means that if there are no control groups present the format string will be printed as just an ordinary string. This is why it is possible to use:

```
printf("just an example");
```

instead of:

```
printf("%s", "just an example");
```

One word of warning here. With string literals, such as the above, you will know what the string contents are. You sometimes see programmers using the shortcut version with ordinary strings, ie writing:

```
printf(text_p);
```

instead of:

```
printf("%s", text_p);
```

Don't do it, unless you can be 100% sure that the string being pointed to will *never* contain a % percent character.

A conversion command will end with any one of a number of characters which, for printf(), have special significance. Here are some examples:

```
d,i   prints an int decimal number
o     prints an int unsigned octal number (no leading zero)
x,X   prints an int unsigned hex number
u     prints an int unsigned decimal number
c     prints a single int character
s     char * prints s string
f     prints a double number
e,E   prints a double in exponential form
%     prints a % sign
```

A number of other characters can be included between the % sign and the group terminator. A minus sign indicates left adjustment of the argument. A number specifies the minimum field width. A period is used to separate the field width from a number which specifies the maximum number of characters to be printed, the number of digits after the decimal point of a floating point number, or the minimum number of digits for an integer.

One useful printf() characteristic is that the width or precision can be specified as an argument itself (of type int) by using an asterisk (*). The looped example:

```
for (length=1;length<=4;length++)
     {
      printf("%*s\n",length, "test");
     }
```

would produce the output:

```
t
te
tes
test
```

As you'll probably realise, printf() uses its first argument to decide how it must handle the other arguments it encounters. It will fail miserably if you mislead it by providing an inappropriate, or otherwise incorrect, format string. Another point worth mentioning is that, although rarely used, printf() does return information to the user – an int value representing the number of characters generated by the function.

The printf() function has many other options. You will find detailed discussions in your compiler manual along with other related functions such as sprintf().

Warning: The above discussion outlines C's printf() function. You should be aware that the version provided in the amiga.lib linker library, ie that used in Chapter 12 is not as sophisticated. The main difference is that it does *not* support the use of floating point numbers!

scanf()

Just as putchar() had a complementary getchar() routine, so printf() has a corresponding data collection function. It's called scanf() and it adopts similar conventions to printf() for its format descriptions and has this arrangement:

```
int scanf(char *format-string, list of pointer arguments)
```

scanf() reads characters from the standard input. As it does so it translates them according to the format string which has been provided. The big difference to watch for is that scanf() expects not the arguments themselves but pointers to them. Why? It's because scanf() isn't interested in their values. It wants to know where they are so it can store data in them. scanf() stops prematurely if it encounters errors returning a zero value to the caller. If all goes well scanf() will return a positive number indicating the number of input items successfully matched.

The format string can contain printable characters and these are then expected to match the next item in the input stream. It can also contain conversion characters which again will be detailed in your compiler manual along with other related functions such as scanf(). Format string options which are available include the following:

d	**pointer to an int decimal number**
i	**pointer to an int octal or hex number**
u	**pointer to an unsigned int decimal number**
s	**pointer to a char character**
e,f,g	**pointer to a floating point number**

Examples

Here are a couple of versions of a short program which asks the user to type something and then prints their response back at the CLI. First the *quick and dirty* version:

```
#include <stdio.h>
main()
{
char user_input[129]; /* Allow for 128 characters plus a NULL */
printf("Please type something\n);
scanf("%128s", user_input);
printf("You typed... %s\n", user_input);
}
```

There is nothing seriously wrong with this code – at least a check has been made to ensure that scanf() does not exceed the space set aside for the user's response. A few improvements could however be made by using #defines to remove the embedded numeric and string constants like this:

```
#include <stdio.h>
#define MAX_SIZE              128
#define INPUT_FORMAT_STRING   "%128s"
#define INPUT_MESSAGE         "Please type something\n"
#define OUTPUT_FORMAT_STRING  "You typed... %s\n"
main()
{
char user_input[MAX_SIZE+1];
printf(INPUT_MESSAGE);
scanf(INPUT_FORMAT_STRING, user_input);
printf(OUTPUT_FORMAT_STRING, user_input);
}
```

Last Words

As you have probably realised, C is both a powerful and flexible high-level language. To start writing C programs on the Amiga you will of course need a C compiler but the good news here is that a number of reasonable public domain C compilers exist so nowadays you can start C programming for just a few pounds. You'll find a number of C books listed in the bibliography.

B: Library Function Tables

The tables in this appendix provide library vector offset values and register usage details for some commonly used Amiga library functions, many of which have been used in the programs of this book. The term *void* in the following descriptions indicates that no return value is supplied. For full details of all libraries and their available functions you should consult the official Amiga documentation.

DOS Functions	LVO offset	
_LVOOpen	-30	file(d0) = Open(name,mode) (d1,d2)
_LVOClose	-36	void() = Close(file) (d1)
_LVORead	-42	collected(d0) = Read(file,buffer,length) (d1,d2,d3)
_LVOWrite	-48	written(d0) = Write(file,buffer,length) (d1,d2,d3)
_LVOLock	-84	lock(d0) = Lock(name,type) (d1,d2)
_LVOUnLock	-90	void() = Unlock(lock) (d1)
_LVOExamine	-102	success(d0) = Examine(lock,info_block) (d1,d2)
_LVOExNext	-108	success(d0) = ExNext(lock,info_block) (d1,d2)
_LVODelay	-198	void() = Delay(time) (d1)

Exec Functions		
_LVODisable	-120	void() = Disable() ()
_LVOEnable	-126	void() = Enable() ()
_LVOForbid	-132	void() = Forbid() ()
_LVOPermit	-138	void() = Permit() ()
_LVOAddIntServer	-168	void() = AddIntServer(number,interrupt) (d0,a1)
_LVORemIntServer	-174	void() = RemIntServer(number,interrupt) (d0,a1)
_LVOAllocMem	-198	block(d0) = AllocMem(size,type) (d0,d1)
_LVOFreeMem	-210	void() = FreeMem(block,size) (a1,d0)
_LVOWait	-318	signals(d0) = Wait(signals) (d0)
_LVOGetMsg	-372	message(d0) = GetMsg(port) (a0)
_LVOReplyMsg	-378	void() = ReplyMsg(message) (a1)
_LVOWaitPort	-384	message(d0) = WaitPort(port) (a0)
_LVOCloseLibrary	-414	void() = CloseLibrary(library) (a1)
_LVOOpenLibrary	-552	base(d0) = OpenLibrary(name, version) (a1,d0)

Graphics Functions

_LVORectFill	-306	void() = RectFill(rastport,x1,y1,x2,y2) (a1,d0,d1,d2,d3)
_LVOSetAPen	-342	void() = SetAPen(rastport,pen) (a0,d0)
_LVOSetBPen	-348	void() = SetBPen(rastport,pen) (a0,d0)

Intuition Functions

_LVOClearMenuStrip	-54	void() = ClearMenuStrip(window) (a0)
_LVOCloseScreen	-66	void() = CloseScreen(screen) (a0)
_LVOCloseWindow	-72	void() = CloseWindow(window) (a0)
_LVODisplayBeep	-96	void() = DisplayBeep(screen) (a0)
_LVODrawBorder	-108	void() = DrawBoarder(rastport,border,x,y) (a0,a1,d0,d1)
_LVODrawImage	-114	void() = DrawImage(rastport,image,x,y) (a0,a1,d0,d1)
_LVOOpenScreen	-198	screen(d0) = OpenScreen(new_screen) (a0)
_LVOOpenWindow	-204	window(d0) = OpenWindow(new_window) (a0)
_LVOPrintIText	-216	void() = PrintIText(rastport,itext,x,y) (a0,a1,d0,d1)
_LVOSetMenuStrip	-264	success(d0) = SetMenuStrip(window,menu) (a0,a1)

Usage Notes

The system macro LINKLIB is used to generate function call code in an easy-to-read, and conceptually tidy, fashion. An Intuition library OpenScreen() call for instance might take this form:

```
LINKLIB _LVOOpenScreen, _IntuitionBase
```

and the instructions generated would be:

```
move.l a6,-(sp)
move.l _IntuitionBase,a6
jsr _LVOOpenScreen(a6)
move.l (sp)+,a6
```

To create an executable program the _LVOOpenScreen reference must at some stage be resolved, ie the real value for it must be

found. This may be done either at link time, via the LVO values present in amiga.lib, by using an include file which contains the appropriate LVO value, or by the programmer inserting a suitable EQUate within their program. Since the numerical LVO values are available from the system documentation, programmers are sometimes tempted to use the numerical equivalents directly. For instance, knowing that the _LVOOpenScreen reference is -198, a programmer could decide to code the above library opening fragment in one of these ways:

```
1)  LINKLIB _LVOOpenScreen, _IntuitionBase

2)  move.l  a6,-(sp)
    move.l  _IntuitionBase,a6
    jsr     _LVOOpenLibrary(a6)
    move.l (sp)+,a6

3)  LINKLIB -198, _IntuitionBase

4)  move.l  a6,-(sp)
    move.l  _IntuitionBase,a6
    jsr     -198(a6)
    move.l (sp)+,a6
```

The preferred approach is to use the LINKLIB macro, or an equivalent macro, but if you do write the code manually you should always use the LVO name and *not* the numerical value. There are two reasons for this. Firstly, the LVO name approach provides more readable code. Secondly, if Commodore-Amiga do ever change the existing function arrangements in a library then, providing you've used the LVO symbolic names, it would be possible to re-assemble/re-link your program with the new LVO data and it would work. This would not be possible if you had used numerical LVO equivalents in your code. In short you should avoid the style of the last two examples shown above!

C: The A68K Assembler

Between April and June 1986 the *Dr Dobbs Journal* published the source for a 68000 cross assembler written in Modula 2 by Brian Anderson. Charlie Gibbs took these ideas, translated them into C, and used them as the basis for an Amiga assembler. After adding a great many enhancements, the package we now know as A68K was born!

A68K is a freely distributable assembler that is available from almost all public domain libraries. It is found both as a separate package and as a component of a variety of public domain high-level languages. If, for example, you have a copy of Steve Hawtin's NorthC compiler then you'll find that you have A68K and Blink (and documentation files) in the *bin* directory of the main compiling disk.

The code examples in this book were created initially using Devpac but the good news is that all of the programs can be assembled using other assemblers with little or no change. A68K however does require that source files contain an explicit END statement at the end of the source code so a small change is necessary before the examples listed in this book can be assembled using A68K.

This is easily done and if you read the source file into any available ASCII text editor (ED or Memacs will do), move to

the end of the text file and insert a terminal END statement as the last line of the source code you will then find that most of the examples will assemble without problem.

With one or two examples, namely those that use the SECTION directive to ensure that graphics data gets placed in chip memory, another small change will be necessary. For A68K users the source code line:

```
SECTION IMAGE,DATA_C
```

which appears just before the graphics data itself will need to be changed to:

```
SECTION IMAGE,DATA,CHIP
```

The A68K and Blink usage options themselves are well explained in the associated document files (which are always distributed along with these programs) and for the examples in this book only simple command lines will be needed. If, for example, a source file called *test.s* is present in the RAM Disk and your include files are present in the include directory of the disk in df0 then the CLI/Shell command line to assemble the program test.s would be:

```
a68k ram:test.s -oram:test.o -idf0:include
```

This would produce in the RAM Disk an object file, *test.o*, which could subsequently be linked using Blink. In the simple case where no startup code or linker libraries were being specified the Blink command line:

```
blink ram:test.o to ram:test
```

would result in an executable (runable) program called *test* being placed in the Ram Disk.

The Official Amiga Include Files

One thing that A68K users do need to be aware of is the fact that they will *not* get the official Commodore include files with their assembler. It is possible however that some high-level language users will already have suitable include files, Lattice/SAS C for instance provides these as part of the compiler package, but if not two options are available.

Firstly, the details of the appropriate parts of the include files can be typed in from the *RKM Includes & Autodocs* manual. Secondly,the files can be obtained by sending a written order for the *Amiga 2.0 Native Developer Update* disk set (accompanied by a cheque for £25) to:

Mrs S. A. McGuffie

Developer Liaison Manager

Commodore Business Machines UK Ltd.

Commodore House, The Switchback, Gardner Road, Maidenhead, Berks, SL6 7XA

D: Bibliography

The following books are a selection of those currently available on assembly language programming, the Amiga, and on general programming. They've been chosen because they have all, at some period in time, been found to be particularly useful.

Title: Amiga ROM Kernel Reference Manual – Libraries
Author: Commodore-Amiga Inc.
Publisher: Addison-Wesley
ISBN: 0-201-56774-1
One of the major Amiga reference books – for details see the discussions in Chapter Eight.

Title: Amiga ROM Kernel Reference Manual – Devices
Author: Commodore-Amiga Inc.
Publisher: Addison-Wesley
ISBN: 0-201-56775-X
One of the major Amiga reference books – for details see the discussions in Chapter Eight.

Title: Amiga ROM Kernel Reference Manual – Includes & Autodocs
Author: Commodore-Amiga Inc.
Publisher: Addison-Wesley
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One of the major Amiga reference books – for details see the discussions in Chapter Eight.

Title: Amiga Hardware Reference Manual
Author: Commodore-Amiga Inc.
Publisher: Addison-Wesley
ISBN: 0-201-56776-8
One of the major Amiga reference books – for details see the discussions in Chapter Eight.

Title: Amiga User Interface Style Guide
Author: Commodore-Amiga Inc.
Publisher: Addison-Wesley
ISBN: 0-201-57757-7
One of the major Amiga reference books – for details see the discussions in Chapter Eight.

Title: The AmigaDOS Manual
Author: Commodore-Amiga Inc.
Publisher: Bantam Books
ISBN: 0-553-35403-5
Now in its third edition this is the most comprehensive guide to the internal workings of AmigaDOS that exists but parts of it are technically heavy going.

Title: Mastering AmigaDOS2 Vols I and II
Authors: Bruce Smith and Mark Smiddy
Publisher: BSB Books Ltd
ISBN: 1-873308-10-8 and 1-873308-09-4
These two volumes contain masses of useful information and bring the AmigaDOS reference material right up to date, including 2.04.

Title: The Kickstart Guide to the Amiga
Author: Dave Parkinson and Mike Boley.
Publisher: Ariadne Software Ltd.
This book has been about for quite a few years now so it is a little out of date in places. Nevertheless it contains a lot of useful information and is still worth reading.

Title: Computers – From Logic to Architecture
Author: R. D. Dowsing and F. W. D Woodhams
Publisher: Van Nostrand Reinhold
ISBN: 0-278-00093-2
Contains good general introductions to hardware issues (processors, memory chips and so on) including some 68000 material.

Title: Dr Dobb's Toolbook of 68000 Programming
Authors: Editors of the Dr Dobbs Journal
Publisher: Prentice Hall
ISBN: 0-13-216557-0
A goldmine for ideas once you are fairly 68000 proficient, but does not contain any Amiga specific material.

Title: 68000 Assembly Language Programming
Authors: Kane, Hawkins and Leventhal
Publisher: Osborne/McGraw-Hill
ISBN: 0-931988-62-4
A very good general Motorola 68000 book with very detailed accounts of the instruction set.

Title: Mastering Amiga System
Author: Paul Andreas Overaa
Publisher: BSB Books Ltd
ISBN: 1-873308-04-6
This provides introductory coverage of Amiga System programming from a C orientated viewpoint. It attempts to answer the questions that other Amiga books either didn't cover or didn't seem to explain well enough.

Title: Mastering Amiga C
Author: Paul Andreas Overaa
Publisher: Bruce Smith Books Ltd
ISBN: 1-873308-04-6
Provides an Amiga-orientated introduction to the C language.

Title: Program Design 3rd Edition
Author: Peter Juliff
Publisher: Prentice Hall
ISBN: 0-13-728916-2
A good, easy-to-read, introduction to program design techniques.

Title: Program Design on the Amiga
Author: Paul Andreas Overaa
Publisher: Kuma Software
ISBN: 0-7457-0032-2
A comprehensive introduction to some serious program design techniques, with a lot of emphasis on the Warnier diagram and the Amiga.

Title: The Software Life Cycle
Editors: Darrel Ince and Derek Andrews
Publisher: Butterworths
ISBN: 0-408-03741-5
This book contains a collection of papers on software design issues of current interest. It is well worth looking at!

Title: Abstract Data Types and Algorithms
Author: Manochehr Azmoodeh
Publisher: Macmillian
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Mastering AmigaDOS3 Vol. 1	N	N	N	Y	N	Y#	Y
Mastering AmigaDOS3 Vol. 2	N	N	N	Y	N	Y#	Y
Mastering Amiga System	Y	Y	Y	Y	Y	Y	Y
Mastering Amiga Printers	Y	Y	Y	Y	Y	Y	Y
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Mastering Amiga Assembler	Y	Y	Y	Y	Y	Y	Y
Mastering Amiga C	Y	Y	Y	Y	Y	Y	Y

Y† State if you have AmigaDOS 1.3. Y* Earlier versions with AmigaDOS2
Y‡ 80% compatible with 2.1 version. Y# Latest versions with AmigaDOS3

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ISBN: 1-873308-34-5, Price £14.95, pages TBA. Available April '94.

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Workbench 3 A to Z Insider Guide by Bruce Smith

ISBN: 1-873308-28-0, Price £14.95, pages TBA. Available April '94.

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Mastering Amiga AMOS by Phil South

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