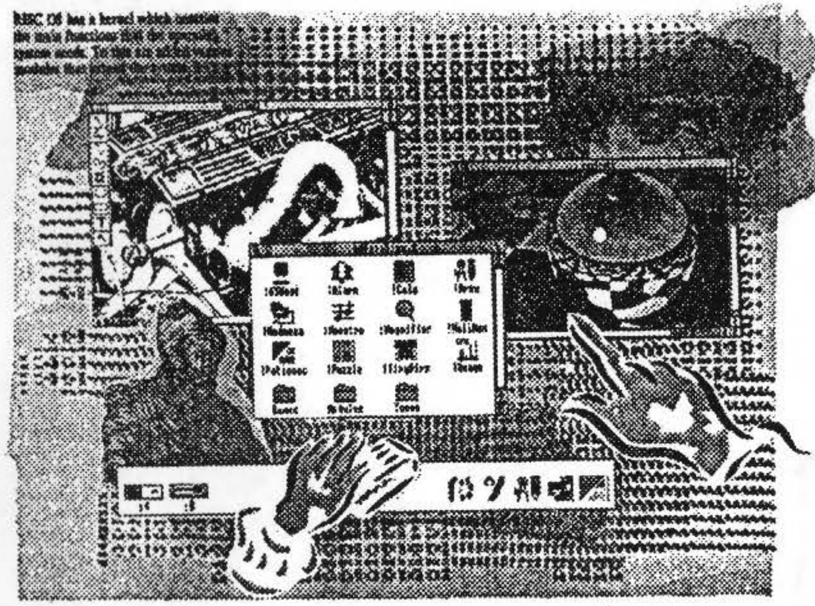
RISC OS

PROGRAMMER'S REFERENCE MANUAL

Volume VI



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Introduction

The Econet module provides the software needed to use Acorn's own Econet networking system. The software allows you to send and receive data over the network.

It is used by RISC OS modules such as NetFS and NetPrint, which provide network filing and printing facilities respectively. It is also used by various other Acorn products that use Econet, such as FileStores, Econet bridges, and so on.

Note that to use the Econet you must have an Econet expansion module fitted to your RISC OS computer. If you do not already have one, they are available from your Acorn supplier.

Overview

Econet is Acorn's own networking system, and the Econet module provides the necessary software to use it.

The main purpose of any networking system is to transfer data from one machine to another. Econet breaks up the data it sends into small parts which are sent using a well defined protocol.

Econet does not use buffers in the same way as most other input and output facilities that RISC OS provides. Instead the data is moved directly between the Econet hardware and memory. This means that each time data is transmitted or received, there has to be a block of memory available for the Econet software to use immediately, either to read data from or place data in.

These blocks of memory are administered by the Econet software, which uses control blocks to do so. Many of the SWIs interact with these control blocks, so you can set them up, read the status of an Econet transmission or reception, and release the control blocks memory when you have finished using them.

In the same way as files under the filing system use file handles, these control blocks also use handles. Just like file handles, your software must keep a record of them while you need to use them.

The Econet also provides a range of immediate operations, which allow you to exercise some control over the hardware of remote machines, assuming you get their co-operation. Some of these will work across the entire range of Acorn computers, whereas others are more hardware-dependent and so may only be possible on RISC OS machines.

Technical Details

Packets and frames

A single transmission of data on an Econet is called a *packet*. Packets travel across the network from the transmitting station to the receiving station. The most common form of packet is called a 'four way handshake'. A 'four way handshake' consists of four frames. Each of these four frames starts with the following four bytes:

- the station number of the destination station
- the network number of the destination station
- the station number of the source station
- the network number of the source station.

These four bytes are sent in this order to facilitate decoding by the software in the receiving station.

The first frame is sent by the transmitting station, it contains the usual first four bytes, the port byte (described later), and the flag byte (also described later). This first frame is called the *scout*. The receiving station then replies with the *scout acknowledge*, which consists of just the usual first four bytes. The third frame is the *data* frame; this frame has the usual first four bytes, followed by all the data to be transferred. Lastly there is a *final acknowledge* frame which is identical to the scout acknowledge frame.

This exchange of frames can be seen with the NetMonitor and is displayed something like this.

```
FE0012008099 1200FE00 FE00120048454C500D 1200FE00
```

- the transmitting station is &12 (18 in decimal)
- the receiving station is &FE (254 in decimal)
- both stations are on network zero
- the flag byte is &80
- the port byte is &99
- the data that is transmitted is &48, &45, &4C, &50, &0D.

Receiving data and using RxCBs

Successful transmission of data requires co-operation from the receiving station. A station shows that it is ready to receive by setting up a *receive control block* (or RxCB). All RxCBs are kept by the Econet software and don't need to concern you. To create an RxCB all you need to do is call a single SWI (Econet_CreateReceive – SWI &40000), telling the Econet software all the required information. The Econet software will return to you a handle which you then use to refer to this particular RxCB in any further dealings with the Econet software.

The information required by the Econet software is:

- which station(s) to accept data from
- which port number(s) to accept data on
- where to put the data when it arrives.

It is important you note that when the data arrives from the transmitting station it is not buffered at all – it is taken directly from the hardware and placed in memory at the address you specify. This area of memory is referred to as a buffer (in this case a *receive buffer*). A consequence of this is that memory used for receiving Econet packets **must** be available at all times whilst the relevant RxCB is open. You **must not** use memory in application space if your program is to run within the Desktop environment.

The Econet software keeps a list of all the open RxCBs. When a packet comes in it is checked to see if it matches any of the currently open RxCBs:

- if it doesn't then the receiving software indicates this to the transmitting software by not sending a scout acknowledge frame
- if it does then the receiving software sends out a scout acknowledge, and then copies the data frame into the corresponding buffer
- if the data frame overruns the buffer then the receiving software does not send the final acknowledge frame.

Status of RxCB's

All RxCBs have a status value. These values are tabulated below.

7	Status_RxReady
8	Status_Receiving
9	Status_Received

The status of a particular RxCB can be read using the Econet_ExamineReceive call (SWI &40001); this takes the receive handle of an RxCB and returns its status.

When an RxCB has been received into, its status will change from RxReady to Received; usually, you will then call Econet_ReadReceive (SWI &40002). This returns information about the reception; most importantly it tells you how much data was received – which can be anything from zero to the size of the buffer. It also returns the value of the flag byte.

The port, station, and network are also returned; these are useful because you can open an RxCB that allows reception on any port or from any station.

Abandoning RxCB's

It is very important that when RxCBs are no longer required, either because they have been received into, or because they have not been received into within a certain time, that they are removed from the system. You do so by calling the SWI Econet_AbandonReceive (SWI &40003). The major function of this call is to return to the RMA the memory that the Econet software used to hold the RxCB; obviously if RxCBs are not abandoned, they will consume memory which will not automatically be recovered by the system.

Receiving data using a single SWI

The usual sequence of operations required for software to receive data is as follows: First call SWI Econet_CreateReceive, then make numerous calls to SWI Econet_ExamineReceive until either a reception occurs, a time out occurs, or the user interferes (by pressing *Escape* for instance). Then read the RxCB if it has been received into. Finally, abandon the RxCB.

To make this task easier the Econet software provides a single SWI (Econet_WaitForReception – SWI &40004) which does the polling, the reading, and the abandoning for you. To call SWI Econet_WaitForReception you must pass in:

- the receive handle
- the amount of time you are prepared to wait
- a flag which indicates whether you wish the call to return if the user presses the Escape key.

Econet_WaitForReception returns one of four status values:

8	Status_Receiving
9	Status_Received
10	Status_NoReply
11	Status_Escape

The call will return as soon as a reception occurs; when this happens the status is *Received*. If the time limit expires then the status is usually *NoReply*, but if reception had started just after the timeout, and so was then abandoned, the status will be *Receiving*. This is not a very likely case. If the escapable flag is set then pressing the Escape key causes the call to return with the *Escape* status.

Transmitting data and using TxCB's

Transmission is roughly similar to reception; a single SWI (Econet_StartTransmit – SWI &40006) is all that is required to get things started. This call requires the following information:

- the destination station (and network)
- the port number to transmit on
- the flag byte to send
- the address and length of the data to send.

SWI Econet_StartTransmit returns a handle. These handles are distinct from the handles used by the receive SWIs.

There is a limit of 8 Kbytes on the size of data you can send with this call.

Status of TxCB's

To check the progress of your transmission you can call Econet_PollTransmit (SWI &40007). This returns the status of the particular TxCB, which will be one of seven possible values:

0	Status_Transmitted
1	Status_LineJammed
2	Status_NetError
3	Status_NotListening
4	Status_NoClock
5	Status_TxReady
6	Status_Transmitting

Status_Transmitted means that your transmission has completed OK and that the data has been received by the destination machine. *Status_TxReady* means that your transmission is waiting to start, either because the Econet is busy receiving or transmitting something else, or your transmission is queued (see later for more details of this). *Status_Transmitting* is obvious; so too is *Status_NoClock*, which means that the Econet is not being clocked, or more likely your station is not plugged into the Econet. *Status_LineJammed* means that the Econet software was unable to gain access to the Econet; this may be because other stations were transmitting, but it is more likely that there is a fault in the Econet cabling somewhere. *Status_NotListening* is returned when the destination station doesn't send back a scout acknowledge frame; this is usually because the destination station doesn't have a suitable open receive block. *Status_NetError* will be returned if some part of the four way handshake is missing or damaged; the usual cause of this status is the sender sending more data than the receiver has buffer space for, so the receiver doesn't send back the final acknowledge frame.

Retrying transmissions

Status returns like *NotListening* and *NetError* can also be caused by transient problems with the Econet such as electrical noise, or by the receiving station using its floppy disc. Because of this it is usual to try more than once to send a packet if these status returns occur. To make this easier for you the Econet software can automatically perform these extra attempts for you. These retries are controlled by passing two further values in to the Econet_StartTransmit SWI:

- the number of times to try, referred to as the Count
- the amount of time to wait between tries, referred to as the Delay.

If the Count is either zero or one then only one attempt to transmit will take place. If the Count is two or more then retries will occur, at the specified interval (given in centi-seconds). To give an example as it would be written in BASIC V:

```
10 DIM Buf% 20
20 Port%=99: Station%=7: Network%=0
50 SYS "Econet_StartTransmit",0,Port%,Station%,Network%,Buf%,20,3,100 TO Tx%
60 END
```

When this partial program was RUN it would try to transmit immediately, probably before the program reached the END statement. If this transmission failed with either *Status_NotListening* or *Status_NetError*, then the Econet software would wait for one second (100 centi-seconds) and try again. If this also failed then the software would wait a further second and try for a third time. The status of the final (in this case third) transmission would be the status finally stored in the TxCB; this could be read using SWI Econet_PollTransmit. To see this we could add some extra lines to the example program.

```
 30 TxReady%=5
 40 Transmitting%=6
 60 REPEAT
 70   SYS "Econet_PollTransmit", Tx% TO Status%
 80   PRINT Status%
 90 UNTIL NOT ((Status%=TxReady%) OR (Status%=Transmitting%))
100 END
```

Now the program will show us the status of the TxCB. We would be very unlikely to see the status value ever be *Status_Transmitting* since it will only have this value for about 90µs during the two seconds it is retrying for. But it is most important that your software should be able to handle such a situation without error.

Abandoning TxCB's

As with receptions it is most important that memory used for transmitting Econet packets **must** be available at all times whilst the relevant TxCB is open. You **must not** use memory in application space if your program is to run within the Desktop environment. This is because like receptions, transmissions move data directly from memory at the address you specify to the hardware. Also, as with receptions, it is important to inform the Econet software that you have finished with your transmission and that memory required for the internal TxCB may be returned to the RMA. You do this by calling Econet_AbandonTransmit (SWI &40008) with the appropriate TxHandle.

```
100 SYS "Econet_AbandonTransmit", Tx% TO FinalStatus%
110 PRINT "The final status was ";FinalStatus%
```

Transmitting data using a single SWI

To make this start, poll, and abandon sequence easier for you the Econet software provides it all as a single call (Econet_DoTransmit – SWI &40009)). This call has the same inputs as SWI Econet_StartTransmit, but instead of returning a handle it returns the final status. Using this call our program would look like this:

```
10 DIM Buf% 20
20 Port%=99: Station%=7: Network%=0
40 SYS"Econet_DoTransmit",0,Port%,Station%,Network%,Buf%,20,3,100 TO Status%
50 PRINT "The final status was ";Status%
```

Converting a status to an error

As you can see this makes things a lot easier. As an aid to presenting these status values to the user there are two SWI calls to convert status values to a textual form, the most frequently used of which is the call Econet_ConvertStatusToError (SWI &4000C). This call takes the status and returns an error with the appropriate error number and an appropriate string describing the error. For instance we could add an extra line to our final program.

```
60 SYS "Econet_ConvertStatusToError", Status%
```

Copying the error to RAM

Our program will now RUN and always have an error, in this case the error 'Not listening at line 50'. This error block is actually in the ROM so it is not possible to add to it, but it is possible to have the call to Econet_ConvertStatusToError copy the error into RAM by specifying in the call where this memory is, and how much there is:

```
60 DIM Error% 30
80 SYS "Econet_ConvertStatusToError", Status%, Error%, 30
```

This new program will function in the same manner as the previous program except that the error block will have been copied from the Econet part of the ROM into RAM (at the address given in R1). The main reason for this is to allow the Econet software to customise the error for you.

Adding station and network numbers

If the station and network numbers are added as inputs to the call, the Econet software will add them to the output string:

```
80 SYS "Econet_ConvertStatusToError",Status%,Error%,30,Station%,Network%
```

Now the error reported will be 'Station 7 not listening at line 50'. It is important to stress that this is a general purpose conversion. It will convert Status_Transmitted just as well as Status_NotListening, so usually you would test the returned status from Econet_DoTransmit, and only convert status values other than Status_Transmitted into errors:

```
30 Transmitted%=0
70 IF Status%=Transmitted% THEN PRINT "OK": END
```

The same program fragment could be written in assembler (this example, like all others in this chapter, uses the ARM assembler rather than the assembler included with BBC BASIC V – there are subtle syntax differences):

```
Tx      MOV     r0, #0
        MOV     r1, #99
        MOV     r2, #7
        MOV     r3, #0
        LDR     r4, Buffer
        MOV     r5, #20
        MOV     r6, #3
        MOV     r7, #100
        SWI     Econet_DoTransmit
        BEQ     r0, #Status_Transmitted
        LDRNE   r1, ErrorBuffer
        MOVNE   r2, #30
        SWINE   Econet_ConvertStatusToError
        MOV     pc, lr
```

Notice here in the assembler version how the return values from Econet_DoTransmit fall naturally into the input values required for Econet_ConvertStatusToError. This code fragment is not really satisfactory since no code written as either a module or a transient command should ever call the non-X form of SWIs. If the routine Tx is treated as a subroutine then it should look more like this:

```
Tx      STMFD   sp!, {lr}
        MOV     r0, #0
        MOV     r1, #99
        MOV     r2, #7
        MOV     r3, #0
        ADR     r4, Buffer
        MOV     r5, #20
        MOV     r6, #3
        MOV     r7, #100
        SWI     XEconet_DoTransmit
        BVS     TxExit
        TEQ     r0, #Status_Transmitted
        ADRNE   r1, ErrorBuffer
        MOVNE   r2, #30
        SWINE   XEconet_ConvertStatusToError
TxExit  LDMFD   sp!, {pc}
```

This routine returns with V clear if all went well; if V is set, then on return R0 will contain the address of a standard error block.

Converting a status to a string

The second error conversion call is Econet_ConvertStatusToString (SWI &4000B), which does exactly what its name suggests. The input requirements are very similar to the string conversion SWIs supported by RISC OS. In this case you pass the status value, a buffer address, and the length of the buffer. As with Econet_ConvertStatusToError you can also pass the station and network numbers, which will be included in the output string. To illustrate this the assembler routine shown above is changed to print the status on the screen:

```
Tx      STMFD   sp!, {lr}
        MOV     r0, #0
        MOV     r1, #99
        MOV     r2, #7
        MOV     r3, #0
        ADR     r4, Buffer
        MOV     r5, #20
        MOV     r6, #3
        MOV     r7, #100
        SWI     XEconet_DoTransmit
        BVS     TxExit
        TEQ     r0, #Status_Transmitted
        BEQ     TxExit
        ADR     r1, TextBuffer
        MOV     r2, #50
        MOV     r5, r0                          ; Save the status value
        SWI     XOS_ConvertCardinal1
        MOVVC   r0, r5                          ; Recall status if no error
        SWIVC   XEconet_ConvertStatusToString
        ADRVC   r0, TextBuffer
        SWIVC   XOS_Write0
TxExit  LDMFD   sp!, {pc}
```


Flag bytes

The flag byte is sent from the transmitting station to the receiving station and can be treated as an extra seven bits of data. By convention, it is used as a simple way of distinguishing different types of packet sent to the same port, and it is worth you doing the same.

This is most useful in server type applications where it is often the case that similar data can be sent for different purposes, or some sorts of data are outside the normal scope. An example is a server that takes requests for teletext pages, but can also return the time. A different value for the flag byte allows the server to differentiate time requests from normal traffic. Another example is the printer server protocol, which uses the flag byte to indicate the packet that is the last in the print job, without having to change the data part of the packet.

Port bytes

The port byte is used in the receiving station to distinguish traffic destined for particular applications or services.

For instance the printer server protocol uses port &D1 for all its connect, data transfer, and termination traffic, whereas the file server uses port &99 for all its incoming commands. This use of separate ports for separate tasks is also exploited further by the file server protocol in that every single request for service by the user can use a different port for its reply. This prevents traffic getting confused.

The Econet software provides some support for you to use ports by providing an allocation service for port numbers. Port numbers should, if possible, be allocated for all incoming data.

Software that requires the use of fixed port numbers, like NetFS and NetPrint, can claim these fixed ports by calling Econet_ClaimPort (SWI &40015). This call takes a port number as its only argument. When these claimed ports are no longer required (when the module dies for instance) it can be 'returned' by calling SWI Econet_ReleasePort (SWI &40012).

Other software that would like a port number allocated to it can call Econet_AllocatePort (SWI &40013), which will return a port number. While this port number is allocated no other calls to Econet_AllocatePort will return that number, until it is 'returned' by calling Econet_DeAllocatePort (SWI &40014) with the port number as an input. The NetFS software uses this method of allocation and deallocation to get ports to use as reply ports in the file server protocol. The Econet software keeps a table in which it records the state of each port number: this can be either free, claimed or allocated.

Freeing ports

Ports that have been claimed will not be allocated, and can only be freed by calling SWI Econet_ReleasePort. Calling SWI Econet_DeAllocatePort will return an error if the port is claimed rather than allocated. Ports that have been allocated can not be claimed, and in fact an attempt to claim an allocated port will return an error. You should be careful with software that uses allocated ports to make sure that all ports are deallocated when they are no longer required, especially after an error. The claiming and releasing of ports should likewise be carefully checked.

An example of use of the port allocator

A typical example of the use of the port allocator would be a multi-player adventure game server. The server would claim one port (eg port &1F). This port number would then be the only fixed port number in the entire protocol. When a player wished to join the game she should ask for a port to be allocated in her machine and send this port, along with all the information required to enter the game, to the game server on port &1F. If the server can't be contacted or doesn't reply within the required time the port should be deallocated and an error returned. When the server receives this packet it should check the user's entry data; if this is OK it should then allocate a port for that user and return it, along with any other information required to start the game off. When the user wants to quit the game the server should deallocate its user's port, then send the last reply to the user. The user should deallocate the port when the reply arrives or if the server doesn't reply soon enough.

To illustrate this example the user entry routine is shown below; note that this routine is coded for clarity rather than size or efficiency.

```
Entry   STMFD   sp!, {r0-r8,lr} ; R0 points to the text string
        SWI     XEconet_AllocatePort
        BVS     Exit

        STRB    r0, Server_ReplyPort
        LDR     r1, Server_Station
        LDR     r2, Server_Network
        ADR     r3, Buffer
        MOV     r4, #?Buffer
        SWI     XEconet_CreateReceive
        BVS     DeAllocateExit
        MOV     r8, r0           ; Preserve the RxHandle

        LDR     r1, [ sp, #0 ]   ; Address of text string to copy
        ADR     r4, Buffer       ; Get buffer to copy into
        MOV     r5, #0           ; Index into Tx Buffer
        LDRB    r0, Server_ReplyPort
        STRB    r0, [ r4, r5 ]   ; Send the port for the server
CopyLoop
        ADD     r5, r5, #1
```



```
        CMP     r5, #?Buffer     ; Have we run out of buffer?
        BHS     BufferOverflow
        LDRB    r0, [ r1 ], #1   ; Pick up byte and move to next one
        CMP     r0, #" "         ; Is this a control character?
        MOVLE   r0, #CR          ; Terminate as the server expects
        STRB    r0, [ r4, r5 ]
        BGT     CopyLoop         ; Loop back for the next byte
        ADD     r5, r5, #1       ; Set entry conditions for Tx

        MOV     r0, #0
        MOV     r1, #EntryPort   ; A constant
        LDR     r2, Server_Station
        LDR     r3, Server_Network
        LDR     r6, Server_TxDelay
        LDR     r7, Server_TxCount
        SWI     XEconet_DoTransmit
        BVS     DeAllocateExit
        TEQ     r0, #Status_Transmitted
        BEQ     WaitForReply
ConvertEconetError
        ADR     r1, Buffer       ; Convert status and exit
        MOV     r2, #?Buffer
        SWI     XEconet_ConvertStatusToError
        B       DeAllocateExit

WaitForReply
        MOV     r0, r8
        LDR     r1, Server_RxDelay
        MOV     r2, #0           ; Don't allow ESCape
        SWI     XEconet_WaitForReception
        BVS     DeAllocateExit
        TEQ     r0, #Status_Received
        BNE     ConvertEconetError

        LDR     r0, Buffer       ; Get server return code
        CMP     r0, #0           ; Has there been an error?
        ADR     r0, Buffer       ; Get address of reply
        BNE     DeAllocateExit   ; Yes, process error
        LDRB    r1, [ r0, #4 ]   ; Load server's port
        STRB    r1, Server_CommandPort

Exit
        STRVS   r0, [ sp, #0 ]   ; Poke error into return regs
        LDMFD   sp!, {r0-r8,pc}  ; Return to caller

BufferOverflowError
        &       ErrorNumber_BufferOverflow
        =       "Command too long for buffer", 0
```

```
        ALIGN

BufferOverflow
        ADR     r0, BufferOverflowError
DeAllocateExit
        MOV     r1, r0              ; Preserve the original error
        LDRB    r0, Server_ReplyPort
        SWI     XEconet_DeAllocatePort
        MOV     r0, r1              ; Ignore deallocation errors
        CMP     pc, #&80000000      ; Set V
        B       Exit                ; Exit through common point
```

Points to notice in the example are:

- the careful use of a single exit point
- the consistent return of errors (no matter what type)
- the opening of the receive block before doing the transmit
- the use of the 'X' form of SWIs.

It should be noted that the routine uses and manipulates global state as well as taking specific input and returning specific output.

Econet events

To allow Econet based programs to be kinder to other applications within the machine, it is possible for your program to be 'notified' when either a reception occurs or a transmission completes. This means that other applications can be using the time that your program would have spent polling, either inside Econet_DoTransmit or inside Econet_WaitForReception. This 'notification' is carried by an event. There are separate events for reception and for completion of transmission. These two events are:

14	Event_Econet_Rx
15	Event_Econet_Tx

On entry to the event vector:

- R0 will contain the event number, either Event_Econet_Rx or Event_Econet_Tx
- R1 will contain the receive or transmit handle as appropriate
- R2 will contain the status of the completed operation.

The status for receive will always be *Status_Received*, but for transmit it will indicate how the transmission completed. These events can be enabled and disabled in the normal way using OS_Byte calls.

Using events from the Wimp

If your program is a client of the Wimp then all your event routine need do is set a flag that your main program polls in its main Wimp polling loop, when the event happens.

```
Event   TEQ     r0, #Event_Econet_Rx
        TEQNE   r0, #Event_Econet_Tx
        MOVNE   pc, lr              ; If not, exit as fast as possible

        STMFD   sp!, { lr }         ; Must preserve all regs for others
        ADR     r14, ForegroundFlag
        STR     pc, [ r14 ]         ; Set flag with non-zero value
        LDMFD   sp!, { pc }         ; Return, without claiming vector
```

Setting up background tasks

Since the interfaces required for reception and transmission can be called from within event routines, you can set up background tasks that make full use of the facilities offered by Econet. Note that it is important to check that the handle offered in the event belongs to your program, since there may well be many programs using this facility. The example given below is of a simple background server for sending out the time. Not all of the code needed is shown, just the event routine:

```
Start   MOV     r0, #EventV         ; The vector we want to get on is the
Event
        ADR     r1, Event           ; Where to got when it happens
        MOV     r2, #0              ; Required so that we can release
        SWI     XOS_Claim

        MOVVC   r0, #14             ; Enable event
        MOV     r1, #Event_Econet_Rx
        SWIVC   XOS_Byte
        MOVVC   r0, #14             ; Enable event
        MOV     r1, #Event_Econet_Tx
        SWIVC   XOS_Byte

        MOVVC   r0, #CommandPort ; First open the reception
        MOV     r1, #0              ; From any station
        MOV     r2, #0              ; From any net
        ADR     r3, Buffer
        MOV     r4, #?Buffer
        SWIVC   XEconet_CreateReceive
        STRVC   r0, RxHandle
        MOV     pc, lr

Event   TEQ     r0, #Event_Econet_Rx
        BNE     LookForTx
        LDR     r0, RxHandle        ; Get our global state
        TEQ     r0, r1              ; Is it for us?
        MOVNE   r0, #Event_Econet_Rx
        MOVNE   pc, lr              ; If not, exit as fast as possible
```

```
        STMFD   sp!, { r3-r7 }  ; Only R1 and R2 are free for use
        MOV     r0, r1          ; Receive handle
        SWI     XEconet_ReadReceive ; R4.R3 is the reply address
        BVS     Exit

        MOV     r6, r3          ; Save the station number for later
        MOV     r0, #Module_Claim
        MOV     r3, #8 + 5      ; Two words and five bytes required
        SWI     XOS_Module      ; Memory MUST come from RMA
        BVS     Exit

        ADD     r1, r2, #8      ; Get the address of the 5 bytes
        MOV     r0, #3          ; Set OS_Word reason code
        STRB    r0, [ r1 ]      ; Read as a five byte time
        MOV     r0, #14         ; Read from the real time clock
        SWI     XOS_Word
        BVS     Exit

        MOV     r0, #0          ; Flag byte
        MOV     r3, r4          ; Network number
        MOV     r4, r1          ; Get the address of the 5 bytes
        LDRB    r1, [ r5 ]      ; The reply port the client sent
        MOV     r2, r6          ; Station number
        MOV     r5, #5          ; Number of bytes to send
        MOV     r6, #ReplyCount
        MOV     r7, #ReplyDelay
        SWI     XEconet_StartTransmit
        BVS     Exit

        SUB     r4, r2, #8      ; Note that the exit register is R2
not R4
        STR     r0, [ r4, #4 ]  ; Save TxHandle in record
        ADR     r1, TxList      ; Address of the head of the list
        LDR     r2, [ r1, #0 ]  ; Head of the list
        STR     r2, [ r4, #0 ]  ; Add the list to new record
        STR     r4, [ r1, #0 ]  ; Make this record the list head

        MOV     r0, #CommandPort ; Now re-open the reception
        MOV     r1, #0          ; From any station
        MOV     r2, #0          ; From any net
        ADR     r3, Buffer
        MOV     r4, #?Buffer
        SWI     XEconet_CreateReceive
        STRVC   r0, RxHandle
Exit
        LDMFD   sp!, { r3-r7, pc } ; Return claiming vector

LookForTx
        TEQ     r0, #Event_Econet_Tx
        MOVNE   pc, lr
        STMFD   sp!, { r3, lr } ; Get two extra registers
        ADR     r3, TxList      ; The address of the head of list
        LDR     r14, [ r3 ]     ; The first record in the list
        B       StartLooking
```



```
NextTx
        MOV     r3, r14         ; Search the next list entry
        LDR     r14, [ r3 ]     ; Get the link address
StartLooking
        CMP     r14, #0         ; Is this the end of the list?
        MOVLE   r0, #Event_Econet_Tx ; Restore entry conditions
        LDMLEFD sp!, { r3, pc } ; Return, continuing to next owner
        LDR     r0, [ r14, #4 ] ; Get the handle for this record
        TEQ     r0, r1          ; Is this event one of ours?
        BNE     NextTx          ; No, try next record in list

        LDR     r2, [ r14 ]     ; Get the remainder of the list
        STR     r2, [ r3 ]      ; Remove this record from list
        MOV     r2, r14         ; The record address for later
        SWI     XEconet_AbandonTransmit
        MOV     r0, #Module_Free
        SWI     XOS_Module      ; Return memory to RMA, ignore error
        LDMFD   sp!, { r3, lr, pc } ; Return, claiming vector
```

This program also illustrates some of the more advanced features of Econet. In particular, it shows the ability to specify reception control blocks that can accept messages from more than one machine, or on more than one port. Receive control blocks like this are referred to as *wild*, as in *wild card matching* used in file name look up. Specifying either the station or network number (usually both) as zero means 'match any'. The same is true of the port number, although this facility is much less useful! This wild facility does not mean that more than one packet can be received, but rather that more than one particular packet will be acceptable. Once a packet has been received, the RxCB has Status_Received and is no longer open.

It is worth noting an implementation detail here. Receive control blocks are kept by the Econet software in a list, when an incoming scout has been received the list is scanned to find the first RxCB that matches it. To ensure that things go as one would expect the Econet software that implements the SWI Econet_CreateReceive always adds wild RxCBs to the tail of the list, and normal RxCBs to the middle of the list (between the normal and the wild ones). This ensures that when packets arrive they will be checked for exact matches before wild matches, and that if there is more than one acceptable RxCB then the one used will be the one that was opened first, ie first in first served.

Broadcast transmissions

As a complement to this concept of wild receive control blocks there are broadcast transmissions. A broadcast has both its destination station and network set to &FF, it can then be received by more than one machine. To achieve this it does not use the normal four way handshake, it is in fact a single packet. On the NetMonitor it would look something like this:

```
FFFF1200809F5052494E54200100
```

The broadcast address at the beginning (&FF, &FF), the source station and network (&12, &00), the control byte (&80), and the port (&9F) are the same as a normal scout frame, but then the data follows, in this case eight bytes.

Although the Econet software within RISC OS can transmit and receive broadcast messages of up to 1020 bytes (RISC OS 2.0) or 1024 bytes (later versions), other machines on Econet can't cope with messages of more than eight bytes without getting confused; this confusion causes them to corrupt such broadcasts. These other machines include things like FileStores and bridges, so beware! It is possible to transmit and/or receive zero to eight bytes without them being corrupted, but only broadcasts of exactly eight bytes can be received by BBC or Master computers, as well as being transported from network to network by bridges.

Transmitting a broadcast is exactly the same as transmitting a normal packet, all you need to do is set the destination station and network to &FF (**not** -1).

Versions of RISC OS after 2.0 support a wider range of broadcasts, allowing local broadcasts (which are only seen on the local net) and long broadcasts (broadcasts of more than eight bytes, which new bridges will recognise and correctly propagate). To use these, set the station number to &FF, and the network number as follows:

Network	Range	Size
&FF	Global	Small (8 bytes maximum)
&FE	Global	Long (1020/1024 bytes maximum)
&FD	Local	Small (1020/1024 bytes maximum)
&FC	*reserved*	*reserved*

Broadcasts don't return the status *Status_NotListening*, since there is no way for the transmitting station to determine whether or not its broadcast was received. Broadcasts are basically designed for locating resources, ie to transmit your desire to know about a particular class of thing. Anything recognising the broadcast will reply, so you know what's what and where it is. NetFS uses broadcast to find file servers by name, and NetPrint uses broadcast to find printer servers. The above example contains the ASCII text 'PRINT' and is, not surprisingly, a request for all printer servers to respond.

Immediate operations

There is a second class of network operations called immediate operations. These operations don't require the explicit co-operation of the destination machine; instead the co-operation is provided by the Econet software in that machine. Immediate operations are similar semantically to normal transmissions but, because they have no need for a port number, have a type instead of a flag; and

most also require an extra input value. They have a separate pair of SWI calls to cause them to happen: Econet_StartImmediate (SWI &40016) and Econet_DoImmediate (SWI &40017).

The call Econet_StartImmediate returns a transmit handle in exactly the same way as Econet_StartTransmit and that handle should be polled and abandoned in the same way. The call Econet_DoImmediate returns a status just as Econet_DoTransmit does.

There are nine types of immediate operations:

1	Econet_Peek	Copy memory from the destination machine
2	Econet_Poke	Copy memory to the destination machine
3	Econet_JSR	Cause JSR/BL on the destination machine
4	Econet_UserProcedureCall	Execute User remote procedure call
5	Econet_OSProcedureCall	Execute OS remote procedure call
6	Econet_Halt	Halt the destination machine
7	Econet_Continue	Continue the destination machine
8	Econet_MachinePeek	Machine peek of the destination machine
9	Econet_GetRegisters	Return registers from the destination machine

The last one, Econet_GetRegisters, can only be transmitted by or received on RISC OS based machines, whereas all the others can be transmitted or received by BBC or Master series computers. The reason for this is that Econet_GetRegisters is specific to the ARM processor.

Econet_Peek and Poke

The poke operation is very similar to a transmit, in that data is moved from the transmitting station to the receiving station. The difference is that the address at which the data is received is supplied by the transmitting station. Peek is the inverse of poke; data is moved from the receiving station into the transmitting station.

Versions of RISC OS after 2.0 validate the address range to be transferred.

Econet_JSR, UserProcedureCall and OSProcedureCall

JSR, UserProcedureCall, and OSProcedureCall are all very similar. They send a small quantity of data, referred to as the argument buffer or arguments, to the destination machine; they then force it to execute a particular section of code. When received a JSR actually does a BL to the address given in R1, whereas UserProcedureCall and OSProcedureCall cause events to occur. These events are:

8	Event_Econet_UserRPC
16	Event_Econet_OSProc

After reception the arguments are buffered so that they may be used by the code that is called, either directly by a BL or indirectly via an event. The format of the Arguments buffer is as follows: word 0 is the length (in bytes) of the arguments, then the arguments follow this first word and may be null (ie the length may be zero).

Conditions on entry to event code

The conditions on entry to the event code are:

R0 = Event number (either Event_Econet_UserRPC or Event_Econet_OSProc)
R1 = Address of the argument buffer
R2 = RPC number (passed in R1 on the transmitting station)
R3 = Station that sent the RPC
R4 = Network that sent the RPC

Conditions on entry to JSR code

The conditions on entry to code that is BL'd to for a JSR are:

R1 = Address of the argument buffer
R2 = Address of the code being executed
R3 = Station that sent the JSR
R4 = Network that sent the JSR

Format of the argument buffer

The format of the argument buffer is exactly the same in all cases. If, in the case of a JSR, the call address transmitted from the remote station is –1 (&FFFFFFFF) then the execution address will be the argument buffer itself; this means that relocatable ARM code can be sent as a JSR. Registers R0 to R4 can be used as they are preserved by the Econet software, and R13 can also be used as an FD stack.

The transmission of Econet_OSProcedureCall is not intended for use by other than system software, and is only documented here for completeness. The transmission of Econet_JSR is only provided as a compatibility feature to allow interworking with BBC and Master computers.

Econet_UserProcedure calls

The Econet_UserProcedureCall is the best method for this style of communications. It does however have some restrictions. The first of these is the most important – it is executed in the destination machine as an event caused by an interrupt, and so it has all the normal restrictions applied to interrupt code. This means that code directly executed as a result of Event_Econet_UserRPC must be fast and clean, and must not call any of the normal input or output SWI routines nor call the filing system, either directly or indirectly. This is paramount if the integrity of the destination machine is to be ensured. However, you can copy away the arguments passed and signal to a foreground task (by altering a flag) that the procedure call has arrived. It is most important that you copy the arguments away, because the buffer that they are in is only valid for the duration of the event call. This means that R1 will point to the arguments whilst you are processing the event, but afterwards the argument buffer may be overwritten. If the requirements for the processing of the call are small then it is possible to do it all within the event. An example of this is a modification of the program presented earlier that returned the time. This new program sends the time in response to a User RPC, rather than a normal packet:

```
        Start   MOV     r0, #EventV       ; The vector we want to get on is the
Event
                ADR     r1, Event         ; Where to got when it happens
                MOV     r2, #0            ; Required so that we can release
                SWI     XOS_Claim

                MOVVC   r0, #14           ; Enable event
                STRVC   r0, ClaimedFlag ; Set it to a non-zero value
                MOV     r1, #Event_Econet_UserRPC
                SWIVC   XOS_Byte
                MOVVC   r0, #14           ; Enable event
                MOV     r1, #Event_Econet_Tx
                SWIVC   XOS_Byte
                MOV     pc, lr

        Event   TEQ     r0, #Event_Econet_UserRPC
                BNE     LookForTx
                TEQ     r2, #RPC_SendTime ; Is it for us?
                MOVNE   pc, lr            ; If not, exit as fast as possible

                LDR     r0, [ r1, #0 ]  ; Get size of arguments
                TEQ     r0, #1            ; Check that it is right
                MOVNE   r0, #Event_Econet_UserRPC ; Restore exit registers
                MOVNE   pc, lr            ; If not, exit as fast as possible

                STMFD   sp!, { r5-r7 }  ; Only R1 to R4 are free for use
                                          ; R4.R3 is the reply address
                MOV     r6, r3            ; Save the station number for later
                MOV     r5, r1            ; Preserve arguments pointer
                MOV     r0, #Module_Claim
                MOV     r3, #8 + 5        ; Two words and five bytes required
```

```
            SWI     XOS_Module      ; Memory MUST Come from RMA
            BVS     Exit

            ADD     r1, r2, #8      ; Get the address of the 5 bytes
            MOV     r0, #3          ; Set OS_Word reason code
            STRB    r0, [ r1 ]      ; Read as a five byte time
            MOV     r0, #14         ; Read from the real time clock
            SWI     XOS_Word
            BVS     Exit

            MOV     r0, #0          ; Flag byte
            MOV     r3, r4          ; Network number
            MOV     r4, r1          ; Get the address of the 5 bytes
            LDRB    r1, [ r5, #4 ]  ; The reply port the client sent
            MOV     r2, r6          ; Station number
            MOV     r5, #5          ; Number of bytes to send
            MOV     r6, #ReplyCount
            MOV     r7, #ReplyDelay
            SWI     XEconet_StartTransmit
            BVS     Exit

            SUB     r4, r2, #8      ; Note that the exit register is R2
not R4
            STR     r0, [ r4, #4 ]  ; Save TxHandle in record
            ADR     r1, TxList      ; Address of the head of the list
            LDR     r2, [ r1, #0 ]  ; Head of the list
            STR     r2, [ r4, #0 ]  ; Add the list to new record
            STR     r4, [ r1, #0 ]  ; Make this record the list head
        Exit
            LDMFD   sp!, { r5-r7, pc } ; Return claiming vector

        LookForTx
            TEQ     r0, #Event_Econet_Tx
            MOVNE   pc, lr          ; This event has only R0 to R2
            STMFD   sp!, { r3, lr } ; Get two extra registers
            ADR     r3, TxList      ; The address of the head of list
            LDR     r14, [ r3 ]     ; The first record in the list
            B       StartLooking
        NextTx
            MOV     r3, r14         ; Search the next list entry
            LDR     r14, [ r3 ]     ; Get the link address
        StartLooking
            CMP     r14, #0         ; Is this the end of the list?
            MOVLE   r0, #Event_Econet_Tx ; Restore entry conditions
            LDMLEFD sp!, { r3, pc } ; Return, continuing to next owner
```



```
            LDR     r0, [ r14, #4 ] ; Get the handle for this record
            TEQ     r0, r1          ; Is this event one of ours?
            BNE     NextTx          ; No, try next record in list

            LDR     r2, [ r14 ]     ; Get the remainder of the list
            STR     r2, [ r3 ]      ; Remove this record from list
            SWI     XEconet_AbandonTransmit
            MOV     r0, #Module_Free
            MOV     r2, r14         ; The record address
            SWI     XOS_Module      ; Return memory to RMA, ignore error
            LDMFD   sp!, { r3, lr, pc } ; Return, claiming vector
```

You will notice how much simpler this program is when compared to the program shown earlier.

Econet_OSProcedure calls

There are five defined OS procedure calls for which only two have implementations under RISC OS. The five are:

0	Econet_OSCharacterFromNotify
1	Econet_OSInitialiseRemote
2	Econet_OSGetViewParameters
3	Econet_OSCauseFatalError
4	Econet_OSCharacterFromRemote

OSCharacterFromNotify

Econet_OSCharacterFromNotify causes the character received to be inserted in to the keyboard buffer; the code that does so looks like this:

```
        InsertCharacter                 ; R1 already pointing at argument
buffer
            MOV     r0, #138            ; Insert into buffer OS_Byte
            LDRB    r2, [ r1, #4 ]      ; Get character from buffer
            MOV     r1, #0              ; Buffer is keyboard
            SWI     XOS_Byte
```

The NetFiler module provides a different implementation whilst the desktop is running.

OSCauseFatalError

Econet_OSCauseFatalError does exactly what its name implies. In fact it calls SWI OS_GenerateError directly from the event routine; normally this would be illegal, but since this is what the RPC is for, that is what it does. It should be observed that this can have a disastrous effect on the integrity of the machine and is not a recommended action; it is provided only for compatibility reasons.

Econet_Halt and Continue

Halt and continue are only acted upon by BBC and Master series machines; there is no implementation for receiving halt or continue on RISC OS machines or RISC iX machines.

Econet_MachinePeek

Machine peek is similar to peek, except that it is not possible to specify the address to be peeked, but rather four bytes are returned that identify the machine that is being machine peeked. Machine peek is used by some of the system software in RISC OS to quickly decide if a particular machine is present or not. The four bytes returned by machine peek are as follows:

Byte(s)	Value
1 and 2	Machine type number
3	Software version number
4	Software release number

Machine type numbers

Machine type numbers are as follows:

&0000	Reserved
&0001	Acorn BBC Micro Computer (OS 1 or OS 2)
&0002	Acorn Atom
&0003	Acorn System 3 or System 4
&0004	Acorn System 5
&0005	Acorn Master 128 (OS 3)
&0006	Acorn Electron (OS 0)
&0007	Acorn Archimedes (OS 6)
&0008	Reserved for Acorn
&0009	Acorn Communicator
&000A	Acorn Master 128 Econet Terminal
&000B	Acorn FileStore
&000C	Acorn Master 128 Compact (OS 5)
&000D	Acorn Ecolink card for Personal Computers
&000E	Acorn UNIX workstation
&000F to &FFF9	Reserved
&FFFA	SCSI Interface
&FFFB	SJ Research IBM PC Econet interface
&FFFC	Nascom 2
&FFFD	Research Machines 480Z
&FFFE	SJ Research File Server
&FFFF	Z80 CP/M

Software version and release number

The software version and release numbers are stored in two bytes. These two bytes are encoded in packed BCD (Binary Coded Decimal) and represent a number between 0 and 99. The easiest way to display packed BCD is to print it as if it was hexadecimal data:

```
ReportStationVersion
        MOV     r2, r0 ; Station number in R0
        MOV     r3, r1 ; Network number in R1
        MOV     r0, #Econet_MachinePeek
        ADR     r4, Buffer
        MOV     r5, #?Buffer
        MOV     r6, #0
        MOV     r7, #0
        SWI     XEconet_DoImmediate
        MOVVS   pc, lr
        TEQ     r0, #Status_Transmitted
        BEQ     PrintVersion
        TEQ     r0, #Status_NotListening ; "Not listening" from
Machine peek
        MOVEQ   r0, #Status_NotPresent  ; should return "Not present"
        ADR     r1, Buffer
        MOV     r2, #?Buffer
        SWI     XEconet_ConvertStatusToError
        MOV     pc, lr

PrintVersion
        LDR     r3, [ r2 ]        ; Buffer address on exit from SWI
        MOV     r0, r3, ASR #24 ; Get top byte
        ADR     r1, Buffer
        MOV     r2, #?Buffer
        SWI     XOS_ConvertHex2 ; Print BCD as hex
        SWIVC   XOS_Write0      ; Display output
        SWIVC   XOS_WriteI+"."  ; Divide release from version number
        MOVVC   r0, r3, ASR #16 ; Get version number in place
        ANDVC   r0, r0, #&FF    ; Only the version number
        ADRVC   r1, Buffer
        MOVVC   r2, #?Buffer
        SWIVC   XOS_ConvertHex2 ; Print BCD as hex
        SWIVC   XOS_Write0      ; Display output
        MOV     pc, lr
```

Econet_GetRegisters

Econet_GetRegisters is similar to machine peek, in that a fixed amount of information is returned from the destination machine; in this case it is 80 bytes (20 words). The registers are returned in the following order: R0 to R14, PC plus PSR, R13_irq, R14_irq, R13_svc, and R14_svc. The FIQ registers are not returned because they are used by the Econet software, and so would always be the same, and of no interest since they would reflect the state of the part of the Econet software that transmits data. It is worthwhile aligning the receive buffer for a machine peek so that each of the 20 words is on a word boundary; this makes loading them easier.

Protection against immediate operations

Because these immediate operations can be quite intrusive it is possible to prevent their reception by manipulating an internal variable of the Econet software. There is one bit in this internal variable for each operation, and you can set or clear each bit. There is also a default value for each bit which is held in CMOS RAM. The SWI that allows you to manipulate this internal variable is Econet_SetProtection (SWI &4000E). These bits are held in a single word; the bit assignments are as follows:

Bit	Immediate operation protected against
0	Peek
1	Poke
2	Remote JSR
3	User procedure call
4	OS procedure call
5	Halt – must be zero on RISC OS computers
6	Continue – must be zero on RISC OS computers
7	Machine peek
8	Get registers
9 - 30	Reserved – must be zero.
31	Write new value to the CMOS RAM

To protect against or disable the reception of a particular immediate operation, the appropriate bit should be set in the internal variable. The SWI Econet_SetProtection call replaces the OldValue with the NewValue. The NewValue is calculated like this:

NewValue = (OldValue AND R1) EOR R0.

Altering the protection held in CMOS RAM

When the Econet software is started up (as a result of Ctrl-Break, or *RMReInit) then the value held in CMOS RAM will be used to initialise the internal variable. To alter the value held in CMOS RAM the entry value of R0 to SWI Econet_SetProtection should have bit 31 set, which causes the resultant value to be written not only to the internal variable, but also to the CMOS RAM. Note that the use of Econet_ReadProtection (SWI &4000D) is deprecated; if you need to read the current value you should use SWI Econet_SetProtection with R0=0, and R1=&FFFFFFFF.

Reading your station and network numbers

To establish what your station number is and which network you are connected to (if you have more than one), the Econet software provides a call to return these two values: Econet_ReadLocalStationAndNet (SWI &4000A). If you don't have more than one network then the network number (returned in R1) will be zero.

These values are the same as those reported by *Help Station (in fact *Help Station calls SWI Econet_ReadLocalStationAndNet to get the values).

Extracting station numbers from a string

To ensure that all Econet oriented software presents a consistent user interface there is a SWI call to read a station and/or network number from a supplied string. This call, Econet_ReadStationNumber (SWI &4000F), is used by both NetFS and NetPrint for all their command line processing. In the case of software that has a concept of a current station (and network) number the return value of –1 should mean 'use the existing value' – this is how *FS works, for example. Where there isn't a current value, as would be expected in a transient command such as *Notify, the return of –1 for the station number should be treated as an error and the return of –1 as a network number should imply the use of zero as a network number. The following is the beginning (and some of the end) of a transient command:

```
CommandStart
        LDRB    r0, [ r1 ]          ; Check the first argument exists
        TEQ     r0, #0              ; Zero means no arguments
        BEQ     SyntaxError         ; Exit with error

        SWI     XEconet_ReadStationNumber
        MOVVS   pc, lr              ; Must be able to cope
        CMP     r2, #-1             ; No station number given
        BEQ     NoStationNumberError
        CMP     r3, #-1             ; No net number given
        MOVEQ   r3, #0              ; Means use zero

        MOV     pc, lr

SyntaxError
        ADR     r0, ErrorGetRegsSyntax
        ORRS    pc, lr, #VFlag

ErrorGetRegsSyntax
        &       ErrorNumber_Syntax
        =       "Syntax: *Command <Station number>"
        =       0
        ALIGN
```

```
NoStationNumberError
        ADR     r0, ErrorUnableToDefault
        ORRS    pc, lr, #VFlag

ErrorUnableToDefault
        &       ErrorNumber_UnableToDefault
        =       "Either a station number or a full"
                " network address is required"
        =       0
        ALIGN
```

Converting station and network to a string

There exist two inverse functions that convert a station and network number pair into a string, see the section on conversions for exact details.

Conventions and values

The following conventions apply to the various values that the Econet uses:

Station numbers

Station numbers are normally in the range 1 to 254. The station number zero is used in SWI Econet_CreateReceive to indicate that reception may occur from any station. The station number 255 is used in SWI Econet_StartTransmit and in SWI Econet_DoTransmit to indicate that a broadcast is to take place; it is also used in SWI Econet_CreateReceive to indicate that reception may occur from any station, and is to be preferred over the value zero for this purpose.

Network numbers

Network numbers are normally in the range 1 to 254. The value zero means the local network; in a SWI Econet_CreateReceive it is taken to indicate that reception may occur from any network. The network number 255 is used in SWI Econet_StartTransmit and in SWI Econet_DoTransmit to indicate that a broadcast is to take place. It is also used in SWI Econet_CreateReceive to indicate that reception may occur from any station; the use of zero to indicate wild reception is deprecated.

Although RISC OS fully supports top-bit-set network numbers (ie 128 - 254), certain Econet devices – such as bridges – will not propagate them, leading to problems. You should beware of this.

Port numbers

Port numbers are normally in the range 1 to 254, although the values &90 through &9F and &D0 through &D2 are reserved by Acorn for existing protocols. Port number zero is reserved. A port number of either zero or 255 in a reception indicates that the reception may occur regardless of the port number on the incoming packet. The use of zero to indicate wild reception is deprecated.

Flag bytes

Flag byte values are in the range 0 to 255 (&FF), but only the bottom seven bits are significant.

Transmission semantics

The transmission semantics are simple. When a transmission is started the client's control information (passed in registers) is stored in a record in a linked list within Econet workspace. At regular intervals the list is scanned, and those records that should be actually transmitted at that moment are passed to the FIQ software. When that particular transmission attempt completes the status of the record is changed accordingly. This means that if two transmissions are started at the same time, they will interleave their transmission retries.

When a transmission has completed but failed:

- if the count is non-zero the delay is added to the predicted start time to give the next start time
- otherwise the status is set to *Status_NotListening* (or *Status_NetError*).

This means that as far as possible the time out time will be the Delay multiplied by the Count.

Local loopback

Versions of RISC OS after 2.0 have added support for local loopback. Transmissions directed at your own station number will be 'received' if there is an acceptable receive block open by directly copying the data. This applies to broadcast transmissions and wild receptions as well as to calls that explicitly address your machine.

Service Calls

Service_ReAllocatePorts (Service Call &48)

Econet restarting

On entry

R1 = &48 (reason code)

On exit

R1 preserved to pass on (do not claim)

Use

This call is made whenever Econet restarts. It is then up to the Econet software to allocate ports, set up TxCBs and RxCBs, etc.

Service_EconetDying (Service Call &56)

Econet is about to leave

On entry

R1 = &56 (reason code)

On exit

R1 preserved to pass on (do not claim)

Use

This call is made whenever Econet is about to leave. It is then up to the Econet software to release ports, delete RxCBs and TxCBs etc.

SWI Calls

Econet_CreateReceive (SWI &40000)

Creates a Receive Control Block

On entry

R0 = port number
R1 = station number
R2 = network number
R3 = buffer address
R4 = buffer size in bytes

On exit

R0 = handle
R2 = 0 if R2 on entry is the local network number

Interrupts

Interrupts are disabled
Fast interrupts are enabled

Processor mode

Processor is in SVC mode

Re-entrancy

SWI is re-entrant

Use

This call creates a Receive Control Block (RxCB) to control the reception of an Econet packet. It returns a handle to the RxCB.

The buffer must remain available all the time that the RxCB is open, as data received over the Econet is read directly from hardware to the buffer. You must not use memory in application space if your program is to run under the Desktop. Instead, you should use memory from the RMA.

Related SWIs

None

Related vectors

None

Econet_ExamineReceive (SWI &40001)

Reads the status of an RxCB

On entry

R0 = handle

On exit

R0 = status

Interrupts

Interrupts are disabled
Fast interrupts are enabled

Processor mode

Processor is in SVC mode

Re-entrancy

SWI is re-entrant

Use

This call reads the status of an RxCB, which may be one of the following:

7	Status_RxReady
8	Status_Receiving
9	Status_Received

Related SWIs

Econet_WaitForReception (SWI &40004)

Related vectors

None

Econet_ReadReceive (SWI &40002)

Returns information about a reception, including the size of data

On entry

R0 = handle

On exit

R0 = status
R1 = 0, or flag byte if R0 = 9 (Status_Received) on exit
R2 = port number
R3 = station number
R4 = network number
R5 = buffer address
R6 = buffer size in bytes, or amount of data received if R0 = 9 on exit (Status_Received)

Interrupts

Interrupts are disabled
Fast interrupts are enabled

Processor mode

Processor is in SVC mode

Re-entrancy

SWI is re-entrant

Use

This call returns information about a reception; most importantly, it tells you how much data was received, if any, and the address of the buffer in which it was placed. The buffer address is the same as that passed to Econet_CreateReceive (SWI &40000). You can call this SWI before a reception has occurred.

The returned values in R3 and R4 (the network and station numbers) are those of the transmitting station if the status is Status_Received; otherwise they are the same values that were passed in to SWI Econet_CreateReceive.

Related SWIs

Econet_WaitForReception (SWI &40004)

Related vectors

None

Econet_AbandonReceive (SWI &40003)

Abandons an RxCB

On entry

R0 = handle

On exit

R0 = status

Interrupts

Interrupts are disabled
Fast interrupts are enabled

Processor mode

Processor is in SVC mode

Re-entrancy

SWI is re-entrant

Use

This call abandons an RxCB, returning its memory to the RMA. The reception may have completed (R0 = 9 – Status_Received – on exit), in which case the data is lost.

Related SWIs

Econet_WaitForReception (SWI &40004)

Related vectors

None

Econet_WaitForReception (SWI &40004)

Polls an RxCB, reads its status, and abandons it

On entry

R0 = handle
R1 = delay in centiseconds
R2 = 0 to ignore Escape; else Escape ends waiting

On exit

R0 = status
R1 = 0, or flag byte if R0 = 9 (Status_Received) on exit
R2 = port number
R3 = station number
R4 = network number
R5 = buffer address
R6 = buffer size in bytes, or amount of data received if R0 = 9 on exit (Status_Received)

Interrupts

Interrupts are disabled
Fast interrupts are enabled

Processor mode

Processor is in SVC mode

Re-entrancy

SWI is not re-entrant

Use

This call repeatedly polls an RxCB (that you have already set up with Econet_CreateReceive) until a reception occurs, or a timeout occurs, or the user interferes (say by pressing Escape). It then reads the status of the RxCB before abandoning it.

The returned values in R3 and R4 (the network and station numbers) are those of the transmitting station if the status is Status_Received; otherwise they are the same values that were passed in to SWI Econet_CreateReceive.

Note that this interface enables interrupts and so can not be called from within either interrupt service code or event routines.

Related SWIs

Econet_ExamineReceive (SWI &40001), Econet_ReadReceive (SWI &40002), and Econet_AbandonReceive (SWI &40003)

Related vectors

None

Econet_EnumerateReceive (SWI &40005)

On entry

R0 = index (1 to start with first receive block)

On exit

R0 = handle (0 if no more receive blocks)

Interrupts

Interrupt status is undefined
Fast interrupts are enabled

Processor mode

Processor is in SVC mode

Re-entrancy

Not defined

Use

This call returns the handles of open RxCBs. On entry R0 is the number of the RxCB being asked for (1, 2, 3...). If the value of R0 is greater than the number of open RxCBs, then the value returned as the handle will be 0, which is an invalid handle.

Related SWIs

Econet_CreateReceive (SWI &40000),
Econet_AbandonReceive (SWI &40003), and
Econet_WaitForReception (SWI &40004)

Related vectors

None

Econet_StartTransmit (SWI &40006)

Creates a Transmit Control Block and starts a transmission

On entry

R0 = flag byte
R1 = port number
R2 = station number
R3 = network number
R4 = buffer address
R5 = buffer size in bytes (less than 8 k)
R6 = count
R7 = delay in centiseconds

On exit

R0 = handle
R1 corrupted
R2 = buffer address
R3 = station number
R4 = network number

Interrupts

Interrupts are disabled
Fast interrupts are enabled

Processor mode

Processor is in SVC mode

Re-entrancy

SWI is re-entrant

Use

This call creates a Transmit Control Block (TxCB) to control the transmission of an Econet packet. It then starts the transmission.

The value returned in R4 (the network number) will be the same as that passed in R3 unless that number is equal to the local network number; in that case the network number will be returned as zero.

Related SWIs

Econet_DoTransmit (SWI &40009)

Related vectors

None

Econet_PollTransmit (SWI &40007)

Reads the status of a TxCB

On entry

R0 = handle

On exit

R0 = status

Interrupts

Interrupts are disabled
Fast interrupts are enabled

Processor mode

Processor is in SVC mode

Re-entrancy

SWI is re-entrant

Use

This call reads the status of a TxCB, which may be one of the following:

0	Status_Transmitted
1	Status_LineJammed
2	Status_NetError
3	Status_NotListening
4	Status_NoClock
5	Status_TxReady
6	Status_Transmitting

Related SWIs

Econet_DoTransmit (SWI &40009)

Related vectors

None

Econet_AbandonTransmit (SWI &40008)

Abandons a TxCB

On entry

R0 = handle

On exit

R0 = status

Interrupts

Interrupts are disabled
Fast interrupts are enabled

Processor mode

Processor is in SVC mode

Re-entrancy

SWI is re-entrant

Use

This call abandons a TxCB, returning its memory to the RMA.

Related SWIs

Econet_DoTransmit (SWI &40009)

Related vectors

None

Econet_DoTransmit (SWI &40009)

Creates a TxCB, polls it, reads its status, and abandons it

On entry

R0 = flag byte
R1 = port number
R2 = station number
R3 = network number
R4 = buffer address
R5 = buffer size in bytes (less than 8k)
R6 = count
R7 = delay in centiseconds

On exit

R0 = status
R1 corrupted
R2 = buffer address
R3 = station number
R4 = network number

Interrupts

Interrupts are enabled
Fast interrupts are enabled

Processor mode

Processor is in SVC mode

Re-entrancy

SWI is not re-entrant

Use

This call creates a TxCB and repeatedly polls it until it finishes transmission, or it exceeds the count of retries. It then reads the final status of the TxCB before abandoning it.

The value returned in R4 (the network number) will be the same as that passed in R3 unless that number is equal to the local network number; in that case the network number will be returned as zero.

Related SWIs

Econet_StartTransmit (SWI &40006), Econet_PollTransmit (SWI &40007), and Econet_AbandonTransmit (SWI &40008)

Related vectors

None

Econet_ReadLocalStationAndNet (SWI &4000A)

Returns a computer's station number and network number

On entry

No parameters passed in registers

On exit

R0 = station number
R1 = network number

Interrupts

Interrupts are enabled
Fast interrupts are enabled

Processor mode

Processor is in SVC mode

Re-entrancy

SWI is not re-entrant

Use

This call returns a computer's station number and network number. The network number will be zero if there are no Econet bridges present on the network.

Related SWIs

None

Related vectors

None

Econet_ConvertStatusToString (SWI &4000B)

Converts a status to a string

On entry

R0 = status
R1 = pointer to buffer
R2 = buffer size in bytes
R3 = station number
R4 = network number

On exit

R0 = buffer
R1 = updated buffer address
R2 = updated buffer size in bytes

Interrupts

Interrupt status is unaltered
Fast interrupts are enabled

Processor mode

Processor is in SVC mode

Re-entrancy

SWI is re-entrant

Use

This call converts a status to a string held in the RISC OS ROM. This is then copied into RAM, preceded by the station and network numbers, giving a string such as:

```
Station 59.254 not listening
```

Related SWIs

Econet_ConvertStatusToError (SWI &4000C)

Related vectors

None

Econet_ConvertStatusToError (SWI &4000C)

Converts a status to a string, and then generates an error

On entry

R0 = status
R1 = pointer to error buffer
R2 = error buffer size in bytes
R3 = station number
R4 = network number

On exit

R0 = pointer to error block
V flag is set

Interrupts

Interrupt status is unaltered
Fast interrupts are enabled

Processor mode

Processor is in SVC mode

Re-entrancy

SWI is re-entrant

Use

This call converts a status to a string held in the RISC OS ROM. This is then copied into RAM, preceded by the station and network numbers, giving a string such as:

```
Station 59.254 not listening
```

Finally this call returns an error by setting the V flag, with R0 pointing to the error block.

If you use a buffer address of zero, then the string is not copied into RAM. On exit, R0 will point to the ROM string instead (which, of course, excludes the station and network numbers).

Related SWIs

Econet_ConvertStatusToString (SWI &4000B)

Related vectors

None

Econet_ReadProtection (SWI &4000D)

Reads the current protection word for immediate operations

On entry

No parameters passed in registers

On exit

R0 = current protection value

Interrupts

Interrupt status is undefined
Fast interrupts are enabled

Processor mode

Processor is in SVC mode

Re-entrancy

Not defined

Use

This call reads the current protection word for immediate operations. Various bits in the word, when set, disable corresponding immediate operations:

Bit	Immediate operation
0	Peek
1	Poke
2	Remote JSR
3	User procedure call
4	OS procedure call
5	Halt – must be zero on RISC OS computers
6	Continue – must be zero on RISC OS computers
7	Machine peek
8	Get registers
9 - 31	Reserved – must be zero

Note – You should preferably use the call Econet_SetProtection (SWI &4000E) to read the protection word instead of this call.

Related SWIs

Econet_SetProtection (SWI &4000E)

Related vectors

None

Econet_SetProtection (SWI &4000E)

Sets or reads the protection word for immediate operations

On entry

R0 = EOR mask word
R1 = AND mask word

On exit

R0 = old value

Interrupts

Interrupt status is undefined
Fast interrupts are enabled

Processor mode

Processor is in SVC mode

Re-entrancy

SWI is not re-entrant

Use

This call sets the protection word for immediate operations as follows:

New value = (old value AND R1) EOR R0

Various bits in the word, when set, disable corresponding immediate operations:

Bit	Immediate operation
0	Peek
1	Poke
2	Remote JSR
3	User procedure call
4	OS procedure call
5	Halt
6	Continue – must be zero on RISC OS computers
7	Machine peek – must be zero on RISC OS computers

8	Get registers
9 - 30	Reserved – must be zero
31	Write new value to the CMOS RAM

Normally this call sets or reads the current value of the word. A default value for this word is held in CMOS RAM.

The most useful values of R0 and R1 are:

Action	R0	R1
Set current value	new value (0 - &1FF)	0
Read current value	0	&FFFFFFFF
Set default value	&80000000 + new value	0

You should use this call to read the value of the protection word, rather than Econet_ReadProtection (SWI &4000D).

Related SWIs

None

Related vectors

None

Econet_ReadStationNumber (SWI &4000F)

Extracts a station and/or network number from a supplied string

On entry

R1 = address of string to read

On exit

R1 = address of terminating space or control character
R2 = station number (–1 for not found)
R3 = network number (–1 for not found)

Interrupts

Interrupts are enabled
Fast interrupts are enabled

Processor mode

Processor is in SVC mode

Re-entrancy

SWI is re-entrant

Use

This call extracts a station and/or network number from a supplied string

Related SWIs

None

Related vectors

None

Econet_PrintBanner (SWI &40010)

Prints the string 'Acorn Econet' followed by a newline

On entry

No parameters passed in registers

On exit

No values returned in registers

Interrupts

Interrupts are enabled
Fast interrupts are enabled

Processor mode

Processor is in SVC mode

Re-entrancy

SWI is not re-entrant

Use

This call prints the string 'Acorn Econet' followed by a newline. It calls OS_Write0 and OS_NewLine and so can not be called from within either interrupt service code or event routines.

If the Econet network data clock is not present then the text ' no clock' is appended to the banner.

Related SWIs

None

Related vectors

None

Econet_ReleasePort (SWI &40012)

Releases a port number that was previously claimed

On entry

R0 = port number

On exit

—

Interrupts

Interrupts are disabled
Fast interrupts are enabled

Processor mode

Processor is in SVC mode

Re-entrancy

SWI is not re-entrant

Use

This call releases a port number that was previously claimed by calling Econet_ClaimPort (SWI &40015).

You must not use this call for port numbers that have been previously claimed using Econet_AllocatePort (SWI &40013); instead, you must call Econet_DeAllocatePort (SWI &40014).

Related SWIs

Econet_ClaimPort (SWI &40015)

Related vectors

None

Econet_AllocatePort (SWI &40013)

Allocates a unique port number

On entry

No parameters passed in registers

On exit

R0 = port number

Interrupts

Interrupts are disabled
Fast interrupts are enabled

Processor mode

Processor is in SVC mode

Re-entrancy

SWI is not re-entrant

Use

This call allocates a unique port number that has not already been claimed or allocated.

When you have finished using the port number, you should call Econet_DeAllocatePort (SWI &40014) to make it available for use again.

Related SWIs

Econet_DeAllocatePort (SWI &40014)

Related vectors

None

Econet_DeAllocatePort (SWI &40014)

Deallocates a port number that was previously allocated

On entry

R0 = port number

On exit

—

Interrupts

Interrupts are disabled
Fast interrupts are enabled

Processor mode

Processor is in SVC mode

Re-entrancy

SWI is not re-entrant

Use

This call deallocates a port number that was previously allocated by calling Econet_AllocatePort (SWI &40013).

You must not use this call for port numbers that have been previously claimed using Econet_ClaimPort (SWI &40015); instead, you must call Econet_ReleasePort (SWI &40012).

Related SWIs

Econet_AllocatePort (SWI &40013)

Related vectors

None

Econet_ClaimPort (SWI &40015)

On entry

R0 = port number

On exit

—

Interrupts

Interrupts are disabled
Fast interrupts are enabled

Processor mode

Processor is in SVC mode

Re-entrancy

SWI is not re-entrant

Use

This call claims a specific port number. If it has already been claimed or allocated, an error is generated.

When you have finished using the port number, you should call Econet_ReleasePort (SWI &40012) to make it available for use again.

Related SWIs

Econet_ReleasePort (SWI &40012)

Related vectors

None

Econet_StartImmediate (SWI &40016)

Creates a TxCB and starts an immediate operation

On entry

R0 = operation type
R1 = remote address or Procedure number
R2 = station number
R3 = network number
R4 = buffer address
R5 = buffer size in bytes (less than 8k)
R6 = count
R7 = delay in centiseconds

On exit

R0 = handle
R1 corrupted
R2 = buffer address
R3 = station number
R4 = network number

Interrupts

Interrupts are disabled
Fast interrupts are enabled

Processor mode

Processor is in SVC mode

Re-entrancy

SWI is re-entrant

Use

This call creates a TxCB and starts an immediate operation. For full details see the section entitled *Immediate operations* on page 6-18.

The value returned in R4 (the network number) will be the same as that passed in R3 unless that number is equal to the local network number; in that case the network number will be returned as zero.

Related SWIs

Econet_DoImmediate (SWI &40017)

Related vectors

None

Econet_DoImmediate (SWI &40017)

Creates a TxCB for an immediate operation, polls it, reads its status, and abandons it

On entry

R0 = operation type
R1 = remote address or procedure number
R2 = station number
R3 = network number
R4 = buffer address
R5 = buffer size in bytes (less than 8k)
R6 = count
R7 = delay in centiseconds

On exit

R0 = status
R1 corrupted
R2 = buffer address
R3 = station number
R4 = network number

Interrupts

Interrupts are enabled
Fast interrupts are enabled

Processor mode

Processor is in SVC mode

Re-entrancy

SWI is re-entrant

Use

This call creates a TxCB for an immediate operation, and repeatedly polls it until it finishes transmission or it exceeds the count of retries. It then reads the final status of the TxCB before abandoning it. For full details see the section entitled *Immediate operations* on page 6-18.

The value returned in R4 (the network number) will be the same as that passed in R3 unless that number is equal to the local network number; in that case the network number will be returned as zero.

Related SWIs

Econet_StartImmediate (SWI &40016)

Related vectors

None

* Commands

The only * Command the Econet module responds to is *Help Station, which displays the current network and station numbers of the machine. It also displays a 'No clock' message if applicable. For more details of the *Help command, see page 2-455.

67 The Broadcast Loader

Introduction and Overview

The Broadcast Loader is a module, loaded into Archimedes RISC OS client machines, that enables files to be effectively broadcast to multiple clients, effectively increasing Econet transport throughput. It works in the following way:

When a client requests a file from the file server, it first broadcasts a request onto the network to ask if any other clients are loading the same file. If no other client is loading it, then it proceeds to load the file itself from the fileserver as normal. If during the loading process other clients ask for the same file, then they are acknowledged by the first client, and they wait for the first client to finish loading the file after which it then broadcasts the file to all the waiting clients.

Performance

The Broadcast Loader greatly reduces the time taken to load the same file or application to a number of users. To a first approximation, the performance of a system using the Broadcast Loader to load a long file to *n* Clients will be 2 × (time to load single copy) as opposed to *n* × (time to load single copy).

Transport of long broadcasts

The use of broadcast messages using the standard broadcast packet but with a packet size of more than eight bytes has the disadvantage that any BBC or Master equipment or Bridge that is present on the network will effectively abort the transmission by enabling their transmitters and causing a collision after the reception of the eighth byte. The following broadcast packet types are not interfered with in such a manner:

Net Number	Station	Packet Type
FF	FF	8 Byte Global Broadcast
FE	FF	N Byte Global Broadcast
FD	FF	N Byte Local Broadcast

Local broadcasts

The Broadcast Loader utilises the N Byte Local Broadcast packet type. This ensures that broadcast loading is restricted to network zero and does not transverse bridges.

FileSwitch call interception

The Broadcast Loader works by intercepting some FileSwitch calls to NetFSEntry_File and dealing with them as appropriate. This is done using the SWI OS_FSControl (13) to return a pointer to the FileSwitch copy of the NetFS filing system control block, that has been modified to be non-relocatable. The Broadcast Loader then modifies the data pointed to so that when FileSwitch despatches calls to NetFSEntry_File they are in fact despatched to the Broadcast Loader first.

Files supported

When FileSwitch calls NetFS to load a file (as a result of a call to OS_File) the Broadcast Loader will attempt to load the file. Under RISC OS 2.00 the loading of Sprite and Template files does **not** result in a call to OS_File(Load), so an extra module BroadcastLoaderUtils has been provided to translate these to operations so that they do call OS_File(Load). The broadcast loading of Sprite and Template files improves application start up time.

All of the Acorn file servers, Level 2, Level 3, FileStore and Level 4 are compatible with the software as well as the SJ Research MDFS products. It can work with files on any standard media type, including Winchester or floppy disc, SCSI, and ADFS.

Maximum number of client computers supported

A Broadcast Loader server can have up to 252 client computers. However, in practice, the number of client computers is determined by the type and configuration of the file server. For example, Level 4 File Server can only support a maximum of 128 users logged on at any time.

Retransmission and errors

Files are transmitted from broadcast server to clients in chunks of approximately one thousand bytes with sequence numbers. If a client enters the transaction during the file transfer, or misses a packet due to transmission errors or other reasons, then 'chunk requests' for missing blocks are made and retransmissions made to complete the transaction. A system of timeouts and error messages is provided to ensure no lock-up or erroneous condition can occur.

68 BBC Econet

Introduction and Overview

The BBC Econet module provides emulation of certain obsolete OSBYTE and OSWORD calls used by old 6502-based BBC computers, thus making it easier for you to port code that uses these calls.

This module is provided solely to support old programs. You should not use these calls in any new programs you write.

Technical details

Summary of calls

The following calls are provided, which emulate the corresponding obsolete OSBYTE and OSWORD calls:

Call	Notes
OS_Byte 50	
OS_Byte 51	
OS_Byte 52	
OS_Word 16	All 8 sub-reason codes are emulated (Transmit, Peek, Poke, JSR, User Procedure Call, Machine type, Halt and Continue)
OS_Word 17	Both sub-reason codes are emulated (OpenRx and ReadRx)
OS_Word 19	Only these function codes are supported: 0 read file server number 1 write file server number 2 read printer server number 3 write printer server number 4 read protection mask 5 write protection mask 8 read local station number 12 read printer server name 13 set printer server name 15 read file server retry delay 16 set file server retry delay 17 translate net number
OS_Word 20	All 3 sub-reason codes are supported (Do File Server Operation, Notify, and Cause Remote Error)

Correspondence between old and new calls

All the above calls use exactly the same parameters as the corresponding obsolete OSBYTE and OSWORD calls. The table below shows the correspondence between the register used on the 6502 to pass a parameter, and the register used on the ARM to pass the same parameter:

6502 register	ARM register
A	R0 (bits 0-7)
X	R1 (bits 0-7)
Y	R2 (bits 0-7)

Bits 8-31 of the ARM registers are ignored.

For more information on any of the obsolete OSBYTE and OSWORD calls, see the *Econet Advanced User Guide*.

Implementation

The BBC Econet module claims the ByteV and WordV vectors. If it recognises an OS_Byte or OS_Word as one that it supports, it first checks the presence of the module(s) that it needs to emulate the call. (These are Econet, NetFS and/or NetPrint.) It then translates the OS_Byte or OS_Word call to appropriate SWI call(s) to these modules.

69 Hourglass

Introduction and Overview

The Hourglass module will change the pointer shape to that of an Hourglass. You can optionally also display:

- a percentage figure
- two 'LED' indicators for status information (one above the Hourglass, and one below).

Note that cursor shapes 3 and 4 are used (and hence corrupted) by the Hourglass. You should not use these shapes in your programs.

Normally the Hourglass module is used to display an hourglass on the screen whenever there is prolonged activity on the Econet. The calls to do so are made by the NetStatus module, which claims the EconetV vector. See the chapter entitled *Software vectors* on page 1-59 and the chapter entitled *NetStatus* on page 6-83 for further details.

The rest of this chapter details the SWIs used to control the Hourglass.

SWI Calls

Hourglass_On (SWI &406C0)

Turns on the Hourglass

On entry

—

On exit

—

Interrupts

Interrupt status is undefined
Fast interrupts are enabled

Processor mode

Processor is in SVC mode

Re-entrancy

Not defined

Use

This turns on the Hourglass. Although control return immediately there is a delay of 1/3 of a second before the Hourglass becomes visible. Thus you can bracket an operation by Hourglass_On/Hourglass_Off so that the Hourglass will only be displayed if the operation takes longer than 1/3 of a second.

You can set a different delay using Hourglass_Start (SWI &406C3).

Hourglass_On's are nestable. If the Hourglass is already visible then a count is incremented and the Hourglass will remain visible until an equivalent number of Hourglass_Off's are done. The LEDs and percentage indicators remain unchanged.

Related SWIs

Hourglass_Off (SWI &406C1), Hourglass_Start (SWI &406C3)

Related vectors

None

Hourglass_Off (SWI &406C1)

Turns off the Hourglass

On entry

—

On exit

—

Interrupts

Interrupt status is undefined
Fast interrupts are enabled

Processor mode

Processor is in SVC mode

Re-entrancy

Not defined

Use

This call decreases the count of the number of times that the Hourglass has been turned on. If this makes the count zero, it turns off the Hourglass.

When the Hourglass is removed the pointer number and colours are restored to those in use at the first Hourglass_On.

Versions of RISC OS after 2.0 also turn the percentage display off if leaving the level that turned it on, even if the hourglass itself is not turned off. See page 6-80 for an example of this.

Related SWIs

Hourglass_On (SWI &406C0), Hourglass_Smash (SWI &406C2)

Related vectors

None

Hourglass_Smash (SWI &406C2)

Turns off the Hourglass immediately

On entry

—

On exit

—

Interrupts

Interrupt status is undefined
Fast interrupts are enabled

Processor mode

Processor is in SVC mode

Re-entrancy

Not defined

Use

This call turns off the Hourglass immediately, taking no notice of the count of nested Hourglass_On's. If you use this call you must be sure neither you, nor anyone else, should be displaying an Hourglass.

When the Hourglass is removed the pointer number and colours are restored to those in use at the first Hourglass_On, except under RISC OS 2.0.

Related SWIs

Hourglass_Off (SWI &406C1)

Related vectors

None

Hourglass_Start (SWI &406C3)

Turns on the Hourglass after a given delay

On entry

R0 = delay before start-up (in centi-seconds), or 0 to suppress the Hourglass

On exit

—

Interrupts

Interrupt status is undefined
Fast interrupts are enabled

Processor mode

Processor is in SVC mode

Re-entrancy

Not defined

Use

This call works in the same way as Hourglass_On, except you can specify your own start-up delay.

If you specify a delay of zero and the Hourglass is currently off, then future Hourglass_On and Hourglass_Start calls have no effect. The condition is terminated by the matching Hourglass_Off, or by an Hourglass_Smash.

Related SWIs

Hourglass_On (SWI &406C0), Hourglass_Off (SWI &406C1)

Related vectors

None

Hourglass_Percentage (SWI &406C4)

Displays a percentage below the Hourglass

On entry

R0 = percentage to display (if in range 0 - 99), else turns off percentage

On exit

—

Interrupts

Interrupt status is undefined
Fast interrupts are enabled

Processor mode

Processor is in SVC mode

Re-entrancy

Not defined

Use

This call controls the display of a percentage below the Hourglass. If R0 is in the range 0-99 the value is displayed; if it is outside this range, the percentage display is turned off.

The default condition of an Hourglass is not to display percentages.

Versions of RISC OS after 2.0 do not allow lower levels of calls to alter the hourglass percentage once a higher level call is using it. Furthermore, Hourglass_Off automatically turns the percentage display off when leaving the level that turned it on, even if the hourglass itself is not turned off. For example:

```
SYS "Hourglass_On"
  SYS "Hourglass_On"
  SYS "Hourglass_Percentage",10           :REM sets to 10%
  SYS "Hourglass_Percentage",20           :REM sets to 20%
    SYS "Hourglass_On"
    SYS "Hourglass_Percentage",30         :REM DOESN'T set to 30%
    SYS "Hourglass_Off"
  SYS "Hourglass_Percentage",30           :REM sets to 30%
  SYS "Hourglass_Off"                     :REM turns off percentages
SYS "Hourglass_Off"                       :REM turns off hourglass
```

Related SWIs

None

Related vectors

None

Hourglass_LEDs (SWI &406C5)

Controls the display indicators above and below the Hourglass

On entry

R0, R1 = values used to set LEDs' word

On exit

R0 = old value of LEDs' word

Interrupts

Interrupt status is undefined
Fast interrupts are enabled

Processor mode

Processor is in SVC mode

Re-entrancy

Not defined

Use

This call controls the two display indicators above and below the Hourglass, which can be used to display status information. These are controlled by bits 0 and 1 respectively of the LEDs' word. The indicator is on if the bit is set, and off if the bit is clear. The new value of the word is set as follows:

New value = (Old value AND R1) XOR R0

The default condition is all indicators off.

Related SWIs

None

Related vectors

None

Hourglass_Colours (SWI &406C6)

Sets the colours used to display the Hourglass

On entry

R0 = new colour to use as colour 1 (&00BBGGRR, or –1 for no change)
R1 = new colour to use as colour 3 (&00BBGGRR, or –1 for no change)

On exit

R0 = old colour being used as colour 1
R1 = old colour being used as colour 3

Interrupts

Interrupt status is undefined
Fast interrupts are enabled

Processor mode

Processor is in SVC mode

Re-entrancy

Not defined

Use

This call sets the colours used to display the hourglass. Alternatively you can use this call to read the current hourglass colours by passing parameters of –1.

The default colours are:

Colour 1	cyan
Colour 3	blue

This call is not available in RISC OS 2.0.

Related SWIs

None

Related vectors

None

70 NetStatus

Introduction and Overview

The NetStatus module controls the display of an hourglass on the screen whenever there is prolonged activity on the Econet.

It claims EconetV, and examines the reason for each call that is made to the vector. It in turn makes an appropriate call to the Hourglass module, so that the appearance of the Hourglass indicates the status of the net. The Hourglass has two 'LEDs', one on top and one on the bottom:

- if only the top LED is on, then your station is trying to receive
- if only the bottom LED is on, then your station is trying to transmit
- if both LEDs are on, then your station is waiting for a broadcast reply.

It also displays percentage figures (when it is able to do so meaningfully) which show the percentage of a transfer that has completed.

Technical Details

This table shows how NetStatus converts the reason codes for calls to EconetV (listed in the chapter entitled *Software vectors*) into the SWI calls that it makes to the Hourglass module:

Reason code	SWI call
NetFS_Start...	Hourglass_On
NetFS_Part...	Hourglass_Percentage
NetFS_Finish...	Hourglass_Off
NetFS_StartWait	Hourglass_LEDs (both on)
Econet_StartTransmission	Hourglass_LEDs (only top one on)
Econet_StartReception	Hourglass_LEDs (only bottom one on)
NetFS_FinishWait	Hourglass_LEDs (both off)
Econet_FinishTransmission	Hourglass_LEDs (both off)
Econet_FinishReception	Hourglass_LEDs (both off)

Versions of RISC OS after 2.0 also change the colour of the hourglass for Broadcast Load and Save calls (as made by the Broadcast Loader). The colours used are:

Type of call	Colours
Broadcast Load	Green/blue
Broadcast Save	Red/blue

71 Expansion Cards and Extension ROMS

Introduction

Expansion Cards provide you with a way to add hardware to your RISC OS computer. They plug into slots provided in the computer, typically in the form of a backplane (these are an optional extra on some models).

Extension ROMs are ROMs fitted in addition to the main ROM set, which provide software modules which are automatically loaded by RISC OS on power-on. Note that **RISC OS 2 does not support extension ROMs**.

This chapter gives details of the software that RISC OS provides to manage and communicate with expansion cards and extension ROMs. It also gives details of what software and data needs to be provided by your expansion cards and extension ROMs for RISC OS to communicate with them; in short, all you need to know to write their software.

The two topics are covered together because both use substantially the same layout of code and data, and the same SWIs. For more information on extension ROMs see the chapter entitled *Extension ROMs* on page 1-473. For more details on writing modules, see the chapter entitled *Modules* on page 1-191.

One thing this chapter does not tell you is how to design the hardware. This is because:

- the range of hardware that can be added to a RISC OS computer is so large that we can't examine them all
- we don't have the space to describe every RISC OS computer that Acorn makes

Instead, you should see the further sources of information to which we refer you.

Overview

RISC OS computers can support internal slots for expansion cards. If you wish to add more cards than can be fitted to the supplied slots, you must use one of the slots to support an expansion card that buffers the signals on the expansion card bus before passing them on to external expansion cards.

Some RISC OS computers can also support extension ROMs. The availability, size and number of extension ROM sockets depends on which type of RISC OS computer you are using. For example, the A5000 has a single socket for an 8 bit wide ROM.

Software

Expansion cards

Expansion cards can have some or all of the following software included:

- an Expansion Card Identity, to give RISC OS information about the card (see page 6-89 and page 6-91)
- Interrupt Status Pointers, to tell RISC OS where to look to find out if the card is generating interrupts (see page 6-96)
- a Chunk Directory, that defines what separate parts of the card's memory space are used for (see page 6-97)
- a Loader, to access paged memory held outside the card's address space (see page 6-99)

A wide range of different types of code and data is supported by the Chunk Directories.

The use of the Loader and paged memory has been made as transparent to the end user as possible.

Extension ROMs

Extension ROMs must include the following software:

- an Extension ROM Header, to give RISC OS information about the ROM and to differentiate it from an expansion card (see page 6-88)
- an Extended Expansion Card Identity, to give RISC OS information about the ROM (see page 6-91)
- null Interrupt Status Pointers, because a ROM cannot generate interrupts (see page 6-96)

- a Chunk Directory, that defines what separate parts of the ROM's memory space are used for (see page 6-97).

Technical Details

In general, RISC OS recognises extension ROMs or ROM sets which are 8, 16 or 32 bits wide, provided the ROM adheres to the specification below. 32 bit wide extension ROM sets are directly executable in place, saving on user RAM. 8 or 16 bit wide sets have to be copied into RAM to execute.

An extension ROM set must end on a 64K boundary or at the start of another extension ROM. This is normally not a problem as it is unlikely you would want to use a ROM smaller than a 27128 (16K), and the normal way of addressing this would mean that the ROM would be visible in 1 byte out of each word, ie within a 64K addressable area.

Extension ROM Headers

Extension ROMs must have a 16 byte *Extension* ROM *Header* at the **end** of the ROM image, which indicates the presence of a valid extension ROM. The 'header' is at the end because RISC OS scans the ROM area downwards from the top.

For a ROM image of size *n* bytes, the format of the header at the end is as follows:

Byte address	Contents
n-16	1-word field containing *n*
n-12	1-word checksum (bottom 32 bits of the sum of all words from addresses 0 to *n*-16 inclusive)
n-8	2-word id 'ExtnROM0' indicating a valid extension ROM, ie:

n-8	&45	'E'
n-7	&78	'x'
n-6	&74	't'
n-5	&6E	'n'
n-4	&52	'R'
n-3	&4F	'O'
n-2	&4D	'M'
n-1	&30	'0'

Extension ROM width

Note that this header will not necessarily appear in the memory map in the last 16 bytes if the ROM set is 8 or 16 bits wide. In the 8-bit case, the header will appear in one of the four byte positions of the last 16 words, and in the 16-bit case, in one of the two half-word positions of the last 8 words. However, RISC OS copes with this, and uses the mapping of the ID field into memory to automatically derive the width of the extension ROM.

Introduction to Expansion Card Identities

Expansion cards

Each expansion card must have an *Expansion Card Identity* (or ECI*d*) so that RISC OS can tell whether an expansion card is fitted in a backplane slot, and if so, identify it. The ECId may be:

- a simple ECId of only one byte – the low one of a word (see below)
- an extended ECId of eight bytes, which may be followed by other information (see page 6-91).

The ECId (whether extended or not) must appear at the bottom of the expansion card space immediately after a reset. However, it does not have to remain readable at all times, and so it can be in a paged address space so long as the expansion card is set to the page containing the ECId on reset.

The ECId is read by a synchronous read of address 0 of the expansion card space. You may only assume it is valid from immediately after a reset until when the expansion card driver is installed.

Extension ROMs

As well as the Extension ROM header at the end of the ROM image, Extension ROMs must also have a header at the **start** of the ROM image. This header is identical in format to an Extended Expansion Card Identity, and is present for the use of the Expansion Card Manager, which handles much of the extension ROM processing. See page 6-91 onwards, paying particular attention to the section entitled *Mandatory values for extension* ROMs.

Simple Expansion Card Identity

Expansion cards can use a simple ECId, which is one byte long. You should only use one for the very simplest of expansion cards, or temporarily during development.

- Most expansion cards should instead implement the extended ECId, which eliminates the possibility of expansion card IDs clashing.
- Extension ROMs must use an extended ECId, rather than a simple ECId.

Restrictions imposed by a Simple ECId

If you do use a simple ECId, your expansion card **must** be 8 bits wide. The only operations that you may perform on its ROM are Podule_RawRead (see page 6-117) or Podule_RawWrite (see page 6-118).

Format of a simple ECId

A simple ECId shares many of the features of the low byte of an extended ECId, and is as follows:

7	6	5	4	3	2	1	0
A	ID[3]	ID[2]	ID[1]	ID[0]	FIQ	0	IRQ

Bit(s)	Value	Meaning
A	0	Acorn conformant expansion card
	1	non-conformant expansion card
ID[3:0]	not 0	ID field
	(0	extended ECId used)
FIQ	0	not requesting FIQ
	1	requesting FIQ
IRQ	0	not requesting IRQ
	1	requesting IRQ

Acorn conformance bit (A)

This bit must be zero for expansion cards that conform to this Acorn specification.

ID field (ID [3:0])

If you are using a simple ECId, the four ID bits may be used for expansion card identification. They must be non-zero, as a value of zero shows that you are instead using an extended ECId.

Interrupt status bits (IRQ and FIQ)

The interrupt status bits are discussed below in the section entitled *Generating interrupts from expansion cards* on page 6-95.

Expansion card presence (bit 1)

This must be zero, as shown above. For more information, see the section entitled *Expansion card and extension ROM presence* on page 6-94.

Extended Expansion Card Identity

An expansion card's ECId is extended if the ID field of its ECId low byte is zero. This means that RISC OS will read the next seven bytes of the ECId. The extended ECId starts at the bottom of the expansion card space, and consists of the eight bytes defined below.

Expansion card width

If an expansion card has an extended ECId, the first 16 bytes of its address space are always assumed to be bytewide. These 16 bytes contain the 8 byte extended ECId itself, and a further 8 bytes (typically the Interrupt status pointers – see below). If the ECId is included in a ROM which is 16 or 32 bits wide, then only the lowest byte in each half-word or word must be used for the first 16 (half) words.

If you use an extended ECId, you may specify the space after this as 8, 16 or 32 bits wide. When you access this space

- if you are using the 8 bit wide mode, you should use byte load and store instructions
- if you are writing using the 16 bit wide mode, you should use word store instructions, putting your half word in both the low and high half words of the register you use
- if you are reading using the 16 bit wide mode, you should use word load instructions, and ignore the upper half word returned
- if you are using the 32 bit wide mode, you should use word load and store instructions.

Synchronous cycles are used by the operating system to read and write any locations within this space (to simplify the design of synchronous expansion cards).

Current restrictions

You should note however that there are currently some restrictions on the widths you can use. These are imposed both by current hardware and software:

- the I/O data bus is only 16 bits wide
- the current version of the RISC OS Expansion Card Manager only supports the 8 bit wide mode; future versions may support the wider modes.

Format of an extended ECId

The format of an extended ECId is as follows:

7	6	5	4	3	2	1	0	
C[7]	C[6]	C[5]	C[4]	C[3]	C[2]	C[1]	C[0]	&1C
M[15]	M[14]	M[13]	M[12]	M[11]	M[10]	M[9]	M[8]	&18
M[7]	M[6]	M[5]	M[4]	M[3]	M[2]	M[1]	M[0]	&14
P[15]	P[14]	P[13]	P[12]	P[11]	P[10]	P[9]	P[8]	&10
P[7]	P[6]	P[5]	P[4]	P[3]	P[2]	P[1]	P[0]	&0C
R	R	R	R	R	R	R	R	&08
R	R	R	R	W[1]	W[0]	IS	CD	&04
A	0	0	0	0	FIQ	0	IRQ	&00

Bit(s)	Value	Meaning
C[7:0]		Country (see below)
M[15:0]		Manufacturer (see below)
P[15:0]		Product Type (see below)
R	0	mandatory at present
	1	reserved for future use
W[1:0]	0	8-bit code follows after byte 15 of Id space
	1	16-bit code follows after byte 15 of Id space
	2	32-bit code follows after byte 15 of Id space
	3	reserved
IS	0	no Interrupt Status Pointers follow ECId
	1	Interrupt Status Pointers follow ECId
CD	0	no Chunk Directory follows
	1	Chunk Directory follows Interrupt Status pointers
A	0	Acorn conformant expansion card
	1	non-conformant expansion card
FIQ	0	not requesting FIQ (or FIQ relocated)
	1	requesting FIQ
IRQ	0	not requesting IRQ (or IRQ relocated)
	1	requesting IRQ

Country code (C[7:0])

Every expansion card should have a code for the country of origin. These match those used by the International module, save that the UK has a country code of 0 for expansion cards. If you do not already know the correct country code for your country, you should consult Acorn.

Manufacturer code (M[15:0])

Every expansion card should have a code for manufacturer. If you have not already been allocated one, you should consult Acorn.

Product type code (P[15:0])

Every expansion card type must have a unique number allocated to it. Consult Acorn if you need to be allocated a new product type code.

Reserved fields (R)

Reserved fields must be set to zero to cater for future expansion.

Width field (W[1:0])

This field must currently be set to zero (expansion card is 8 bits wide). For more information, see the earlier section entitled *Expansion card width* on page 6-91.

Interrupt Status Pointers presence (IS)

See the sections entitled *Generating interrupts from expansion cards* on page 6-95, and *Interrupt Status Pointers* on page 6-96.

Chunk directory presence (CD)

See the section entitled *Chunk directory structure* on page 6-97.

Acorn conformance bit (A)

This bit must be zero for expansion cards that conform to this Acorn specification.

ID field (bits 6 - 3 of low byte)

If you are using an extended ECId, these bits must be zero, as shown above. A non-zero value shows that you are instead using a simple ECId; for more information see page 6-90.

Interrupt status bits (IRQ and FIQ)

The interrupt status bits are discussed below in the section entitled *Generating interrupts from expansion cards* on page 6-95.

Expansion card presence (bit 1 of low byte)

This must be zero, as shown above. For more information, see the section entitled *Expansion card and extension ROM presence* on page 6-94.

Mandatory values for extension ROMs

An extension ROM must include an extended ECId. This starts at the bottom of the ROM image, and consists of eight bytes as defined above.

For an extension ROM, certain fields within the extended ECId must have particular values:

- The product type code must be &87 (ie the product type is an extension ROM).
- The width field must always be 0 (8 bits wide), irrespective of the ROM's actual width, which RISC OS automatically derives (see the section entitled *Extension ROM width* on page 6-88).

  Because the width field does not vary, you do not need to change the image of an extension ROM if you change the width of ROM in which it is placed.
- Both the Interrupt Status Pointer field and the Chunk Directory field must be 1, showing the ECId is followed by Interrupt Status Pointers, then by a Chunk Directory.
- The Acorn conformant field must be 0, to show that the extension ROM is Acorn conformant.
- The interrupt status bits (FIQ and IRQ) must both be clear, to show that the extension ROM is not requesting an interrupt.

Expansion card and extension ROM presence

All expansion cards and extension ROMs **must have bit 1 low** in the low byte of an ECId (whether simple or extended), so that RISC OS can tell if there are any of them present.

Normally bit 1 of the I/O data bus is pulled high by a weak pullup. Therefore:

- If no expansion card is present and RISC OS tries to read the ECId low byte, bit 1 will be set.
- If an expansion card is present, and the ECId is mapped into memory (which it must be immediately after a reset), the bit will instead be clear.

Generating interrupts from expansion cards

Expansion cards must provide two status bits to show if the card is requesting IRQ or FIQ.

with a simple ECId

If an expansion card only has a simple ECId, then the FIQ and IRQ status bits are bits 2 and 0 respectively in the ECId. If the card does not generate one or both of these interrupts then the relevant bit(s) must be driven low.

with an extended ECId

If an expansion card has an extended ECId, you must set the IS bit of the ECId and provide *Interrupt Status Pointers* (see below) if either of the following applies:

- you are also using Chunk Directories (see below)
- you want to relocate the interrupt status bits from the low byte of the ECId.

If neither of the above apply, then you can omit the Interrupt Status Pointers. The interrupt status bits are located in the low byte of the ECId, and are treated in exactly the same way as for a simple ECId (see above).

Finding out more

To find out more about generating interrupts from expansion cards under RISC OS, you can:

- see the chapters entitled *ARM Hardware* on page 1-7 and *Interrupts and handling them* on page 1-109.
- consult the *Acorn RISC Machine family Data Manual*. VLSI Technology Inc. (1990) Prentice-Hall, Englewood Cliffs, NJ, USA: ISBN 0-13-781618-9.
- consult the datasheets for any components you use
- contact Customer Support and Services for further hardware-specific details.

Interrupt Status Pointers

Expansion cards

An Interrupt Status Pointer has two 4 byte numbers, each consisting of a 3 byte address field and a 1 byte position mask field. These numbers give the locations of the FIQ and IRQ status bits:

	&40
IRQ Status Bit address (24 bits)	&34
IRQ Status Bit position mask	&30
FIQ Status Bit address (24 bits)	&24
IRQ Status Bit position mask	&20

The 24-bit address field must contain a signed 2's-complement number giving the offset from &3240000 (the base of the area of memory into which podules are mapped). Hence the cycle speed to access the status register can be included in the offset (encoded by bits 19 and 20). Bits 14 and 15 (that encode the slot number) should be zero. If the status register is in module space then the offset should be negative: eg &DC0000, which is –&240000.

The 8-bit position mask should only have a single bit set, corresponding to the position of the interrupt status bit at the location given by the address field.

Note that these eight bytes are always assumed to be bytewide. Only the lowest byte in each word should be used.

The addresses may be the same (ie the status bits are in the same byte), so long as the position masks differ. An example of this is if you have had to provide an Interrupt Status Pointer, but do not want to relocate the status bits from the low byte of the ECId; the address fields will both point to the low byte of the ECId, the IRQ mask will be 1, and the FIQ mask will be 4.

If the card does not generate FIQ or IRQ

If the card does not generate one or both of these interrupts then you must set to zero:

- the corresponding address field(s) of the Interrupt Status Pointer
- the corresponding position mask field(s) of the Interrupt Status Pointer
- the corresponding status bit(s) in the low byte of the ECId.

Extension ROMs

Extension ROMs must have a Chunk Directory, hence they must also provide Interrupt Status Pointers. However, extension ROMs generate neither FIQ nor IRQ; consequently their Interrupt Status Pointers always consist of eight zero bytes.

Chunk directory structure

If the CD bit of an extended ECId is set, then:

- the IS bit of the ECId must also be set
- Interrupt Status Pointers must be defined
- a directory of *Chunks* follow the Interrupt Status Pointers.

The chunks of data and/or code are stored in the expansion card's ROM, or in the extension ROM.

The lengths and types of these Chunks and the manner in which they are loaded is variable, so after the eight bytes of Interrupt Status Pointers there follow a number of entries in the Chunk Directory. The Chunk Directory entries are eight bytes long and all follow the same format. There may be any number of these entries. This list of entries is terminated by a block of four bytes of zeros.

You should note that, from the start of the Chunk Directory onwards, the width of the expansion card space is as set in the ECId width field. From here on the definition is in terms of bytes:

	n+8
Start address: 4 bytes (32 bits)	n+4
Size in bytes: 3 bytes (24 bits)	n+1
Operating System Identity byte	n

The start address is an offset from the base of the expansion card's address space.

Operating System Identity Byte

The Operating System Identity Byte forms the first byte of the Chunk Directory entry, and determines the type of data which appears in the Chunk to which the Chunk Directory refers. It is defined as follows:

7	6	5	4	3	2	1	0
OS[3]	OS[2]	OS[1]	OS[0]	D[3]	D[2]	D[1]	D[0]

OS[3]	0	reserved		
OS[3]	1	mandatory at present		
OS[2:0]	0	Acorn Operating System 0: Arthur/RISC OS		
		D[3:0]	0	Loader
			1	Relocatable Module
			2	BBC ROM
			3	Sprite
			4 - 15	reserved
	1	reserved		
		D[3:0]	0 - 15	reserved
	2	Acorn Operating System 2: UNIX		
		D[3:0]	0	Loader
			1 - 15	reserved
	3 - 5	reserved		
		D[3:0]	0 - 15	reserved
	6	manufacturer defined		
		D[3:0]	0 - 15	manufacturer specific
	7	device data		
		D[3:0]	0	link (for 0, the object pointed to is another directory)
			1	serial number
			2	date of manufacture
			3	modification status
			4	place of manufacture
			5	description
			6	part number (for 1 - 6, the data in the location pointed to contains the ASCII string of the information.)
			7 - 14	reserved
			15	empty chunk

Those Chunks with OS[2:0] = 7, are operating system independent and are always treated as ASCII strings terminated with a zero byte. They are not intended to be read by programs, but rather inspected by users. It is expected that even minimum expansion cards will have an entry for D[3:0] = 5 (description), and it is this string which is printed out by the command *Podules.

Binding a ROM image

For a ROM to be read by the Expansion Card Manager it must conform to the specification, even if only minimally. The simplest way to generate ROM images is to use a BASIC program to combine the various parts together and to compute the header and Chunk Directory structure.

An example program used with an expansion card is shown at the end of this chapter. Its output is a file suitable for programming into a PROM or an EPROM.

Expansion card Code Space

The above forms the basis of storing software and data in expansion cards. However, there is an obvious drawback in that the expansion card space is only 4 Kbytes (at word boundaries), and so its usefulness is limited as it stands. To allow expansion cards to accommodate more than this 4 Kbytes an extension of the addressing capability is used. This extension is called the Code Space.

The Code Space is an abstracted address space that is accessed in an expansion card independent way via a software interface. It is a large linear address space that is randomly addressable to a byte boundary. This will typically be used for driver code for the expansion card, and will be downloaded into system memory by the operating system before it is used. The manner in which this memory is accessed is variable and so it is accessed via a loader.

Writing a loader for an expansion card

The purpose of the loader is to present to the Expansion Card Manager a simple interface that allows the reading (and writing) of the Code Space on a particular expansion card. The usual case is a ROM paged to appear in 2 Kbyte pages at the bottom of the expansion card space, with the page address stored in a latch. This then permits the Expansion Card Manager to load software (Relocatable Modules) or data from an expansion card without having to know how that particular expansion card's hardware is arranged.

The loader is a simple piece of relocatable code with four entry points and clearly defined entry and exit conditions. The format of the loader is optimised for ease of implementation and small code size rather than anything else.

Registers

The register usage is the same for each of the four entry points.

	Input/Output	Comments
R0	Write/Read data	Treated as a byte
R1	Address	Must be preserved
R2-R3		May be used
R4-R9		Must be preserved
R10		May be used
R11	Hardware	Combined hardware address: must be preserved
R12		Private: must be preserved
R13	sp	Stack pointer (FD): must be preserved
R14		Return address: use BICS pc, lr, #V_bit
R15		PC

The exception to this is the CallLoader entry point where R0 - R2 are the user's entry and exit data.

Entry points

All code must be relocatable and position independent. It can be assumed that the code will be run in RAM in SVC mode.

Origin + &00	Read a byte
Origin + &04	Write a byte
Origin + &08	Reset to initial state
Origin + &0C	SWI Podule_CallLoader

Initialisation

The first call made to the loader will be to Read address 0, the start of a Chunk directory for the Code Space.

Errors

Errors are returned in the usual way; V is set and R0 points at a word-aligned word containing the error number, which is followed by an optional error string, which in turn must be followed by a zero byte. ReadByte and WriteByte may be able to return errors like 'Bad address' if the device is not as big as the address given, or 'Bad write' if using read after write checks on the WriteByte call. If the CallLoader entry is not supported then don't return an error. If Reset fails then return an error.

Since your device drivers may well be short of space, you can return an error with R0=0. The Expansion Card Manager will then supply a default message. Note that this is not encouraged, but is offered as a suggestion of last resort. Errors are returned to the caller by using ORRS pc, lr, #V_bit rather than the usual BICS exit.

Example

Here is an example of a loader (this example, like all others in this chapter, uses the ARM assembler rather than the assembler included with BBC BASIC V – there are subtle syntax differences):

```
00                          LEADR  &FFFFFD00          ; Data
00 00003000 PageReg         *      &3000
00 0000000B PageSize        *      11                 ; Bits
00 EA00000B Origin          B      ReadByte
04 EA000019                 B      WriteByte
08 EA000001                 B      Reset
0C E3DEF201                 BICS   pc, lr, #V_bit
10 E59FA0E4 Reset           LDR    r10, =2_00000011111111111111000000000000
14 E00BA00A                 AND    r10, r11, r10   ; Get hardware address from combined one
18 E28AAA03                 ADD    r10, r10, #PageReg
1C E3A02000                 MOV    r2, #0
20 E4CA2000                 STRB   r2, [ r10 ]
24 E3DEF201                 BICS   pc, lr, #V_bit
28 E59F40C4 ReadByte        LDR    r3, =2_00000011111111111111000000000000
2C E00B4004                 AND    r3, r11, r3     ; Get hardware address from combined one
30 E284AA03                 ADD    r10, r3, #PageReg
34 E3510B3E                 CMP    r1, #&F800         ; Last page
38 228F0048                 ADRHS  Error, ErrorATB
3C 239EF201                 ORRHSS pc, lr, #V_bit
40 E2812B02                 ADD    r2, r1, #1 :SHL: PageSize
44 E1A025C2                 MOV    r2, r2, ASR #PageSize
48 E4CA2000                 STRB   r2, [ r10 ]
4C E3C12BFE                 BIC    r2, r1, #&7F :SHL: PageSize
50 E7D40102                 LDRB   r0, [ r3, r2, ASL #2 ] ; Word addressing
54 E3DEF201                 BICS   pc, lr, #V_bit
58 E28F0000 WriteByte       ADR    Error, ErrorNW
5C E39EF201                 ORRS   pc, lr, #V_bit
60 00000580 ErrorNW         DCD    ErrorNumber_NotWriteable
64                          DCB    ErrorString_NotWriteable,0
92 00 00                    ALIGN
94 00000584 ErrorATB        DCD    ErrorNumber_AddressTooBig
98                          DCB    ErrorString_AddressTooBig,0
AC                          END
```

The bit masks are used to separate the fields of a combined hardware address – see the description of Podule_HardwareAddress (page 6-120) for details of these.

Loading the loader

If the Expansion Card Manager is ever asked to 'EnumerateChunk' a Chunk containing a Loader, it will automatically load the Loader. Since RISC OS enumerates all Chunks from all expansion cards at a hard reset this is achieved by default.

If no Loader is loaded then Podule_EnumerateChunks will terminate on the zero at the end of the Chunk Directory in the expansion card space. If, however, when the end of the expansion card space Chunk Directory is reached a Loader has been loaded, then a second Chunk Directory, stored in the Code Space, will appear as a continuation of the original Chunk Directory. This is transparent to the user.

This second Chunk Directory is in exactly the same format as the original Chunk Directory. Addresses in the Code Space Chunk Directory refer to addresses in the Code Space. The Chunk Directory starts at address 0 of the Code Space (rather than address 16 as the one in expansion card Space does).

CMOS RAM

Each of the four possible internal expansion card slots has four bytes of CMOS RAM reserved for it. These bytes can be used to store status information, configuration, and so on.

You can find the base address of these four bytes by calling Podule_HardwareAddress (page 6-120) or Podule_HardwareAddresses (page 6-124).

ROM sections

Most of the SWIs provided by the Expansion Card Manager take a ROM section as a parameter. This identifies the expansion card or extension ROM upon which the command acts. ROM sections used by RISC OS are:

ROM section	Meaning	
–1	System ROM	
0	Expansion card 0	
1	Expansion card 1	
2	Expansion card 2	
3	Expansion card 3	
–2	Extension ROM 1	(not in RISC OS 2)
–3	Extension ROM 2	(not in RISC OS 2)
–4	Extension ROM 3 (etc)	(not in RISC OS 2)

None of the SWIs described in this chapter will act upon the system ROM.

'Podules'

In the Arthur operating system, expansion cards were known as *Podules*. The word 'Podule' was used in all the names of SWIs and * Commands.

These old names have been retained, so that software written to run under Arthur will still run under RISC OS.

Service Calls

Service_PreReset
(Service Call &45)

Pre-Reset

On entry

R1 = &45 (reason code)

On exit

R1 preserved to pass on (do not claim)

Use

This call is made just before a software generated reset takes place, when the user releases Break. This gives a chance for expansion card software to reset its devices, as this type of reset does not actually cause a hardware reset signal to appear on the expansion card bus. This call must not be claimed.

Service_ADFSPodule
(Service Call &10800)

Issued by ADFS to locate an ST506 expansion card.

On entry

Issuing the service call:

Call OS_ServiceCall with:

R1 = &10800 (reason code)
R2 = DefaultHDC (address of controller)
R3 = IoChip+IoIrqBStatus (address of IRQ status register)
R4 = WinnieBits (mask into IRQ status register)
R5 = IoChip+IoIrqBMask (address of IRQ mask register)
R6 = WinnieBits (mask into IRQ mask register)

Will return with regs adjusted to the values which should be used.

Responding to the service call:

R1 = &10800

On exit

R1 = 0 (Service_Serviced, ie claim the service)
R2 = address of hard disc controller
R3 = address of IRQ status register
R4 = mask into IRQ status register
R5 = address of IRQ mask register
R6 = mask into IRQ mask register

Use

Issued by ADFS to enable ST506 hard disc expansion cards to intercept ADFS to use its hardware rather than the hardware built into the machine.

Service_ADFSPoduleIDE
(Service Call &10801)

Issued by ADFS to locate an IDE expansion card.

On entry

R1 = &10801 (reason code)
R2 -> current IDE controller
R3 -> interrupt status of controller
R4 = AND with status, NE => IRQ
R5 -> interrupt mask
R6 = OR into mask enables IRQ
R7 -> data read routine (0 for default)
R8 -> data write routine (0 for default)

On exit

R1 = Service_Serviced
R2 -> new IDE controller
R3 -> interrupt status of controller
R4 = AND with status, NE => IRQ
R5 -> interrupt mask
R6 = OR into mask enables IRQ
R7 -> data read routine (0 for default)
R8 -> data write routine (0 for default)

Use

Issued by ADFS to enable IDE hard disc expansion cards to intercept ADFS to use its hardware rather than the hardware built into the machine.

Service_ADFSPoduleIDEDying
(Service Call &10802)

IDE expansion card dying

On entry

R1 = &10802 (reason code)

On exit

All registers preserved

Use

Issued by expansion card module to tell ADFS of imminent demise.

SWI calls

Podule_ReadID (SWI &40280)

Reads an expansion card or extension ROM's identity byte

On entry

R3 = ROM section (see page 6-102)

On exit

R0 = expansion card identity byte (ECId)

Interrupts

Interrupt status is unaltered
Fast interrupts are enabled

Processor mode

Processor is in SVC mode

Re-entrancy

SWI is re-entrant

Use

This call reads into R0 a simple Expansion Card Identity, or the low byte of an extended Expansion Card Identity. It also resets the loader.

Related SWIs

Podule_ReadHeader (page 6-109)

Related vectors

None

Podule_ReadHeader (SWI &40281)

Reads an expansion card or extension ROM's header

On entry

R2 = pointer to buffer of 8 or 16 bytes
R3 = ROM section (see page 6-102)

On exit

—

Interrupts

Interrupt status is unaltered
Fast interrupts are enabled

Processor mode

Processor is in SVC mode

Re-entrancy

SWI is re-entrant

Use

This call reads an extended Expansion Card Identity into the buffer pointed to by R2. If the IS bit is set (bit 1 of byte 1) then the expansion card also has Interrupt Status Pointers, and these are also read into the buffer. This call also resets the loader.

If you do not know whether the card has Interrupt Status Pointers, you should use a 16 byte buffer. Extension ROMs always have Interrupt Status Pointers (although they're always zero), so you should always use a 16 byte buffer for them.

Related SWIs

Podule_ReadID (page 6-108)

Related vectors

None

Podule_EnumerateChunks (SWI &40282)

Reads information about a chunk from the Chunk Directory

On entry

R0 = chunk number (zero to start)
R3 = ROM section (see page 6-102)

On exit

R0 = next chunk number (zero if final chunk enumerated)
R1 = size (in bytes) if R0 ≠ 0 on exit
R2 = operating system identity byte if R0 ≠ 0 on exit
R4 = pointer to a copy of the module's name if the chunk is a relocatable module, else preserved

Interrupts

Interrupt status is unaltered by the SWI, but may be altered by the loader
Fast interrupts are enabled

Processor mode

Processor is in SVC mode

Re-entrancy

SWI is not re-entrant

Use

This call reads information about a chunk from the Chunk Directory. It returns its size and operating system identity byte. If the chunk is a module it also returns a pointer to a copy of its name; this is held in the Expansion Card Manager's private workspace and will not be valid after you have called the Manager again.

If the chunk is a Loader, then RISC OS also loads it.

To read information on all chunks you should set R0 to 0 and R3 to the correct ROM section. You should then repeatedly call this SWI until R0 is set to 0 on exit.

RISC OS 2 automatically does this on a reset for all expansion cards; if there is a Loader it will be transparently loaded, and any chunks in the code space will also be enumerated. Later versions of RISC OS use Podule_EnumerateChunksWithInfo.

Related SWIs

Podule_ReadChunk (page 6-112), Podule_EnumerateChunksWithInfo (page 6-122)

Related vectors

None

Podule_ReadChunk (SWI &40283)

Reads a chunk from an expansion card or extension ROM

On entry

R0 = chunk number
R2 = pointer to buffer (assumed large enough)
R3 = ROM section (see page 6-102)

On exit

—

Interrupts

Interrupt status is unaltered by the SWI, but may be altered by the loader
Fast interrupts are enabled

Processor mode

Processor is in SVC mode

Re-entrancy

SWI is not re-entrant

Use

This call reads the specified chunk from an expansion card. The buffer must be large enough to contain the chunk; you can use Podule_EnumerateChunks (see page 6-110) to find the size of the chunk.

Related SWIs

Podule_EnumerateChunks (page 6-110)

Related vectors

None

Podule_ReadBytes (SWI &40284)

Reads bytes from within an expansion card's code space

On entry

R0 = offset from start of code space
R1 = number of bytes to read
R2 = pointer to buffer
R3 = expansion card slot number

On exit

—

Interrupts

Interrupt status is unaltered by the SWI, but may be altered by the loader
Fast interrupts are enabled

Processor mode

Processor is in SVC mode

Re-entrancy

SWI is not re-entrant

Use

This call reads bytes from within an expansion card's code space. It does so using repeated calls to offset 0 (read a byte) of its Loader. RISC OS must already have loaded the Loader; note that the kernel does this automatically on a reset when it enumerates all expansion cards' chunks.

This command returns an error for extension ROMs, because they have neither code space nor a loader.

Related SWIs

Podule_WriteBytes (page 6-114)

Related vectors

None

Podule_WriteBytes (SWI &40285)

Writes bytes to within an expansion card's code space

On entry

R0 = offset from start of code space
R1 = number of bytes to write
R2 = pointer to buffer
R3 = expansion card slot number

On exit

—

Interrupts

Interrupt status is unaltered by the SWI, but may be altered by the loader
Fast interrupts are enabled

Processor mode

Processor is in SVC mode

Re-entrancy

SWI is not re-entrant

Use

This call writes bytes to within an expansion card's code space. It does so using repeated calls to offset 4 (write a byte) of its Loader. RISC OS must already have loaded the Loader; note that the kernel does this automatically on a reset when it enumerates all expansion cards' chunks.

This command returns an error for extension ROMs, because they have neither code space nor a loader.

Related SWIs

Podule_ReadBytes (page 6-113)

Related vectors

None

Podule_CallLoader (SWI &40286)

Calls an expansion card's Loader

On entry

R0 - R2 = user data
R3 = expansion card slot number

On exit

R0 - R2 = user data

Interrupts

Interrupt status is unaltered by the SWI, but may be altered by the loader
Fast interrupts are enabled

Processor mode

Processor is in SVC mode

Re-entrancy

Depends on loader

Use

This call enters an expansion card's Loader at offset 12. Registers R0 - R2 can be used to pass data.

The action the Loader takes will vary from card to card, and you should consult your card's documentation for further details.

If you are developing your own card, you can use this SWI as an entry point to add extra features to your Loader. You may use R0 - R2 to pass any data you like. For example, R0 could be used as a reason code, and R1 and R2 to pass data.

This command returns an error for extension ROMs, because they have neither code space nor a loader.

Related SWIs

None

Related vectors

None

Podule_RawRead (SWI &40287)

Reads bytes directly within an expansion card or extension ROM's address space

On entry

R0 = offset from base of a podule's address space (0…&FFF)
R1 = number of bytes to read
R2 = pointer to buffer
R3 = ROM section (see page 6-102)

On exit

—

Interrupts

Interrupt status is unaltered
Fast interrupts are enabled

Processor mode

Processor is in SVC mode

Re-entrancy

SWI is re-entrant

Use

This call reads bytes directly within an expansion card or extension ROM's address space. It is typically used to read from the registers of hardware devices on an expansion card, or to read successive bytes from an extension ROM.

You should use Podule_ReadBytes (page 6-113) to read from within an expansion card's code space.

Related SWIs

Podule_RawWrite (page 6-118)

Related vectors

None

Podule_RawWrite (SWI &40288)

Writes bytes directly within an expansion card's address space

On entry

R0 = offset from base of a podule's address space (0...&FFF)
R1 = number of bytes to write
R2 = pointer to buffer
R3 = expansion card slot number

On exit

—

Interrupts

Interrupt status is unaltered
Fast interrupts are enabled

Processor mode

Processor is in SVC mode

Re-entrancy

SWI is re-entrant

Use

This call writes bytes directly within an expansion card's address space. It is typically used to write to the registers of hardware devices on an expansion card.

You should use Podule_WriteBytes (see page 6-114) to write within an expansion card's code space.

Obviously you cannot write to an extension ROM. You must not use this call to try to write to the ROM area; if you do so, you risk reprogramming the memory and video controllers.

Related SWIs

Podule_RawRead (page 6-117)

Related vectors

None

Podule_HardwareAddress (SWI &40289)

Returns an expansion card or extension ROM's base address, and the address of an expansion card's CMOS RAM

On entry

R3 = ROM section (see page 6-102), or base address of expansion card/extension ROM

On exit

R3 = combined hardware address

Interrupts

Interrupt status is unaltered
Fast interrupts are enabled

Processor mode

Processor is in SVC mode

Re-entrancy

SWI is re-entrant

Use

This call returns an expansion card or extension ROM's combined hardware address:

Bits	Meaning
0 - 11	base address of CMOS RAM – expansion cards only (4 bytes)
12 - 25	bits 12 - 25 of base address of expansion card/extension ROM
26 - 31	reserved

You can use a mask to extract the relevant parts of the returned value. The CMOS address in the low 12 bits is suitable for passing directly to OS_Byte 161 and 162.

In practice there is little point in finding the combined hardware address of an extension ROM. The base address of the extension ROM is of little use, as the width of the ROM can vary; and extension ROMs do not have CMOS RAM reserved for them.

Related SWIs

OS_Byte 161 (page 1-353), OS_Byte 162 (page 1-355), Podule_HardwareAddresses (page 6-124)

Related vectors

None

Podule_EnumerateChunksWithInfo (SWI &4028A)

Reads information about a chunk from the Chunk Directory

On entry

R0 = chunk number (zero to start)
R3 = ROM section (see page 6-102)

On exit

R0 = next chunk number (zero if final chunk enumerated)
R1 = size (in bytes) if R0 ≠ 0 on exit
R2 = operating system identity byte if R0 ≠ 0 on exit
R4 = pointer to a copy of the module's name if the chunk is a relocatable module, else preserved
R5 = pointer to a copy of the module's help string if the chunk is a relocatable module, else preserved
R6 = address of module if the chunk is a directly executable relocatable module, or 0 if the chunk is a non-directly-executable relocatable module, else preserved

Interrupts

Interrupt status is unaltered by the SWI, but may be altered by the loader
Fast interrupts are enabled

Processor mode

Processor is in SVC mode

Re-entrancy

SWI is not re-entrant

Use

This call reads information about a chunk from the Chunk Directory. It returns its size and operating system identity byte. If the chunk is a module it also returns pointers to copies of its name and its help string, and its address if it is executable. These are held in the Expansion Card Manager's private workspace and will not be valid after you have called the Manager again.

If the chunk is a Loader, then RISC OS also loads it.

To read information on all chunks you should set R0 to 0 and R3 to the correct ROM section. You should then repeatedly call this SWI until R0 is set to 0 on exit.

RISC OS automatically does this on a reset for all expansion cards; if there is a Loader it will be transparently loaded, and any chunks in the code space will also be enumerated. RISC OS 2 uses Podule_EnumerateChunks instead.

Related SWIs

Podule_EnumerateChunks (page 6-110), Podule_ReadChunk (page 6-112)

Related vectors

None

Podule_HardwareAddresses (SWI &4028B)

Returns an expansion card or extension ROM's base address, and the address of an expansion card's CMOS RAM

On entry

R3 = ROM section (see page 6-102)

On exit

R0 = base address of expansion card/extension ROM
R1 = combined hardware address

Interrupts

Interrupt status is unaltered
Fast interrupts are enabled

Processor mode

Processor is in SVC mode

Re-entrancy

SWI is re-entrant

Use

This call returns an expansion card or extension ROM's base address, and its combined hardware address:

Bits	Meaning
0 - 11	base address of CMOS RAM – expansion cards only (4 bytes)
12 - 25	bits 12 - 25 of base address of expansion card/extension ROM
26 - 31	reserved

You can use a mask to extract the relevant parts of the returned value. The CMOS address in the low 12 bits is suitable for passing directly to OS_Byte 161 and 162.

In practice there is little point in finding the combined hardware address of an extension ROM. The base address of the extension ROM is of little use, as the width of the ROM can vary; and extension ROMs do not have CMOS RAM reserved for them.

Related SWIs

OS_Byte 161 (page 1-353), OS_Byte 162 (page 1-355), Podule_HardwareAddress (page 6-120)

Related vectors

None

Podule_ReturnNumber (SWI &4028C)

Returns the number of expansion cards and extension ROMs

On entry

—

On exit

R0 = number of expansion cards
R1 = number of extension ROMs

Interrupts

Interrupt status is unaltered
Fast interrupts are enabled

Processor mode

Processor is in SVC mode

Re-entrancy

SWI is re-entrant

Use

This call returns the number of expansion cards and extension ROMs. The number of expansion cards returned is currently always 4, but you must be prepared to handle any other value, including 0.

This call is used by the *Podules command.

Related SWIs

None

Related vectors

None

* Commands

*PoduleLoad

Copies a file into an expansion card's RAM

Syntax

`*PoduleLoad expansion_card_number filename [offset]`

Parameters

expansion_card_number	the expansion card's number, as given by *Podules
filename	a valid pathname, specifying a file
offset	offset (in hexadecimal by default) into space accessed by Loader

Use

*PoduleLoad copies the contents of a file into an installed expansion card's RAM, starting at the specified offset. If no offset is given, then a default value of 0 is used.

Example

```
*PoduleLoad 1 $.Midi.Data 100
```

Related commands

*Podules, *PoduleSave

Related SWIs

Podule_WriteBytes (page 6-114)

Related vectors

None

*Podules

Displays a list of the installed expansion cards and extension ROMs

Syntax

`*Podules`

Parameters

None

Use

*Podules displays a list of the installed expansion cards and extension ROMs, using the description that each one holds internally. Some expansion cards and/or extension ROMs – such as one that is still being designed – will not have a description; in this case, an identification number is displayed.

This command still refers to expansion cards as podules, to maintain compatibility with earlier operating systems. This command does not show extension ROMs under RISC OS 2.

Example

```
*Podules
Podule 0: Midi and BBC I/O podule
Podule 1: Simple podule &8
Podule 2: No installed podule
Podule 3: No installed podule
```

Related commands

None

Related SWIs

Podule_EnumerateChunks (page 6-110)

Related vectors

None

*PoduleSave

Copies the contents of an expansion card's ROM into a file

Syntax

*PoduleSave *expansion_card_number filename size* [*offset*]

Parameters

expansion_card_number	the expansion card's number, as given by *Podules
filename	a valid pathname, specifying a file
size	in bytes
offset	offset (in hexadecimal by default) into space accessed by Loader

Use

*PoduleSave copies the given number of bytes of an installed expansion card's ROM into a file. If no offset is given, then a default value of 0 is used.

Example

```
*PoduleSave 1 $.Midi.Data 200 100
```

Related commands

*Podules, *PoduleLoad

Related SWIs

Podule_ReadBytes (page 6-113)

Related vectors

None

Example program

This program is an example of how to combine the various parts of an expansion card ROM. It also computes the header and Chunk Directory structure. The file it outputs is suitable for programming into a PROM or EPROM:

```
  10 REM > &.arm.MidiAndI/O.MidiJoiner
  20 REM Author    : RISC OS
  30 REM Last edit : 06-Jan-87
  40 PRINT"Joiner for expansion card ROMs"'"Version 1.05."
  50 PRINT"For Midi board.": DIM Buffer% 300, Block% 20
  70 INPUT'"Enter name of output file : "OutName$
  75 H%=OPENOUT(OutName$)
  80 IF H%=0 THEN PRINT"Could not create '";OutName$;"'.":END
  90 ONERRORONERROROFF:CLOSE#H%:REPORT:PRINT" at line ";ERL:END
 100 Device%=0:L%=TRUE:REPEAT
 120 Max%=&800:REM Max% is the size of the normal area
 130 Low%=&100:REM Low% is the size of the pseudo directory
 140 Base%=0:REM The offset for file address calculations
 150 Rom%=&4000:REM Rom% is the size of BBC ROMs
 170 PROCByte(0):PROCHalf(3):PROCHalf(19):PROCHalf(0):PROCByte(0)
 180 PROCByte(0):PROC3Byte(0):PROCByte(0):PROC3Byte(0)
 190 IF PTR#H% <> 16 STOP
 200 Bot%=PTR#H%:REM Bot% is where the directory grows from
 210 Top%=Max%:REM Top% is where normal files decend from
 230 INPUT"Enter filename of loader : "Loader$
 240 IF Loader$ <> "" THEN K%=FNAddFile( &80, Loader$ )
 250 IF K% ELSE PRINT"No room for loader.":
     PTR#H%=Bot%:PROCByte(0):CLOSE#H%:END
 270 INPUTLINE'"Enter product description : "Dat$
 280 IF Dat$ <> "" THEN PROCAddString( &F5, Dat$ )
 300 PRINT:REPEAT
 310 INPUT"Enter name of file to add : "File$
 320 IF File$ <> "" THEN T%=FNType( File$ ) ELSE T%=0
 330 IF T%=0 ELSE K%=FNAddFile( T%, File$ )
 340 IF K% ELSE PRINT"No more room."
 350 UNTIL (File$ = "") OR (K%=FALSE)
 360 IF K% ELSE PTR#H%=Bot%:PROCByte(0):CLOSE#H%:END
 370 IF L% PROCChange
 390 INPUTLINE"Enter serial number : "Dat$
 400 IF Dat$ <> "" THEN PROCAddString( &F1, Dat$ )
 410 INPUTLINE"Enter modification status : "Dat$
 420 IF Dat$ <> "" THEN PROCAddString( &F3, Dat$ )
 430 INPUTLINE"Enter place of manufacture : "Dat$
 440 IF Dat$ <> "" THEN PROCAddString( &F4, Dat$ )
 450 INPUTLINE"Enter part number : "Dat$
 460 IF Dat$ <> "" THEN PROCAddString( &F6, Dat$ )
 480 Date$=TIME$
 490 Date$=MID$(Date$,5,2)+"-"+MID$(Date$,8,3)+"-"+MID$(Date$,14,2)
 500 PROCAddString( &F2, Date$ )
 530 REM PROCHeader( &F0, Z%+W%*Rom%-Base%, 0 ):REM Link
 550 PTR#H%=Bot%:PROCByte(0)
 570 CLOSE#H%: END
 590 DEF PROCByte(D%):BPUT#H%,D%:ENDPROC
 610 DEF PROCHalf(D%):BPUT#H%,D%:BPUT#H%,D%DIV256:ENDPROC
 630 DEF PROC3Byte(D%)
 640 BPUT#H%,D%:BPUT#H%,D%DIV256:BPUT#H%,D%DIV65535:ENDPROC
 660 DEF PROCWord(D%)
 670 BPUT#H%,D%:BPUT#H%,D%DIV256:BPUT#H%,D%DIV65535
 680 BPUT#H%,D%DIV16777216:ENDPROC
 700 DEF PROCAddString( T%, S$ )
 710 S$=S$+CHR$0
 720 IF L% THEN PROCAddNormalString ELSE PROCAddPsuedoString
 730 ENDPROC
 750 DEF PROCAddNormalString
 760 IF Top%-Bot% < 10+LEN(S$) THEN STOP
 770 PROCHeader( T%, Top%-LEN(S$)-Base%, LEN(S$) )
 780 Top%=Top%-LEN(S$):PTR#H%=Top%:FOR I%=1 TO LEN(S$)
 790 BPUT#H%,ASC(MID$(S$,I%,1)):NEXTI%:ENDPROC
 810 DEF PROCAddPsuedoString
 820 IF Max%+Low%-Bot% < 9 THEN STOP
 830 PROCHeader( T%, Top%-Base%, LEN(S$) )
 840 PTR#H%=Top%:FOR I%=1 TO LEN(S$)
 850 BPUT#H%,ASC(MID$(S$,I%,1)):NEXTI%
 860 Top%=Top%+LEN(S$):ENDPROC
 880 DEF PROCHeader( Type%, Address%, Size% )
 890 PTR#H%=Bot%
 900 PROCByte( Type% )
 910 PROC3Byte( Size% )
 920 PROCWord( Address% )
 930 Bot%=Bot%+8:ENDPROC
 950 DEF FNAddFile( T%, N$ )
 960 F%=OPENIN( N$ )
 970 IF F%=0 THEN PRINT"File '";N$;"' not found.":=FALSE
 980 S%=EXT#F%
 990 IF L% THEN =FNAddNormalFile ELSE =FNAddPsuedoFile
1010 DEF FNAddNormalFile
1020 E%=S%+9-(Top%-Bot%)
1030 IF E%>0 THEN PRINT"Oversize by ";E%;" bytes."':
     PROCChange:=FNAddPsuedoFile
1040 PROCHeader( T%, Top%-S%-Base%, S% )
1050 Top%=Top%-S%:PTR#H%=Top%:FOR I%=1 TO S%
1060 BPUT#H%,BGET#F%:NEXTI%:CLOSE#F%:=TRUE
1080 DEF FNAddPsuedoFile
1090 IF Max%+Low%-Bot% < 9 THEN =FALSE
1100 PROCHeader( T%, Top%-Base%, S% )
1110 PTR#H%=Top%
1120 FOR I%=1 TO S%:BPUT#H%,BGET#F%:NEXTI%
1130 Top%=Top%+S%:CLOSE#F%:=TRUE
1150 DEF PROCChange
1160 PRINT"Changing up.  Wasting ";Top%-Bot%;" bytes."
1170 PTR#H%=Bot%:PROCByte(0):REM Terminate bottom directory
```

```
1180 Bot%=Max%:Top%=Max%+Low%:Base%=Max%:L%=FALSE
1190 REM In the pseudo area files grow upward from Top%
1200 ENDPROC
1220 DEF FNType( N$ )
1230 $Buffer%=N$:X%=Block%:Y%=X%/256:A%=5:X%!0=Buffer%
1240 B%=USR&FFDD:IF (B%AND255) <> 1 THEN PRINT"Not a file":=0
1250 V%=(Block%!3)AND&FFFFFF
1260 IFV%=&FFFFFA THEN =&81
1270 IF((Block%!2AND&FFFF)=&8000)AND((Block%!6AND&FFFF)=&8000)THEN=&82
1280 IFV%=&FFFFF9 THEN =&83
1290 =0
```

72 Debugger

Introduction

The debugger is a module that allows program to be stopped at set places called breakpoints. Whenever the instruction that a breakpoint is set on is reached, a command line will be entered. From here, you can type debug commands and resume the program when you want.

Other commands may be called at any time to examine or change the values contained at particular addresses in memory and to list the contents of the registers. You can display memory as words or bytes.

There is also a facility to disassemble instructions. This means converting the instruction, stored as a word into a string representation of its meaning. This allows you to examine the code anywhere in readable memory.

Technical Details

The debugger provides one SWI, Debugger_Disassemble (SWI &40380), which will disassemble one instruction. There are also the following * Commands:

Command	Description
*BreakClr	Remove breakpoint
*BreakList	List currently set breakpoints
*BreakSet	Set a breakpoint at a given address
*Continue	Start execution from a breakpoint saved state
*Debug	Enter the debugger
*InitStore	Fill memory with given data
*Memory	Display memory between two addresses/register
*MemoryA	Display and alter memory
*MemoryI	Disassemble ARM instructions
*ShowRegs	Display registers caught by traps

When an address is required, it should be given in hexadecimal, without a preceding &. That is, unlike most of the rest of the system, the debugger uses hexadecimal as a default base rather than decimal.

*Quit should be used to return from the debugger to the previous environment after a breakpoint – see page 1-316.

Note that the breakpoints discussed here are separate from those caused by OS_BreakPt. See page 1-298 for details of this SWI.

When a breakpoint is set, the previous contents of the breakpoint address are replaced with a branch into the debugger code. This means that breakpoints may only be set in RAM. If you try to set a breakpoint in ROM, the error 'Bad breakpoint address' will be given.

When a breakpoint instruction is reached, the debugger is entered, with the prompt

```
Debug*
```

from which you can type any * Command. An automatic register dump is also displayed.

From RISC OS 3 onwards this module supports ARM 3 instructions, and warns of certain unwise or invalid code sequences. Some of the output when disassembling has been changed for greater clarity than that provided by RISC OS 2.

SWI Calls

Debugger_Disassemble (SWI &40380)

Disassemble an instruction

On entry

R0 = instruction to disassemble
R1 = address to assume the word came from

On exit

R0 = preserved
R1 = address of buffer containing null-terminated text
R2 = length of disassembled line

Interrupts

Interrupt status is undefined
Fast interrupts are enabled

Processor Mode

Processor is in SVC mode

Re-entrancy

Not defined

Use

R0 contains the 32-bit instruction to disassemble. R1 contains the address to assume the word came from, which is needed for instructions such as `B`, `BL`, `LDR Rn, [PC…]`, and so on. On exit, R1 points to a buffer which contains a zero terminated string. This string consists of the instruction mnemonic, and any operands, in the format used by the *MemoryI instruction. The length in R2 excludes the zero-byte.

Related SWIs

None

Related vectors

None

*Commands

*BreakClr

Removes a breakpoint

Syntax

`*BreakClr [addr|reg]`

Parameters

addr	hexadecimal address of breakpoint to clear
reg	register containing address of breakpoint to clear. Allowed register names are r0 - r15, sp (equivalent to r13), lr (r14 without the psr bits) and pc (r15 without the psr bits). These are taken from the current ExceptionDumpArea.

Use

*BreakClr removes the breakpoint at the specified address/register value, putting the original contents back into that location. You can unset the last hit breakpoint with the command `*BreakClr pc`

If you give no parameter then you can remove all breakpoints – you will be prompted:

```
Clear all breakpoints [Y/N]?
```

Example

```
*BreakClr 816C
```

Related commands

*BreakSet, *BreakList

Related SWIs

None

Related vectors

None

*BreakList

List all the breakpoints that are currently set

Syntax

```
*BreakList
```

Parameters

None

Use

*BreakList lists all the breakpoints that are currently set with *BreakSet.

Example

```
*BreakList
Address     Old Data
0000816C    EF00141C
```

Related commands

*BreakSet

Related SWIs

None

Related vectors

None

*BreakSet

Sets a breakpoint

Syntax

```
*BreakSet addr|reg
```

Parameters

addr	hexadecimal address of breakpoint to set
reg	register containing address of breakpoint to set Allowed register names are r0 - r15, sp (equivalent to r13), lr (r14 without the psr bits) and pc (r15 without the psr bits). These are taken from the current ExceptionDumpArea.

Use

*BreakSet sets a breakpoint at the specified address or register value, so that when the code is executed and the instruction at that address is reached, execution will be halted.

When a breakpoint is set, the previous contents of the breakpoint address are replaced with a branch into the debugger code. This means that you may only set breakpoints in RAM. If you try to set a breakpoint in ROM, the error 'Bad breakpoint address' is generated.

Example

```
*BreakSet 816C
```

Related commands

*BreakClr, *BreakList

Related SWIs

None

Related vectors

None

*Continue

Resumes execution after a breakpoint

Syntax

```
*Continue
```

Parameters

None

Use

*Continue resumes execution after a breakpoint, using the saved state. If there is a breakpoint at the continuation position, then this prompt is given:

```
Continue from breakpoint set at &0000816C
Execute out of line? [Y/N]?
```

Reply 'Y' if it is permissible to execute the instruction at a different address (ie it does not refer to the PC).

If the instruction that was replaced by the breakpoint contains a PC-relative reference (such as `LDR R0, label`, a `B` or `BL` instruction, or an `ADR` directive), you should not execute it out of line. Instead you should clear the breakpoint, and then re-issue the *Continue command. The instruction will then be executed in line, avoiding the wrong address from being referenced.

Related commands

*BreakClr

Related SWIs

None

Related vectors

None

*Debug

Enters the debugger

Syntax

```
*Debug
```

Parameters

None

Use

*Debug enters the debugger. A prompt of `Debug*` appears. Use Escape to return to the caller, or *Quit to exit to the caller's parent.

*Quit is documented on page 1-316.

Related commands

*Quit

Related SWIs

None

Related vectors

None

*InitStore

Fills user memory with a value

Syntax

```
*InitStore [value|reg]
```

Parameters

value	word with which to fill user memory
reg	register value with which to fill user memory Allowed register names are r0 - r15, sp (equivalent to r13), lr (r14 without the psr bits) and pc (r15 without the psr bits). These are taken from the current ExceptionDumpArea.

Use

*InitStore fills user memory with the specified value or register value, or with the value &E6000010 (which is an illegal instruction) if no parameter is given. If you give this command from within an application (eg BASIC) the machine will crash, and will have to be reset.

RISC OS 2 used the value &E1000090 instead. This is no longer guaranteed to be an illegal instruction for all versions of the ARM processor.

Example

```
*InitStore &381E6677
```

Related commands

None

Related SWIs

None

Related vectors

None

*Memory

Displays the values in memory

Syntax

```
*Memory [B] addr1|reg1
*Memory [B] addr1|reg1 [+|-]addr2|reg2
*Memory [B] addr1|reg1 +|-addr2|reg2 +addr3|reg3
```

Parameters

B	optionally display as bytes
addr1|reg1	hexadecimal address, or register containing address for start of display
addr2|reg2	hexadecimal offset, or register containing offset
addr3|reg3	hexadecimal offset, or register containing offset Allowed register names are r0 - r15, sp (equivalent to r13), lr (r14 without the psr bits) and pc (r15 without the psr bits). These are taken from the current ExceptionDumpArea.

Use

*Memory displays the values in memory, in bytes if the optional B is given, or in words otherwise.

If only one address is given, 256 bytes are displayed starting from addr1. If two addresses are given, addr2 specifies the end of the range to be displayed (as an offset from addr1). If three addresses are given, addr2 specifies an offset for the start from addr1, and addr3 specifies the end of the range to be displayed (as an offset from the combined address given by addr1 and addr2).

Example

```
*Memory 1000 -200 +500
```
Display memory from &E00 *to* &1300

Related commands

*MemoryA, *MemoryI

Related SWIs

None

Related vectors

None

*MemoryA

Displays and alters memory

Syntax

`*MemoryA [B] addr/reg1 [value|reg2]`

Parameters

B	optionally display as bytes
addr1|reg1	hexadecimal address, or register containing address for start of display
value	value to write into the specified location
reg2	register containing value to write into the specified location
	Allowed register names are r0 - r15, sp (equivalent to r13), lr (r14 without the psr bits) and pc (r15 without the psr bits). These are taken from the current ExceptionDumpArea.

Use

*MemoryA displays and alters memory in bytes, if the optional B is given, or in words otherwise.

If you give no further parameters, interactive mode is entered. At each line, something similar to the following is printed:

```
+ 00008000 : xg.. : 00008F78 : ANDEQ R8,R0,R8,ROR PC
  Enter new value :
```

or, for byte mode:

```
+ 00008001 : g : 8F :
  Enter new value :
```

The first character shows the direction in which Return steps ('+' for forwards, '–' for backwards). Next is the address of the word/byte being altered, then the character(s) in that word/byte, then the current hexadecimal value of the word/byte, and finally (for words only) the instruction at that address.

You may type any of the following at the prompt:

Return	to go to the 'next' location
–	to step backwards in memory
+	to step forwards in memory
hex digits	to alter a location and proceed
.	to exit.

As an alternative to using this command interactively, you can give the new data value on the line after the address.

Example

```
*MemoryA 87A0 12345678
```

Related commands

*Memory, *MemoryI

Related SWIs

None

Related vectors

None

*MemoryI

Disassembles memory into ARM instructions

Syntax

*MemoryI *addr1|reg1*

*MemoryI *addr1|reg1 [+|-]addr2|reg2*

*MemoryI *addr1|reg1 +|-addr2|reg2 +addr3|reg3*

Parameters

B	optionally display as bytes
addr1|reg1	hexadecimal address, or register containing address for start of display
addr2|reg2	hexadecimal offset, or register containing offset
addr3|reg3	hexadecimal offset, or register containing offset
	Allowed register names are r0 - r15, sp (equivalent to r13), lr (r14 without the psr bits) and pc (r15 without the psr bits). These are taken from the current ExceptionDumpArea.

Use

*MemoryI disassembles memory into ARM instructions.

If only one address is given, 24 instructions are disassembled starting from addr1. If two addresses are given, addr2 specifies the end of the range to be disassembled (as an offset from addr1). If three addresses are given, addr2 specifies an offset for the start from addr1, and addr3 specifies the end of the range to be disassembled (as an offset from the combined address given by addr1 and addr2).

These options are particularly useful for disassembling modules which contain offsets, not addresses.

Example

```
*modules
No. Position Workspace Name
...
 22 0184D684 01801684 Debugger                 Find address of Debugger
...
*memoryi 184D684 +24
0184D684 : .... : 00000000 : ANDEQ R0,R0,R0
0184D688 : \... : 0000005C : ANDEQ R0,R0,R12,ASR R0
0184D68C : {... : 00000128 : ANDEQ R0,R0,R8,LSR #2
0184D690 : .... : 00000104 : ANDEQ R0,R0,R4,LSL #2
0184D694 : (... : 00000028 : ANDEQ R0,R0,R8,LSR #32
0184D698 : >... : 0000003E : ANDEQ R0,R0,R14,LSR R0
0184D69C : h... : 00000168 : ANDEQ R0,R0,R8,ROR #2
0184D6A0 :  ... : 00040380 : ANDEQ R0,R4,R0,LSL #7
0184D6A4 : Q... : 000005FC : MULEQ R0,R12,R5    ← Offset of SWI handler is &5FC

*memoryi 184D684 +5FC +20                       Disassemble SWI handler
0184DC80 : .B-♣ : E92D4200 : STMDB R13!,{R9,R14}
0184DC84 : .Ât‡ : E49CC000 : LDR R12,[R12],#0
0184DC88 : ..;‡ : E33B0000 : TEQ R11,#0
0184DC8C : .... : 0A000005 : BEQ &0184DCA8
0184DC90 : ..·‡ : E28F0004 : ADR R0,&0184DC9C
0184DC94 : _..• : EB00075F : BL &0184FA18
0184DC98 : . ¾à : E8BD8200 : LDMIA R13!,{R9,PC}
0184DC9C : .... : 0000010F : ANDEQ R0,R0,PC,LSL #2
```

Related commands

*Memory, *MemoryA

Related SWIs

None

Related vectors

None

*ShowRegs

Displays the register contents for the saved state

Syntax

`*ShowRegs`

Parameters

None

Use

*ShowRegs displays the register contents for the saved state, which may be caught on one of the five following traps:

- unknown instruction
- address exception
- data abort
- abort on instruction fetch
- breakpoint.

It also prints the address in memory where the registers are stored, so you can alter them (for example after a breakpoint) by using *MemoryA on these locations, before using *Continue.

Example

```
*ShowRegs
Register dump (stored at &01804D2C) is:
R0  = 0026D2CF R1  = 002483C1 R2  = 00000000 R3  = 00000000
R4  = 00000000 R5  = 52491ACE R6  = 42538FFD R7  = 263598DE
R8  = B278A456 R9  = C2671D37 R10 = A72B34DC R11 = 82637D2F
R12 = 00004000 R13 = 2538DAF0 R14 = 24368000 R15 = 7629D100
Mode USR flags set : nzcvif
```

Related commands

None

Related SWIs

None

Related vectors

None

73 Floating point emulator

Introduction

The Acorn RISC machine has a general coprocessor interface. The first coprocessor available is one which performs floating point calculations to the IEEE standard. To ensure that programs using floating point arithmetic remain compatible with all Archimedes machines, a standard ARM floating point instruction set has been defined. This can be implemented invisibly to the customer program by one of several systems offering various speed performances at various costs. The current 'bundled' floating point system is the software only floating point emulator module. Floating point instructions may be incorporated into any assembler text, provided they are called from user mode. These instructions are recognised by the Assembler and converted into the correct coprocessor instructions. However, these instructions are not supported by the BASIC interpreter.

Because this module doesn't present any SWIs or other usual interface to programs (apart from a SWI to return the version number), it is structured differently from the others. First, there is a discussion of the programmer's model of the IEEE 754 floating point system. This is followed by the floating point instruction set. Finally the SWI is detailed.

Generally, programs do not need to know whether a co-processor is fitted; the only effective difference is in the speed of execution. Note that there may be slight variations in accuracy between hardware and software – refer to the instructions supplied with the co-processor for details of these variations.

Programmer's model

The ARM IEEE floating point system has eight 'high precision' *floating point registers*, F0 to F7. The format in which numbers are stored in these registers is not specified. Floating point formats only become visible when a number is transferred to memory, using one of the formats described below.

There is also a *floating point status register* (FPSR) which, like the ARM's combined PC and PSR, holds all the necessary status and control information that an application is intended to be able to access. It holds *flags* which indicate various error conditions, such as overflow and division by zero. Each flag has a corresponding *trap enable bit*, which can be used to enable or disable a 'trap' associated with the error condition. Bits in the FPSR allow a client to distinguish between different implementations of the floating point system.

There may also be a *floating point control register* (FPCR); this is used to hold status and control information that an application is not intended to access. For example, there are privileged instructions to turn the floating point system on and off, to permit efficient context changes. Typically, hardware based systems have an FPCR, whereas software based ones do not.

Available systems

Floating point systems may be built from software only, hardware only, or some combination of software and hardware. The following terminology will be used to differentiate between the various ARM floating point systems already in use or planned:

System name	System components
Old FPE	Versions of the floating point emulator up to (but not including) 4.00
FPPC	Floating Point Protocol Convertor (interface chip between ARM and WE32206), WE32206 (AT&T Math Acceleration Unit chip), and support code
New FPE	Versions of the floating point emulator from 4.00 onwards
FPA	ARM Floating Point Accelerator chip, and support code

The results look the same to the programmer. However, if clients are aware of which system is in use, they may be able to extract better performance. For example, compilers can be tuned to generate bunched FP instructions for the FPE and dispersed FP instructions for the FPA, which will improve overall performance.

Precision

All basic floating point instructions operate as though the result were computed to infinite precision and then rounded to the length, and in the way, specified by the instruction. The rounding is selectable from:

- Round to nearest
- Round to +infinity (P)
- Round to –infinity (M)
- Round to zero (Z).

The default is 'round to nearest'; in the event of a tie, this rounds to 'nearest even'. If any of the others are required they must be given in the instruction.

The working precision of the system is 80 bits, comprising a 64 bit mantissa, a 15 bit exponent and a sign bit. Specific instructions that work only with single precision operands may provide higher performance in some implementations, particularly the fully software based ones.

Floating point number formats

Like the ARM instructions, the floating point data processing operations refer to registers rather than memory locations. Values may be stored into ARM memory in one of five formats (only four of which are visible at any one time, since P and EP are mutually exclusive):

IEEE Single Precision (S)

31	30 … 23	22		0
Sign	Exponent	msb	Fraction	lsb

Figure 73.1 Single precision format

- If the exponent is 0 and the fraction is 0, the number represented is ±0.
- If the exponent is 0 and the fraction is non-zero, the number represented is $\pm 0.fraction \times 2^{-126}$.
- If the exponent is in the range 1 to 254, the number represented is $\pm 1.fraction \times 2^{exponent - 127}$.
- If the exponent is 255 and the fraction is 0, the number represented is ±∞.
- If the exponent is 255 and the fraction is non-zero, a NaN (not-a-number) is represented. If the most significant bit of the fraction is set, it is a non-trapping NaN; otherwise it is a trapping NaN.

IEEE Double Precision (D)

	31	30 … 20	19		0
First word	Sign	Exponent	msb	Fraction	lsb
Second word	msb			Fraction	lsb

Figure 73.2 Double precision format

- If the exponent is 0 and the fraction is 0, the number represented is ±0.
- If the exponent is 0 and the fraction is non-zero, the number represented is $\pm 0.fraction \times 2^{-1022}$.
- If the exponent is in the range 1 to 2046, the number represented is $\pm 1.fraction \times 2^{exponent - 1023}$.
- If the exponent is 2047 and the fraction is 0, the number represented is ±∞.
- If the exponent is 2047 and the fraction is non-zero, a NaN (not-a-number) is represented. If the most significant bit of the fraction is set, it is a non-trapping NaN; otherwise it is a trapping NaN.

Double Extended Precision (E)

	31	30 … 15	14		0
First word	Sign	zeros	Exponent		
Second word	J	msb	Fraction		lsb
Third word	msb		Fraction		lsb

Figure 73.3 Double extended precision format

- If the exponent is 0, J is 0, and the fraction is 0, the number represented is ±0.
- If the exponent is 0, J is 0, and the fraction is non-zero, the number represented is $\pm 0.fraction \times 2^{-16382}$.
- If the exponent is in the range 0 to 32766, J is 1, and the fraction is non-zero, the number represented is $\pm 1.fraction \times 2^{exponent - 16383}$.
- If the exponent is 32767, J is 0, and the fraction is 0, the number represented is ±∞.
- If the exponent is 32767 and the fraction is non-zero, a NaN (not-a-number) is represented. If the most significant bit of the fraction is set, it is a non-trapping NaN; otherwise it is a trapping NaN.

Other values are illegal and shall not be used (ie the exponent is in the range 1 to 32766 and J is 0; or the exponent is 32767, J is 1, and the fraction is 0).

The FPPC system stores the sign bit in bit 15 of the first word, rather than in bit 31.

Storing a floating point register in 'E' format is guaranteed to maintain precision when loaded back by the same floating point system in this format. Note that in the past the layout of E format has varied between floating point systems, so software should not have been written to depend on it being readable by other floating point systems. For example, no software should have been written which saves E format data to disc, potentially loaded into another system. In particular, E format in the FPPC system varies from all other systems in its positioning of the sign bit. However, for the FPA and the new FPE, the E format is now defined to be a particular form of IEEE Double Extended Precision and will not vary in future.

Packed Decimal (P)

	31							0
First word	Sign	e3	e2	e1	e0	d18	d17	d16
Second word	d15	d14	d13	d12	d11	d10	d9	d8
Third word	d7	d6	d5	d4	d3	d2	d1	d0

Figure 73.4 Packed decimal format

The sign nibble contains both the significand's sign (top bit) and the exponent's sign (next bit); the other two bits are zero.

d18 is the most significant digit of the significand, and e3 of the exponent. The significand has an assumed decimal point between d18 and d17, and is normalised so that for a normal number $1 \leq d18 \leq 9$. The guaranteed ranges for d and e are 17 and 3 digits respectively; d0, d1 and e3 may always be zero in a particular system. A single precision number has 9 digits of significand and a maximum exponent of 53; a double precision number has 17 digits in the significand and a maximum exponent of 340.

The result is undefined if any of the packed digits is hexadecimal A - F, save for a representation of $\pm\infty$ or a NaN (see below).

- If the exponent's sign is 0, the exponent is 0, and the significand is 0, the number represented is ±0.
  Zero will always be output as +0, but either +0 or –0 may be input.
- If the exponent is in the range 0 to 9999 and the significand is in the range 1 to 9.999999999999999999, the number represented is $\pm d \times 10^{\pm e}$.
- If the exponent is &FFFF (ie all the bits in e3 - e0 are set) and the significand is 0, the number represented is $\pm\infty$.
- If the exponent is &FFFF and d0 - d17 are non-zero, a NaN (not-a-number) is represented. If the most significant bit of d18 is set, it is a non-trapping NaN; otherwise it is a trapping NaN.

All other combinations are undefined.

Expanded Packed Decimal (EP)

	31							0
First word	Sign	e6	e5	e4	e3	e2	e1	e0
Second word	d23	d22	d21	d20	d19	d18	d17	d16
Third word	d15	d14	d13	d12	d11	d10	d9	d8
Fourth word	d7	d6	d5	d4	d3	d2	d1	d0

Figure 73.5 Expanded packed decimal format

The sign nibble contains both the significand's sign (top bit) and the exponent's sign (next bit); the other two bits are zero.

d23 is the most significant digit of the significand, and e6 of the exponent. The significand has an assumed decimal point between d23 and d22, and is normalised so that for a normal number $1 \leq d23 \leq 9$. The guaranteed ranges for d and e are 21 and 4 digits respectively; d0, d1, d2, e4, e5 and e6 may always be zero in a particular system. A single precision number has 9 digits of significand and a maximum exponent of 53; a double precision number has 17 digits in the significand and a maximum exponent of 340.

The result is undefined if any of the packed digits is hexadecimal A - F, save for a representation of $\pm\infty$ or a NaN (see below).

- If the exponent's sign is 0, the exponent is 0, and the significand is 0, the number represented is ±0.
  Zero will always be output as +0, but either +0 or –0 may be input.
- If the exponent is in the range 0 to 9999999 and the significand is in the range 1 to 9.99999999999999999999999, the number represented is $\pm d \times 10^{\pm e}$.
- If the exponent is &FFFFFFF (ie all the bits in e6 - e0 are set) and the significand is 0, the number represented is $\pm\infty$.
- If the exponent is &FFFFFFF and d0 - d22 are non-zero, a NaN (not-a-number) is represented. If the most significant bit of d23 is set, it is a non-trapping NaN; otherwise it is a trapping NaN.

All other combinations are undefined.

This format is not available in the old FPE or the FPPC. You should only use it if you can guarantee that the floating point system you are using supports it.

Floating point status register

There is a floating point status register (FPSR) which, like ARM's combined PC and PSR, has all the necessary status for the floating point system. The FPSR contains the IEEE flags but not the result flags – these are only available after floating point compare operations.

The FPSR consists of a system ID byte, an exception trap enable byte, a system control byte and a cumulative exception flags byte.

	31–24	23–16	15–8	7–0
FPSR	System ID	Trap Enable	System Control	Exception Flags

Figure 73.6 Floating point status register byte usage

System ID byte

The System ID byte allows a user or operating system to distinguish which floating point system is in use. The top bit (bit 31 of the FPSR) is set for **hardware** (ie fast) systems, and clear for **software** (ie slow) systems. Note that the System ID is read-only.

The following System IDs are currently defined:

System	System ID
Old FPE	&00
FPPC	&80
New FPE	&01
FPA	&81

Exception Trap Enable Byte

Each bit of the exception trap enable byte corresponds to one type of floating point exception, which are described in the section entitled *Cumulative Exception Flags Byte* on page 6-160.

	23–21	20	19	18	17	16
FPSR	Reserved	INX	UFL	OFL	DVZ	IVO

Figure 73.7 Exception trap enable byte

If a bit in the cumulative exception flags byte is set as a result of executing a floating point instruction, and the corresponding bit is also set in the exception trap enable byte, then that exception trap will be taken.

Currently, the reserved bits shall be written as zeros and will return 0 when read.

System Control Byte

These control bits determine which features of the floating point system are in use.

	15–13	12	11	10	9	8
FPSR	Reserved	AC	EP	SO	NE	ND

Figure 73.8 System control byte

By placing these control bits in the FPSR, their state will be preserved across context switches, allowing different processes to use different features if necessary. The following five control bits are defined for the FPA system and the new FPE:

ND	No Denormalised numbers
NE	NaN Exception
SO	Select synchronous Operation of FPA
EP	Use Expanded Packed decimal format
AC	Use Alternative definition for C flag on compare operations

The old FPE and the FPPC system behave as if all these bits are clear.

Currently, the reserved bits shall be written as zeros and will return 0 when read. Note that all bits (including bits 8 - 12) are reserved on FPPC and early FPE systems.

ND – No denormalised numbers bit

If this bit is set, then the software will force all denormalised numbers to zero to prevent lengthy execution times when dealing with denormalised numbers. (Also known as abrupt underflow or flush to zero.) This mode is not IEEE compatible but may be required by some programs for performance reasons.

If this bit is clear, then denormalised numbers will be handled in the normal IEEE-conformant way.

NE – NaN exception bit

If this bit is set, then an attempt to store a signalling NaN that involves a change of format will cause an exception (for full IEEE compatibility).

If this bit is clear, then an attempt to store a signalling NaN that involves a change of format will not cause an exception (for compatibility with programs designed to work with the old FPE).

SO – Select synchronous operation of FPA

If this bit is set, then all floating point instructions will execute synchronously and ARM will be made to busy-wait until the instruction has completed. This will allow the precise address of an instruction causing an exception to be reported, but at the expense of increased execution time.

If this bit is clear, then that class of floating point instructions that can execute asynchronously to ARM will do so. Exceptions that occur as a result of these instructions may be raised some time after the instruction has started, by which time the ARM may have executed a number of instructions following the one that has failed. In such cases the address of the instruction that caused the exception will be imprecise.

The state of this bit is ignored by software-only implementations, which always operate synchronously.

EP – Use expanded packed decimal format

If this bit is set, then the expanded (four word) format will be used for Packed Decimal numbers. Use of this expanded format allows conversion from extended precision to packed decimal and back again to be carried out without loss of accuracy.

If this bit is clear, then the standard (three word) format is used for Packed Decimal numbers.

AC – Use alternative definition for C flag on compare operations

If this bit is set, the ARM C flag, after a compare, is interpreted as 'Greater Than or Equal or Unordered'. This interpretation allows more of the IEEE predicates to be tested by means of single ARM conditional instructions than is possible using the original interpretation of the C flag (as shown below).

If this bit is clear, the ARM C flag, after a compare, is interpreted as 'Greater Than or Equal'.

Cumulative Exception Flags Byte

	7 – 5	4	3	2	1	0
FPSR	Reserved	INX	UFL	OFL	DVZ	IVO

Figure 73.9 Cumulative exception flags byte

Whenever an exception condition arises, the appropriate cumulative exception flag in bits 0 to 4 will be set to 1. If the relevant trap enable bit is set, then an exception is also delivered to the user's program in a manner specific to the operating

system. (Note that in the case of underflow, the state of the trap enable bit determines under which conditions the underflow flag will be set.) These flags can only be cleared by a WFS instruction.

Currently, the reserved bits shall be written as zeros and will return 0 when read.

IVO – Invalid operation

The IVO flag is set when an operand is invalid for the operation to be performed. Invalid operations are:

- Any operation on a trapping NaN (not-a-number)
- Magnitude subtraction of infinities, eg $+\infty + -\infty$
- Multiplication of 0 by $\pm\infty$
- Division of 0/0 or ∞/∞
- x REM y where $x = \infty$ or $y = 0$
  (REM is the 'remainder after floating point division' operator.)
- Square root of any number < 0 (but $\sqrt{(-0)} = -0$)
- Conversion to integer or decimal when overflow, ∞ or a NaN operand make it impossible
  If overflow makes a conversion to integer impossible, then the largest positive or negative integer is produced (depending on the sign of the operand) and IVO is signalled
- Comparison with exceptions of Unordered operands
- ACS, ASN when argument's absolute value is > 1
- SIN, COS, TAN when argument is $\pm\infty$
- LOG, LGN when argument is ≤ 0
- POW when first operand is < 0 and second operand is not an integer, or first operand is 0 and second operand is ≤ 0
- RPW when first operand is not an integer and second operand is < 0, or first operand is ≤ 0 and second operand is 0.

DVZ – division by zero

The DVZ flag is set if the divisor is zero and the dividend a finite, non-zero number. A correctly signed infinity is returned if the trap is disabled.

The flag is also set for LOG(0) and for LGN(0). Negative infinity is returned if the trap is disabled.

OFL – overflow

The OFL flag is set whenever the destination format's largest number is exceeded in magnitude by what the rounded result would have been were the exponent range unbounded. As overflow is detected after rounding a result, whether overflow occurs or not after some operations depends on the rounding mode.

If the trap is disabled either a correctly signed infinity is returned, or the format's largest finite number. This depends on the rounding mode and floating point system used.

UFL – underflow

Two correlated events contribute to underflow:

- *Tininess* – the creation of a tiny non-zero result smaller in magnitude than the format's smallest normalised number.
- *Loss of accuracy* – a loss of accuracy due to denormalisation that may be greater than would be caused by rounding alone.

The UFL flag is set in different ways depending on the value of the UFL trap enable bit. If the trap is enabled, then the UFL flag is set when tininess is detected regardless of loss of accuracy. If the trap is disabled, then the UFL flag is set when both tininess and loss of accuracy are detected (in which case the INX flag is also set); otherwise a correctly signed zero is returned.

As underflow is detected after rounding a result, whether underflow occurs or not after some operations depends on the rounding mode.

INX – inexact

The INX flag is set if the rounded result of an operation is not exact (different from the value computable with infinite precision), or overflow has occurred while the OFL trap was disabled, or underflow has occurred while the UFL trap was disabled. OFL or UFL traps take precedence over INX.

The INX flag is also set when computing SIN or COS, with the exceptions of SIN(0) and COS(1).

The old FPE and the FPPC system may differ in their handling of the INX flag. Because of this inconsistency we recommend that you do not enable the INX trap.

Floating Point Control Register

The Floating Point Control register (FPCR) may only be present in some implementations: it is there to control the hardware in an implementation specific manner, for example to disable the floating point system. The user mode of the ARM is not permitted to use this register (since the right is reserved to alter it between implementations) and the WFC and RFC instructions will trap if tried in user mode.

You are unlikely to need to access the FPCR; this information is principally given for completeness.

The FPPC system

The FPCR bit allocation in the FPPC system is as shown below:

	31 – 8	7	6	5	4	3	2	1	0
FPCR	—	PR	SBd	SBn	SBm	—	AS	EX	DA

Figure 73.10 FPCR bit allocation in the FPPC system

Bit		Meaning
31-8		Reserved – always read as zero
7	PR	Last RMF instruction produced a partial remainder
6	SBd	Use Supervisor Register Bank 'd'
5	SBn	Use Supervisor Register Bank 'n'
4	SBm	Use Supervisor Register Bank 'm'
3		Reserved – always read as zero
2	AS	Last WE32206 exception was asynchronous
1	EX	Floating point exception has occurred
0	DA	Disable

Reserved bits are ignored during write operations (but should be zero for future compatibility.) The reserved bits will return zero when read.

The FPA system

In the FPA, the FPCR will also be used to return status information required by the support code when an instruction is bounced. You should not alter the register unless you really know what you're doing. Note that the register will be read sensitive; **even reading the register may change its value, with disastrous consequences.**

The FPCR bit allocation in the FPA system is **provisionally** as follows:

	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FPCR	RU	—		IE	MO	EO	—		OP				—	S1		

	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
(cont'd)	OP	DS			SB	AB	RE	EN	PR	RM		OP	S2			

Figure 73.11 FPCR bit allocation in the FPA system

Bit		Meaning
31	RU	Rounded Up Bit
30		Reserved
29		Reserved
28	IE	Inexact bit
27	MO	Mantissa overflow
26	EO	Exponent overflow
25, 24		Reserved
23-20	OP	AU operation code
19	PR	AU precision
18-16	S1	AU source register 1
15	OP	AU operation code
14-12	DS	AU destination register
11	SB	Synchronous bounce: decode (R14) to get opcode
10	AB	Asynchronous bounce: opcode supplied in rest of word
9	RE	Rounding Exception: Asynchronous bounce occurred during rounding stage and destination register was written
8	EN	Enable FPA (default is **off**)
7	PR	AU precision
6, 5	RM	AU rounding mode
4	OP	AU operation code
3-0	S2	AU source register 2 (bit 3 set denotes a constant)

Note that the SB and AB bits are cleared on a read of the FPCR. Only the EN bit is writable. All other bits shall be set to zero on a write.

The instruction set

Floating point coprocessor data transfer

`op{condition}prec` `Fd,addr`

`op`	is LDF for load, STF for store
`condition`	is one of the usual ARM conditions
`prec`	is one of the usual floating point precisions
`addr`	is `[Rn]{,#offset}` or `[Rn,#offset]{!}` (`{!}` if present indicates that write-back is to take place.)
`Fd`	is a floating point register symbol (defined via the FN directive).

Load (LDF) or store (STF) the high precision value from or to memory, using one of the five memory formats. On store, the value is rounded using the 'round to nearest' rounding method to the destination precision, or is precise if the destination has sufficient precision. Thus other rounding methods may be used by having previously applied some suitable floating point data operation; this does not compromise the requirement of 'rounding once only', since the store operation introduces no additional rounding error.

The offset is in words from the address given by the ARM base register, and is in the range −1020 to +1020. In pre-indexed mode you must explicitly specify write-back to add the offset to the base register; but in post-indexed mode the assembler forces write-back for you, as without write back post-indexing is meaningless.

You should not use R15 as the base register if write-back will take place.

Floating point literals

LDFS and LDFD can be given literal values instead of a register relative address, and the Assembler will automatically place the required value in the next available literal pool. In the case of LDFS a single precision value is placed, in the case of LDFD a double precision value is placed. Because the allowed offset range within a LDFS or LDFD instruction is less than that for a LDR instruction (−1020 to +1020 instead of −4095 to +4095), it may be necessary to code LTORG directives more frequently if floating point literals are being used than would otherwise be necessary.

Syntax: `LDFx Fn, = floating point number`

Floating point coprocessor multiple data transfer

The LFM and SFM multiple data transfer instructions are supported by the assemblers, but are not provided by the old FPE or the FPPC system. Executing these instructions on such systems will cause undefined instruction traps, so you should only use these instructions in software intended for machines you are confident are using the new FPE or the FPA system.

The LFM and SFM instructions allow between 1 and 4 floating point registers to be transferred from or to memory in a single operation; such a transfer otherwise requires several LDF or STF operations. The multiple transfers are therefore useful for efficient stacking on procedure entry/exit and context switching. These new instructions are the preferred way to preserve exactly register contents within a program.

The values transferred to memory by SFM occupy three words for each register, but the data format used is not defined, and may vary between floating point systems. The only legal operation that can be performed on this data is to load it back into floating point registers using the LFM instruction. The data stored in memory by an SFM instruction should not be used or modified by any user process.

The registers transferred by a LFM or SFM instruction are specified by a base floating point register and the number of registers to be transferred. This means that a register set transferred has to have adjacent register numbers, unlike the unconstrained set of ARM registers that can be loaded or saved using LDM and STM. Floating point registers are transferred in ascending order, register numbers wrapping round from 7 to 0: eg transferring 3registers with F6 as the base register results in registers F6, F7 then F0 being transferred.

The assembler supports two alternative forms of syntax, intended for general use or just stack manipulation:

`op{condition} Fd,count,addr`

`op{condition}stacktype Fd,count,[Rn]{!}`

op	is LFM for load, SFM for store.
condition	is one of the usual ARM conditions.
Fd	is the base floating point register, specified as a floating point register symbol (defined via the FN directive).
count	is an integer from 1 to 4 specifying the number of registers to be transferred.
addr	is `[Rn]{,#offset}` or `[Rn,#offset]{!}` (`{!}` if present indicates that write-back is to take place).
stacktype	is FD or EA, standing for Full Descending or Empty Ascending, the meanings as for LDM and STM.

The offset (only relevant for the first, general, syntax above) is in words from the address given by the ARM base register, and is in the range −1020 to +1020. In pre-indexed mode you must explicitly specify write-back to add the offset to the base register; but in post-indexed mode the assembler forces write-back for you, as without write back post-indexing is meaningless.

You should not use R15 as the base register if write-back will take place.

Examples:

```
SFMNE  F6,4,[R0]          ;If NE is true, transfer F6, F7,
                          ;F0 and F1 to the address
                          ;contained in R0

LFMFD  F4,2,[R13]!        ;load F4 and F5 from FD stack -
LFM    F4,2,[R13],#24     ;equivalent to same instruction
                          ;in general syntax
```

Floating point coprocessor register transfer

```
FLT{condition}prec{round}    Fn,Rd
FLT{condition}prec{round}    Fn,#value
FIX{condition}{round}        Rd,Fn
WFS{condition}               Rd
RFS{condition}               Rd
WFC{condition}               Rd
RFC{condition}               Rd
```

{round}	is the optional rounding mode: P, M or Z; see below.
Rd	is an ARM register symbol.
Fn	is a floating point register symbol.

The value may be of the following: 0, 1, 2, 3, 4, 5, 10, 0.5. Note that these values must be written precisely as shown above, for instance '0.5' is correct but '.5' is not.

FLT	Integer to Floating Point	Fn := Rd	
FIX	Floating point to integer	Rd := Fm	
WFS	Write Floating Point Status	FPSR := Rd	
RFS	Read Floating Point Status	Rd := FPSR	
WFC	Write Floating Point Control	FPC := R	Supervisor Only
RFC	Read Floating Point Control	Rd := FPC	Supervisor Only

The rounding modes are:

Mode	Letter
Nearest	(no letter required)
Plus infinity	P
Minus infinity	M
Zero	Z

Floating point coprocessor data operations

The formats of these instructions are:

```
binop{condition}prec{round}    Fd, Fn, Fm
binop{condition}prec{round}    Fd, Fn, #value
unop{condition}prec{round}     Fd, Fm
unop{condition}prec{round}     Fd, #value
```

binop	is one of the binary operations listed below
unop	is one of the unary operations listed below
Fd	is the FPU destination register
Fn	is the FPU source register (binops only)
Fm	is the FPU source register
#value	is a constant, as an alternative to Fm. It must be 0, 1, 2, 3, 4, 5, 10 or 0.5, as above.

The binops are:

ADF	Add	Fd := Fn + Fm
MUF	Multiply	Fd := Fn × Fm
SUF	Sub	Fd := Fn – Fm
RSF	Reverse Subtract	Fd := Fm – Fn
DVF	Divide	Fd := Fn/Fm
RDF	Reverse Divide	Fd := Fm/Fn
POW	Power	Fd := Fn to the power of Fm
RPW	Reverse Power	Fd := Fm to the power of Fn
RMF	Remainder	Fd := remainder of Fn / Fm (Fd := Fn – integer value of (Fn/Fm) × Fm)
FML	Fast Multiply	Fd := Fn × Fm
FDV	Fast Divide	Fd := Fn / Fm
FRD	Fast Reverse Divide	Fd := Fm / Fn
POL	Polar angle	Fd := polar angle of Fn, Fm

The unops are:

MVF	Move	Fd := Fm
MNF	Move Negated	Fd := –Fm
ABS	Absolute value	Fd := ABS (Fm)
RND	Round to integral value	Fd := integer value of Fm
SQT	Square root	Fd := square root of Fm
LOG	Logarithm to base 10	Fd := log Fm
LGN	Logarithm to base e	Fd := ln Fm
EXP	Exponent	Fd := e to the power of Fm
SIN	Sine	Fd := sine of Fm
COS	Cosine	Fd := cosine of Fm
TAN	Tangent	Fd := tangent of Fm
ASN	Arc Sine	Fd := arcsine of Fm
ACS	Arc Cosine	Fd := arccosine of Fm
ATN	Arc Tangent	Fd := arctangent of Fm
URD	Unnormalised Round	Fd := integer value of Fm (may be abnormal)
NRM	Normalise	Fd := normalised form of Fm

Note that wherever Fm is mentioned, one of the floating point constants 0, 1, 2, 3, 4, 5, 10, or 0.5 can be used instead.

FML, FRD and FDV are only defined to work with single precision operands. These 'fast' instructions are likely to be faster than the equivalent MUF, DVF and RDF instructions, but this is not necessarily so for any particular implementation.

Rounding is done only at the last stage of a SIN, COS etc – the calculations to compute the value are done with 'round to nearest' using the full working precision.

The URD and NRM operations are only supported by the FPA and the new FPE.

Floating point coprocessor status transfer

```
op{condition}prec{round} Fm, Fn
```

op is one of the following:

CMF	Compare floating	compare Fn with Fm
CNF	Compare negated floating	compare Fn with –Fm
CMFE	Compare floating with exception	compare Fn with Fm
CNFE	Compare negated floating with exception	compare Fn with –Fm

`{condition}`	an ARM condition.
prec	a precision letter
`{round}`	an optional rounding mode: P, M or Z
Fm	A floating point register symbol.
Fn	A floating point register symbol.

Compares are provided with and without the exception that could arise if the numbers are unordered (ie one or both of them is not-a-number). To comply with IEEE 754, the CMF instruction should be used to test for equality (ie when a BEQ or BNE is used afterwards) or to test for unorderedness (in the V flag). The CMFE instruction should be used for all other tests (BGT, BGE, BLT, BLE afterwards).

When the AC bit in the FPSR is clear, the ARM flags N, Z, C, V refer to the following after compares:

N	Less than	ie Fn less than Fm (or –Fm)
Z	Equal	
C	Greater than or equal	ie Fn greater than or equal to Fm (or –Fm)
V	Unordered	

Note that when two numbers are not equal, N and C are not necessarily opposites. If the result is unordered they will both be clear.

When the AC bit in the FPSR is set, the ARM flags N, Z, C, V refer to the following after compares:

N	Less than
Z	Equal
C	Greater than or equal or unordered
V	Unordered

In this case, N and C are necessarily opposites.

Finding out more...

Further details of the floating point instructions (such as the format of the bitfields within the instruction) can be found in the *Acorn RISC Machine family Data Manual.* VLSI Technology Inc. (1990) Prentice-Hall, Englewood Cliffs, NJ, USA: ISBN 0-13-781618-9 and in the *Acorn Assembler Release* 2 manual.

SWI Calls

FPEmulator_Version (SWI &40480)

Returns the version number of the floating point emulator

On entry

—

On exit

R0 = BCD version number

Interrupts

Interrupt status is undefined
Fast interrupts are enabled

Processor mode

Processor is in SVC mode

Re-entrancy

Not defined

Use

This call returns the version number of the floating point emulator as a binary coded decimal (BCD) number in R0.

This SWI will coninue to be supported by the hardware expansion.

Related SWIs

None

Related vectors

None

74 ARM3 Support

Introduction and Overview

The ARM3 Support module provides commands to control the use of the ARM3 processor's cache, where one is fitted to a machine. The module will immediately kill itself if you try to run it on a machine that only has an ARM2 processor fitted.

Summary of facilities

Two * Commands are provided: one to configure whether or not the cache is enabled at a power-on or reset, and the other to independently turn the cache on or off.

There is also a SWI to turn the cache on or off. A further SWI forces the cache to be flushed. Finally, there is also a set of SWIs that control how various areas of memory interact with the cache.

The default setup is such that all RISC OS programs should run unchanged with the ARM3's cache enabled. Consequently, you are unlikely to need to use the SWIs (beyond, possibly, turning the cache on or off).

Notes

A few poorly-written programs may not work correctly with ARM3 processors, because they make assumptions about processor timing or clock rates.

This module is not available in RISC OS 2.0.

Finding out more

For more details of the ARM3 processor, see the *Acorn RISC Machine family Data Manual*. VLSI Technology Inc. (1990) Prentice-Hall, Englewood Cliffs, NJ, USA: ISBN 0-13-781618-9.

SWI Calls

Cache_Control (SWI &280)

Turns the cache on or off

On entry

R0 = XOR mask
R1 = AND mask

On exit

R0 = old state (0 ⇒ cacheing was disabled, 1 ⇒ cacheing was enabled)

Interrupts

Interrupts are disabled
Fast interrupts are enabled

Processor mode

Processor is in SVC mode

Re-entrancy

Not defined

Use

This call turns the cache on or off. Bit 0 of the ARM3's control register 2 is altered by being masked with R1 and then exclusive ORd with R0: ie new value = ((old value AND R1) XOR R0). Bit 1 of the control register is also set, so the ARM 3 does **not** separately cache accesses to the same address for user and non-user modes. (To do so would degrade cache performance, and potentially cause cache inconsistency). Other bits of the control register are set to zero.

Related SWIs

None

Related vectors

None

Cache_Cacheable (SWI &281)

Controls which areas of memory may be cached

On entry

R0 = XOR mask
R1 = AND mask

On exit

R0 = old value (bit *n* set ⇒ 2MBytes starting at *n*×2MBytes are cacheable)

Interrupts

Interrupts are disabled
Fast interrupts are enabled

Processor mode

Processor is in SVC mode

Re-entrancy

Not defined

Use

This call controls which areas of memory may be cached (ie are *cacheable*). The ARM3's control register 3 is altered by being masked with R1 and then exclusive ORd with R0: ie new value = ((old value AND R1) XOR R0). If bit *n* of the control register is set, the 2MBytes starting at *n*×2MBytes are cacheable.

The default value stored is &FC007CFF, so ROM and logical non-screen RAM are cacheable, but I/O space, physical memory, the RAM disc and logical screen memory are not.

Related SWIs

Cache_Updateable (page 6-176), Cache_Disruptive (page 6-177)

Related vectors

None

Cache_Updateable (SWI &282)

Controls which areas of memory will be automatically updated in the cache

On entry

R0 = XOR mask
R1 = AND mask

On exit

R0 = old value (bit *n* set ⇒ 2MBytes starting at *n*×2MBytes are cacheable)

Interrupts

Interrupts are disabled
Fast interrupts are enabled

Processor mode

Processor is in SVC mode

Re-entrancy

Not defined

Use

This call controls which areas of memory will be automatically updated in the cache when the processor writes to that area (ie are *updateable*). The ARM3's control register 4 is altered by being masked with R1 and then exclusive ORd with R0: ie new value = ((old value AND R1) XOR R0). If bit *n* of the control register is set, the 2MBytes starting at *n*×2MBytes are updateable.

The default value stored is &00007FFF, so logical non-screen RAM is updateable, but ROM/CAM/DAG, I/O space, physical memory and logical screen memory are not.

Related SWIs

Cache_Cacheable (page 6-175), Cache_Disruptive (page 6-177)

Related vectors

None

Cache_Disruptive (SWI &283)

Controls which areas of memory cause automatic flushing of the cache on a write

On entry

R0 = XOR mask
R1 = AND mask

On exit

R0 = old value (bit *n* set ⇒ 2MBytes starting at *n*×2MBytes are disruptive)

Interrupts

Interrupts are disabled
Fast interrupts are enabled

Processor mode

Processor is in SVC mode

Re-entrancy

Not defined

Use

This call controls which areas of memory cause automatic flushing of the cache when the processor writes to that area (ie are *disruptive*). The ARM3's control register 5 is altered by being masked with R1 and then exclusive ORd with R0: ie new value = ((old value AND R1) XOR R0). If bit *n* of the control register is set, the 2MBytes starting at *n*×2MBytes are updateable.

The default value stored is &F0000000, so the CAM map is disruptive, but ROM/DAG, I/O space, physical memory and logical memory are not. This causes automatic flushing whenever MEMC's page mapping is altered, which allows programs written for the ARM2 (including RISC OS itself) to run unaltered, but at the expense of unnecessary flushing on page swaps.

Related SWIs

Cache_Cacheable (page 6-175), Cache_Updateable (page 6-176)

Related vectors

None

Cache_Flush (SWI &284)

Flushes the cache

On entry

—

On exit

—

Interrupts

Interrupts are disabled
Fast interrupts are enabled

Processor mode

Processor is in SVC mode

Re-entrancy

Not defined

Use

This call flushes the cache by writing to the ARM3's control register 1.

Related SWIs

None

Related vectors

None

* Commands

*Cache

Turns the cache on or off, or gives the cache's current state

Syntax

```
*Cache [On|Off]
```

Parameters

On or `Off`

Use

*Cache turns the cache on or off. With no parameter, it gives the cache's current state.

Example

```
*Cache Off
```

Related commands

*Configure Cache

Related SWIs

Cache_Control (page 6-174)

Related vectors

None

*Configure Cache

Sets the configured cache state to be on or off

Syntax

```
*Configure Cache On|Off
```

Parameters

On or `Off`

Use

*Configure Cache sets the configured cache state to be on or off.

Example

```
*Configure Cache On
```

Related commands

*Cache

Related SWIs

Cache_Control (page 6-174)

Related vectors

None

75 The Shared C Library

Introduction

The shared C library is a RISC OS relocatable module (called SharedCLibrary) which contains the whole of the ANSI C library. It is used by many programs written in C. Consequently, it saves both RAM space and disc space.

The shared C library is used by the RISC OS applications Edit, Paint, Draw and Configure.

Generally you will use the shared C library by linking your programs with the library stubs, however, you may also call it directly from assembly language by means of SWIs provided by the shared C library (you would normally only want to do this if you are implementing your own library stubs for your own language run time system (RTS)).

Overview

How to use the C library kernel

C library structure

The C library is organised into three layers:

- at the centre is the language-independent library kernel providing basic support services;
- at the next level is a C-specific layer providing compiler support functions;
- at the outermost level is the actual C library.

A full description of all the C library functions is given in the section entitled *C library functions* on page 6-221.

The library kernel

The library kernel is designed to allow run-time libraries for different languages to co-reside harmoniously, so that inter-language calling can be smooth. It provides the following facilities:

- a generic, status-returning, procedural interface to SWIs
- a procedural interface to commonly used SWIs, arithmetic functions and miscellaneous functions
- support for manipulating the IRQ state from a relocatable module
- support for allocating and freeing memory in the RMA area
- support for stack-limit checking and stack extension
- trap handling, error handling, event handling and escape handling.

A full description of all the library kernel functions is given in the section entitled *Library kernel functions* on page 6-208.

Interfacing a language run-time system to the Acorn library kernel

Describes how to write your own language Run Time System which uses the shared C library.

How the run-time stack is managed and extended

Management

The run-time stack consists of a doubly-linked list of stack chunks. Each stack chunk is allocated by the storage manager of the master language (in a C program allocating and freeing stack chunks is accomplished using `malloc()` and `free()`).

Stack extension

Two types of stack extension are provided:

- Pascal/Modula-2 style
- C-style

Calling other programs from C

Describes how to call other programs and built-in RISC OS * commands from C.

Storage management

Describes how the storage manager manages a heap and how you may best make use of the storage manager.

Handling host errors

Describes how to find out what operating system error a call made via one of the kernel functions caused.

Technical details

The shared C library module implements a single SWI which is called by code in the library stubs when your program linked with the stubs starts running. That SWI call tells the stubs where the library is in the machine. This allows the vector of library entry points contained in the stubs to be patched up in order to point at the relevant entry points in the library module.

The stubs also contain your private copy of the library's static data. When code in the library executes on your behalf, it does so using your stack and relocates its accesses to its static data by a value stored in your stack-chunk structure by the stubs initialisation code and addressed via the stack-limit register (this is why you must preserve the stack-limit register everywhere if you use the shared C library and call your own assembly language sub-routines). The compiler's register allocation strategy ensures that the real dynamic cost of the relocation is almost always low: for example, by doing it once outside a loop that uses it many times.

Execution time costs

It costs only 4 cycles (0.5μs) per function call and a very small penalty on access to the library's static data by the library (the user program's access to the same data is unpenalised). In general, the difference in performance between using the shared C library and linking a program stand-alone with ANSILib is less than 1%. For the important Dhrystone-2.1 benchmark the performance difference cannot be measured.

How to use the C library kernel

C library structure

The C library is organised into three separate layers. At the centre is the language-independent library kernel. This is implemented in assembly language and provides basic support services, described below, to language run-time systems and, directly, to client applications.

One level out from the library kernel is a thin, C-specific layer, also implemented in assembly language. This provides compiler support functions such as structure copy, interfaces to stack-limit checking and stack extension, `setjmp` and `longjmp` support, etc. Everything above this level is written in C.

Finally, there is the C library proper. This is implemented in C and, with the exception of one module which interfaces to the library kernel and the C-specific veneer, is highly portable.

The library kernel

The library kernel provides the following facilities:

- initialisation functions
- stack management functions:
  unwinding the stack
  finding the current stack chunk
  four kinds of stack extension –
  small-frame and large-frame extension,
  number of actual arguments known (eg Pascal), or unknown (eg C) by the callee.
- program environment functions:
  finding the identity of the host system (RISC OS, Arthur, etc)
  determining whether the floating point instruction set is available
  getting the command string with which the program was invoked
  returning the identity of the last OS error
  reading an environment variable
  setting an environment variable
  invoking a sub-application
  claiming memory to be managed by a heap manager
  finding the name of a function containing a given address
  finding the source language associated with code at a given address
  determining if IRQs are enabled
  enabling IRQs
  disabling IRQs.
- general utility functions:
  generic SWI interface routines
  special SWI interfaces for certain commonly used SWIs.
- memory allocation functions:
  allocating a block of memory in the RMA
  extending a block of memory in the RMA
  freeing a block of memory in the RMA.
- language support functions:
  unsigned integer division
  unsigned integer remainder
  unsigned divide by 10 (much faster than general division)
  signed integer division
  signed integer remainder
  signed divide by 10 (much faster than general division).

Interfacing a language run-time system to the Acorn library kernel

In order to use the kernel, a language run-time system must provide an area named RTSK$$DATA, with attributes READONLY. The contents of this area must be a `_kernel_languagedescription` as follows:

```
typedef enum { NotHandled, Handled } _kernel_HandledOrNot

typedef struct {
   int regs [16];
} _kernel_registerset;

typedef struct {
   int regs [10];
} _kernel_eventregisters;

typedef void (*PROC) (void);
typedef _kernel_HandledOrNot
   (*_kernel_trapproc) (int code, _kernel_registerset *regs);
typedef _kernel_HandledOrNot
   (*_kernel_eventproc) (int code, _kernel_registerset *regs);

typedef struct {
   int size;
   int codestart, codeend;
   char *name;
   PROC (*InitProc)(void);  /* that is, InitProc returns a PROC */
   PROC FinaliseProc;
   _kernel_trapproc TrapProc;
   _kernel_trapproc UncaughtTrapProc;
   _kernel_eventproc EventProc;
   _kernel_eventproc UnhandledEventProc;
   void (*FastEventProc) (_kernel_eventregisters *);
   int (*UnwindProc) (_kernel_unwindblock *inout, char **language);
   char * (*NameProc) (int pc);
} _kernel_languagedescription;
```

Any of the procedure values may be zero, indicating that an appropriate default action is to be taken. Procedures whose addresses lie outside `[codestart...codeend]` also cause the default action to be taken.

codestart, codeend

These values describe the range of program counter (PC) values which may be taken while executing code compiled from the language. The linker ensures that this is describable with just a single base and limit pair if all code is compiled into areas with the same unique name and same attributes (conventionally, *Language*$$code, CODE, READONLY. The values required are then accessible through the symbols *Language*$$code$$Base and *Language*$$code$$Limit).

InitProc

The kernel contains the entrypoint for images containing it. After initialising itself, the kernel calls (in a random order) the InitProc for each language RTS present in the image. They may perform any required (language-library-specific) initialisation: their return value is a procedure to be called in order to run the main program in the image. If there is no main program in its language, an RTS should return 0. (An InitProc may not itself enter the main program, otherwise other language RTSs might not be initialised. In some cases, the returned procedure may be the main program itself, but mostly it will be a piece of language RTS which sets up arguments first.)

It is an error for all InitProcs in a module to return 0. What this means depends on the host operating system; if RISC OS, SWI OS_GenerateError is called (having first taken care to restore all OS handlers). If the default error handlers are in place, the difference is marginal.

FinaliseProc

On return from the entry call, or on call of the kernel's Exit procedure, the FinaliseProc of each language RTS is called (again in a random order). The kernel then removes its OS handlers and exits setting any return code which has been specified by call of `_kernel_setreturncode`.

TrapProc, UncaughtTrapProc

On occurrence of a trap, or of a fatal error, all registers are saved in an area of store belonging to the kernel. These are the registers at the time of the instruction causing the trap, except that the PC is wound back to address that instruction rather than pointing a variable amount past it.

The PC at the time of the trap together with the call stack are used to find the TrapHandler procedure of an appropriate language. If one is found, it is invoked in user mode. It may return a value (Handled or NotHandled), or may not return at all. If it returns Handled, execution is resumed using the dumped register set (which should have been modified, otherwise resumption is likely just to repeat the trap). If it returns NotHandled, then that handler is marked as failed, and a search for an appropriate handler continues from the current stack frame.

If the search for a trap handler fails, then the same procedure is gone through to find a 'uncaught trap' handler.

If this too fails, it is an error. It is also an error if a further trap occurs while handling a trap. The procedure `_kernel_exittraphandler` is provided for use in the case the handler takes care of resumption itself (eg via `longjmp`).

(A language handler is appropriate for a PC value if LanguageCodeBase ≤ PC and PC < LanguageCodeLimit, and it is not marked as failed. Marking as 'failed' is local to a particular kernel trap handler invocation. The search for an appropriate handler examines the current PC, then R14, then the link field of successive stack frames. If the stack is found to be corrupt at any time, the search fails).

EventProc, UnhandledEventProc

The kernel always installs a handler for OS events and for Escape flag change. On occurrence of one, all registers are saved and an appropriate EventProc, or failing that an appropriate UnhandledEventProc is found and called. Escape pseudo-events are processed exactly like Traps. However, for 'real' events, the search for a handler terminates as soon as a handler is found, rather than when a willing handler is found (this is done to limit the time taken to respond to an event). If no handler is willing to claim the event, it is handed to the event handler which was in force when the program started. (The call happens in CallBack, and if it is the result of an Escape, the Escape has already been acknowledged.)

In the case of escape events, all side effects (such as termination of a keyboard read) have already happened by the time a language escape handler is called.

FastEventProc

The treatment of events by EventProc isn't too good if what the user level handler wants to do is to buffer events (eg conceivably for the key up/down event), because there may be many to one event handler call. The FastEventProc allows a call at the time of the event, but this is constrained to obey the rules for writing interrupt code (called in IRQ mode; must be quick; may not call SWIs or enable interrupts; must not check for stack overflow). The rules for which handler gets called in this case are rather different from those of (uncaught) trap and (unhandled) event handlers, partly because the user PC is not available, and partly because it is not necessarily quick enough. So the FastEventProc of each language in the image is called in turn (in some random order).

UnwindProc

UnwindProc unwinds one stack frame (see description of `_kernel_unwindproc` for details). If no procedure is provided, the default unwind procedure assumes that the ARM Procedure Call Standard has been used; languages should provide a procedure if some internal calls do not follow the standard.

NameProc

NameProc returns a pointer to the string naming the procedure in whose body the argument PC lies, if a name can be found; otherwise, 0.

How the run-time stack is managed and extended

The run-time stack consists of a doubly-linked list of stack chunks. The initial stack chunk is created when the run-time kernel is initialised. Currently, the size of the initial chunk is 4Kb. Subsequent requests to extend the stack are rounded up to at least this size, so the granularity of chunking of the stack is fairly coarse. However, clients may not rely on this.

Each chunk implements a portion of a descending stack. Stack frames are singly linked via their frame pointer fields within (and between) chunks. See the appendix entitled *Appendix C: ARM procedure call standard* on page 6-329 for more details.

In general, stack chunks are allocated by the storage manager of the master language (the language in which the root procedure – that containing the language entry point – is written). Whatever procedures were last registered with `_kernel_register_allocs()` will be used (each chunk 'remembers' the identity of the procedure to be called to free it). Thus, in a C program, stack chunks are allocated and freed using `malloc()` and `free()`.

In effect, the stack is allocated on the heap, which grows monotonically in increasing address order.

The use of stack chunks allows multiple threading and supports languages which have co-routine constructs (such as Modula-2). These constructs can be added to C fairly easily (provided you can manufacture a stack chunk and modify the `fp`, `sp` and `sl` fields of a `jmp_buf`, you can use `setjmp` and `longjmp` to do this).

Stack chunk format

A stack chunk is described by a `_kernel_stack_chunk` data structure located at its low-address end. It has the following format:

```
typedef struct stack_chunk {
    unsigned long sc_mark;          /* == 0xf60690ff */
    struct stack_chunk *sc_next, *sc_prev;
    unsigned long sc_size;
    int (*sc_deallocate)();
} _kernel_stack_chunk;
```

`sc_mark` is a magic number; `sc_next` and `sc_prev` are forward and backward pointers respectively, in the doubly linked list of chunks; `sc_size` is the size of the chunk in bytes and includes the size of the stack chunk data structure; `sc_deallocate` is a pointer to the procedure to call to free this stack chunk – often `free()` from the C library. Note that the chunk lists are terminated by NULL pointers – the lists are not circular.

The seven words above the stack chunk structure are reserved to Acorn. The stack-limit register points 512 bytes above this (ie 560 bytes above the base of the stack chunk).

Stack extension

Support for stack extension is provided in two forms:

- `fp`, arguments and `sp` get moved to the new chunk (Pascal/Modula-2-style)
- `fp` is left pointing at arguments in the old chunk, and `sp` is moved to the new chunk (C-style).

Each form has two variants depending on whether more than 4 arguments are passed (Pascal/Modula-2-style) or on whether the required new frame is bigger than 256 bytes or not (C-style). See the appendix entitled *Appendix C: ARM procedure call standard* on page 6-329 for more details.

_kernel_stkovf_copyargs

Pascal/Modula-2-style stack extension, with some arguments on the stack (ie stack overflow in a procedure with more than four arguments). On entry, `ip` must contain the number of argument words on the stack.

_kernel_stkovf_copy0args

Pascal/Modula-2-style stack extension, without arguments on the stack (ie stack overflow in a procedure with four arguments or fewer).

_kernel_stkovf_split_frame

C-style stack extension, where the procedure detecting the overflow needs more than 256 bytes of stack frame. On entry, `ip` must contain the value of `sp` – the required frame size (ie the desired new `sp` which would be below the current stack limit).

_kernel_stkovf_split_0frame

C-style stack extension, where the procedure detecting the overflow needs 256 or fewer bytes of stack frame.

Stack chunks are deallocated on returning from procedures which caused stack extension, but with one chunk of latency. That is, one extra stack chunk is kept in hand beyond the current one, to reduce the expense of repeated call and return when the stack is near the end of a chunk; others are freed on return from the procedure which caused the extension.

Calling other programs from C

The C library procedure `system()` provides the means whereby a program can pass a command to the host system's command line interpreter. The semantics of this are undefined by the draft ANSI standard.

RISC OS distinguishes two kinds of commands, which we term *built-in commands* and *applications*. These have different effects. The former always return to their callers, and usually make no use of application workspace; the latter return to the previously set-up 'exit handler', and may use the currently-available application workspace. Because of these differences, `system()` exhibits three kinds of behaviour. This is explained below.

Applications in RISC OS are loaded at a fixed address specified by the application image. Normally, this is the base of application workspace, 0x8000. While executing, applications are free to use store between the base and end of application workspace. The end is the value returned by SWI OS_GetEnv. They terminate with a call of SWI OS_Exit, which transfers control to the current exit handler.

When a C program makes the call `system("command")` several things are done:

- The calling program and its data are copied to the top end of application workspace and all its handlers are removed.
- The current end of application workspace is set to just below the copied program and an exit handler is installed in case `"command"` is another application.
- `"command"` is invoked using SWI OS_CLI.

When `"command"` returns, either directly (if it is a built-in command) or via the exit handler (if it is an application), the caller is copied back to its original location, its handlers are re-installed and it continues, oblivious of the interruption.

The value returned by `system()` indicates

- whether the command or application was successfully invoked
- if the command is an application which obeys certain conventions, whether or not it ran successfully.

The value returned by `system` (with a non-NULL command string) is as follows:

< 0 – couldn't invoke the command or application (eg command not found);

>=0 – invoked OK and set Sys$ReturnCode to the returned value.

By convention, applications set the environmental variable Sys$ReturnCode to 0 to indicate success and to something non-0 to indicate some degree of failure. Applications written in C do this for you, using the value passed as an argument to the `exit()` function or returned from the `main()` function.

If it is necessary to replace the current application by another, use:

```
system("CHAIN:command");
```

If the first characters of the string passed to `system()` are `"CHAIN:"` or `"chain:"`, the caller is not copied to the top end of application workspace, no exit handler is installed, and there can be no return (return from a built-in command is caught by the C library and turned into a SWI OS_Exit).

Typically, `CHAIN:` is used to give more memory to the called application when no return from it is required. The C compiler invokes the linker this way if a link step is required. On the other hand, the Acorn Make Utility (AMU) calls each command to be executed. Such commands include the C compiler (as both use the shared C library, the additional use of memory is minimised). Of course, a called application can call other applications using `system()`. A callee can even `CHAIN:` to another application and still, eventually, return to the caller. For example, AMU might execute:

```
system("cc hello.c");
```

to call the C compiler. In turn, `cc` executes:

```
system("CHAIN:link -o hello o.hello $.CLib.o.Stubs");
```

to transfer control to the linker, giving link all the memory cc had.

However, when Link terminates (calls `exit()`, returns from `main()` or aborts) it returns to AMU, which continues (providing Sys$ReturnCode is good).

Storage management (malloc, calloc, free)

The aim of the storage manager is to manage the heap in as 'efficient' a manner as possible. However, 'efficient' does not mean the same to all programs and since most programs differ in their storage requirements, certain compromises have to be made.

You should always try to keep the peak amount of heap used to a minimum so that, for example, a C program may invoke another C program leaving it the maximum amount of memory. This implementation has been tuned to hold the overhead due to fragmentation to less than 50%, with a fast turnover of small blocks.

The heap can be used in many different ways. For example it may be used to hold data with a long life (persistent data structures) or as temporary work space; it may be used to hold many small blocks of data or a few large ones or even a

combination of all of these allocated in a disorderly manner. The storage manager attempts to address all of these problems but like any storage manager, it cannot succeed with all storage allocation/deallocation patterns. If your program is unexpectedly running out of storage, see the section entitled *Guidelines on using memory efficiently* on page 1-332. This gives you information on the storage manager's strategy for managing the heap, and may help you to remedy the problem.

Note the following:

- The word *heap* refers to the section of memory currently under the control of the storage manager.
- All block sizes are in bytes and are rounded up to a multiple of four bytes.
- All blocks returned to the user are word-aligned.
- All blocks have an overhead of eight bytes (two words). One word is used to hold the block's length and status, the other contains a guard constant which is used to detect heap corruptions. The guard word may not be present in future releases of the ANSI C library.

Handling host errors

Calls to RISC OS can be made via one of the kernel functions, (such as `_kernel_osfind(64, "...")`). If the call causes an operating system error, the function will return the value -2. To find out what the error was, a call to `_kernel_last_oserror` should be made. This will return a pointer to a `_kernel_oserror` block containing the error number and any associated error string. If there has been no error since `_kernel_last_oserror` was last called, the function returns the NULL pointer. Some functions in the C library call `_kernel` functions, so if an C library function (such as `fopen("...", "r")`) fails, try calling `_kernel_last_oserror` to find out what the error was.

SWI Calls

SharedCLibrary_LibInitAPCS_A (SWI &80680)

This SWI interfaces an application which uses the old 'A' variant (SP=R12) of the Procedure Call Standard to the Shared C library. Its use is deprecated and it should not be called in any programs. Use SharedCLibrary_LibInitAPCS_R instead.

SharedCLibrary_LibInitAPCS_R (SWI &80681)

Interfaces an application with the shared C library

On entry

R0 = pointer to list of stub descriptions each having the following format:
+00: library chunk id (1 or 2)
+04: entry vector base
+08: entry vector limit
+12: static data base
+16: static data limit

The list is terminated by an entry with a library chunk id of –1

R1 = pointer to workspace start
R2 = pointer to workspace limit
R3 = base of area to be zero-initialised for modules (–1 for applications)
R4 = pointer to start of static data for modules (0 for applications)
R5 = pointer to limit of static data for modules (–1 for applications)
R6 = Bits 0 - 15 = 0
Bits 16 - 31 = Root stack size in Kilobytes

On exit

Entry vectors specified by the stubs descriptions are patched to contain branches to routines in the library.

If R5 > R4 on entry the users statics are copied to the bottom of the workspace specified in R1 and the Client static data offset (at byte offset +24 from the stack base) is initialised.

For each library chunk the library statics are copied either into the workspace specified in R1 if R5 > R4 on entry or to the static data area specified in the chunks stub description if R5 ≤ R4.

The Library static data offset (at byte offset +20 from the stack base) is initialised. Space for the root stack chunk is claimed from the workspace specified in R1.

R0 = value of R2 on entry
R1 = stack base
R2 = limit of space claimed from workspace passed in R1. This value should be used as the SP for the root stack chunk
R6 = library version number (currently = 5)

Interrupts

Interrupts are enabled
Fast interrupts are enabled

Processor mode

Processor is in SVC mode

Re-entrancy

SWI is re-entrant

Use

This SWI allows you to interface an application with the shared C library without using the shared C library stubs.

LibInitAPCS_R is used by applications which use APCS_R (see *Appendix C: ARM procedure call standard* on page 6-329 for more details).

Two library chunks are currently defined.

Chunk Id 1 - The Kernel module

The Kernel module defines 48 entries, these are described in the section entitled *Library kernel functions* on page 6-208. You must reserve 48 words in your branch vector table. The words at offsets +04 and +08 of the Kernel stub description must be initialised to the start and limit (end + 1) of your vector table.

The Kernel module requires &31C bytes of static data space. You must reserve this amount of storage. The words at offsets +12 and +16 must be initialised to the start and limit (end + 1) of this storage.

Chunk Id 2 - The C library module

If you wish to use the C library module you must include the Kernel stub description before the C library stub description in the list of stubs descriptions.

The C library module defines 183 entries, these are described in the section entitled *C library functions* on page 6-221. You must reserve 183 words in your branch vector table.

The words at offsets +04 and +08 of the Kernel stub description must be initialised to the start and limit (end + 1) of your vector table.

The C library module requires &B48 bytes of static data space. You must reserve this amount of storage. The words at offsets +12 and +16 must be initialised to the start and limit (end + 1) of this storage. This storage must be contiguous with that for the Kernel module.

Calling library functions

Before calling any library functions you must call the kernel function _kernel_init (entry no. 0). For details on how to call these functions refer to their entries in the section entitled *Library kernel functions* on page 6-208.

SP, SL and FP must be set up before calling any library function. _kernel_init initialises these for the root stack chunk passed to it.

If you wish to call C library functions you must pass a suitable kernel language description block to _kernel_init. For details on the format of a kernel language description block refer to the section entitled *Interfacing a language run-time system to the Acorn library kernel* on page 6-184.

To call C library functions the fields of the kernel language description block must be as follows

size	The size of this structure in bytes (24 - 52 depending on the number of entries in this block)
codestart, codelimit	These two words should be set to the start and limit of an area which is to be treated as C code with respect to trap and event handling. Both these values may be set to 0 in which case no traps or events will be passed to the trap or event handler described in this language description block.
name	This must contain a pointer to the 0 terminated string "C".
InitProc	Pointer to your initialisation procedure. Your initialisation procedure must call _clib_initialise (entry no. 20). For details on how to call _clib_initialise refer to its entry in the section entitled *C library functions* on page 6-221. It should then load R0 with the address at which execution is to continue at the end of initialisation.
FinaliseProc	Pointer to your finalisation procedure. This may contain 0.

The remainder of the entries are optional and may omitted. You must set the size field correctly if omitting entries. If all optional entries are omitted the size field should be set to 24.

Related SWIs

SharedCLibrary_LibInitAPCS_A (SWI &80680)

Related vectors

None

SharedCLibrary_LibInitModule (SWI &80682)

Interfaces a module with the shared C library

On entry

R0 = pointer to list of stub descriptions each having the following format:

+00: library chunk id (1 or 2)
+04: entry vector base
+08: entry vector limit
+12: static data base
+16: static data limit

The list is terminated by an entry with a library chunk id of –1

R1 = pointer to workspace start
R2 = pointer to workspace limit
R3 = base of area to be zero-initialised for modules (–1 for applications)
R4 = pointer to start of static data for modules (0 for applications)
R5 = pointer to limit of static data for modules (–1 for applications)
R6 = Bits 0 - 15 = 0
Bits 16 - 31 = Root stack size in Kilobytes

On exit

Entry vectors specified by the stubs descriptions are patched to contain branches to routines in the library.

If R5 > R4 on entry the users statics are copied to the bottom of the workspace specified in R1 and the Client static data offset (at byte offset +24 from the stack base) is initialised.

For each library chunk the library statics are copied either into the workspace specified in R1 if R5 > R4 on entry or to the static data area specified in the chunks stub description if R5 ≤ R4.

The Library static data offset (at byte offset +20 from the stack base) is initialised.

Space for the root stack chunk is claimed from the SVC stack.

R0 = value of R2 on entry
R1 = stack base
R2 = limit of space claimed from workspace passed in R1
R6 = library version number (currently = 5)

Note: You must save the words at offsets +20 and +24 from the returned stack base. You must do this before exiting your module initialisation code. These words contain the shared libraries static data offset and the client static data offset (the offset you must use when accessing your static data). These must be restored in the static data offset locations at offsets +00 and +04 from the base of the SVC stack when you are re-entering the module in SVC mode (e.g. in a SWI handler). When restoring the static data offsets you must save the previous static data offsets around the module entry.

Interrupts

Interrupts are enabled
Fast interrupts are enabled

Processor mode

Processor is in SVC mode

Re-entrancy

SWI is re-entrant

Use

This SWI allows you to interface a module with the shared C library without using the shared C library stubs.

SharedCLibrary_LibInitModule is used by modules, which must use APCS_R, and must be called in the module initialisation code.

Two library chunks are currently defined.

Chunk Id 1 - The Kernel module

The Kernel module defines 48 entries, these are described in the section entitled *Library kernel functions* on page 6-208. You must reserve 48 words in your branch vector table. The words at offsets +04 and +08 of the Kernel stub description must be initialised to the start and limit (end + 1) of your vector table.

The Kernel module requires &31C bytes of static data space. You must reserve this amount of storage. The words at offsets +12 and +16 must be initialised to the start and limit (end + 1) of this storage.

Chunk Id 2 - The C library module

If you wish to use the C library module you must include the Kernel stub description before the C library stub description in the list of stubs descriptions.

The C library module defines 183 entries, these are described in the section entitled *C library functions* on page 6-221. You must reserve 183 words in your branch vector table.

The words at offsets +04 and +08 of the Kernel stub description must be initialised to the start and limit (end + 1) of your vector table.

The C library module requires &B48 bytes of static data space. You must reserve this amount of storage. The words at offsets +12 and +16 must be initialised to the start and limit (end + 1) of this storage. This storage must be contiguous with that for the Kernel module.

Calling library functions

Before calling any library functions you must call the kernel function _kernel_moduleinit (entry no. 38). For details on how to call these functions refer to their entries in the section entitled *Library kernel functions* on page 6-208.

SP, SL and FP must be set up before calling any library function. _kernel_init initialises these for the root stack chunk passed to it.

If you wish to call C library functions you must pass a suitable kernel language description block to _kernel_init. For details on the format of a kernel language description block refer to the section entitled *Interfacing a language run-time system to the Acorn library kernel* on page 6-184.

To call C library functions the fields of the kernel language description block must be as follows

size	The size of this structure in bytes (24 - 52 depending on the number of entries in this block)
codestart, codelimit	These two words should be set to the start and limit of an area which is to be treated as C code with respect to trap and event handling. Both these values may be set to 0 in which case no traps or events will be passed to the trap or event handler described in this language description block.
name	This must contain a pointer to the 0 terminated string "C".
InitProc	Pointer to your initialisation procedure. Your initialisation procedure must call _clib_initialise (entry no. 20). For details on how to call _clib_initialise refer to its entry in the section entitled *C library functions* on page 6-221. It should then load R0 with the address at which execution is to continue at the end of initialisation.
FinaliseProc	Pointer to your finalisation procedure. This may contain 0.

The remainder of the entries are optional and may omitted. You must set the size field correctly if omitting entries. If all optional entries are omitted the size field should be set to 24.

Related SWIs

None

Related vectors

None

Example program

```
; This example demonstates how to call the shared C library.
; It is written for the ObjAsm assembler supplied with the Software
; Developers Toolkit (SDT) and the Desktop Development Environment (DDE).
;
r0              RN      0
r1              RN      1
r2              RN      2
r3              RN      3
r4              RN      4
r5              RN      5
r6              RN      6
sp              RN      13
lr              RN      14
pc              RN      15

|_kernel_init|          EQU     0 * 4           ; Offsets in kernel vector table

|_clib_initialise|      EQU     20 * 4          ; Offsets in C vector table
fopen                   EQU     87 * 4
fprintf                 EQU     92 * 4
fclose                  EQU     85 * 4

OS_GenerateError        EQU     &2b
OS_Exit                 EQU     &11

SharedCLibrary_LibInitAPCS_R EQU &80681

                IMPORT  |Image$$RO$$Base|       ; Linker defined symbol giving
                                                ; start of image.
                AREA    printf, CODE, READONLY

                ENTRY

                ADR     r0, stubs
                ADRL    r1, workspace
                ADD     r2, r1, #32 * 1024      ; 32K workspace. A real program
                MOV     r3, #-1                 ; would use OS_ChangeEnvironment
                MOV     r4, #0                  ; to find the memorylimit.
                MOV     r5, #-1
                MOV     r6, #&00080000
                SWI     SharedCLibrary_LibInitAPCS_R
                MOV     r4, r0
                ADR     r0, kernel_init_block
                MOV     r3, #0
                B kernel_vectors + |_kernel_init|   ; Continues at c_init below

stubs
                DCD     1
                DCD     kernel_vectors
                DCD     kernel_vectors_end
                DCD     kernel_statics
                DCD     kernel_statics_end
```

```
                DCD     2
                DCD     clib_vectors
                DCD     clib_vectors_end
                DCD     clib_statics
                DCD     clib_statics_end

                DCD     -1

kernel_init_block
                DCD     |Image$$RO$$Base|
                DCD     rts_block
                DCD     rts_block_end

rts_block
                DCD     rts_block_end - rts_block
                DCD     0
                DCD     0
                DCD     c_str
                DCD     c_init
                DCD     0

rts_block_end

c_str           DCB     "C", 0                  ; Must be "C" for CLib to finalise
                ALIGN                           ; properly.

c_init          MOV     r0, sp
                MOV     r1, #0
                MOV     r2, #0
                STMDB   sp!, {lr}
                BL      clib_vectors + |_clib_initialise|
                ADR     r0, c_run               ; Continue at c_run below
                LDMIA   sp!, {pc}^

c_run           ADR     r0, outfile
                ADR     r1, access
                BL      clib_vectors + fopen
                CMP     r0, #0
                ADREQ   r0, Err_Open            ; Will actually say
                SWIEQ   OS_GenerateError        ; Uncaught trap: Error opening ...
                MOV     r4, r0
                ADR     r1, format
                BL      clib_vectors + fprintf
                MOV     r0, r4
                BL      clib_vectors + fclose
                CMP     r0, #0
                ADRNE   r0, Err_Close
                SWINE   OS_GenerateError        ; Uncaught trap: Error writing ...
                SWI     OS_Exit

outfile         DCB     "OutFile", 0
access          DCB     "w", 0
format          DCB     "Sample string printed from asm using fprintf!", 10, 0
                ALIGN

Err_Open        DCD     &1000
                DCB     "Error opening OutFile", 0
                ALIGN
```



```
Err_Close       DCD     &1001
                DCB     "Error writing OutFile", 0
                ALIGN

kernel_vectors %        48 * 4
kernel_vectors_end

clib_vectors   %        183 * 4
clib_vectors_end

kernel_statics %        &31c
kernel_statics_end

clib_statics   %        &b48
clib_statics_end

workspace                                       ; Start of workspace at end of app.

                END
```

Library kernel functions

The library kernel functions are grouped under the following headings:

- initialisation functions
- stack management functions
- program environment functions
- general utility functions
- memory allocation functions
- language support functions.

Index of library kernel functions by entry number

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The following structure is common to all library kernel functions:

```
typedef struct {
  int errnum; /* error number */
  char errmess[252];/* error message (zero terminated) */
} _kernel_oserror;
```


Initialisation functions

Entry no. 0: _kernel_init

On entry

R0 = Pointer to kernel init block having the following format
+00: Image base (e.g. the value of the linker symbol ImageS$$RO$$Base)
+04: pointer to start of language description blocks
+08: pointer to end of language description blocks

R1 = base of root stack chunk (value returned in R1 from LibInitAPCS_A or LibInitAPCS_R)

R2 = top of root stack chunk (value returned in R2 from LibInitAPCS_A or LibInitAPCS_R)

R3 = 0 for application
1 for module

R4 = end of workspace

On exit

Does not return. Control is regained through the procedure pointer returned in R0 by one of the language initialisation procedures (i.e. control is passed to the run code of the language).

This call does not obey the APCS. All registers are altered. The APCS_R SL, FP and SP (R10, R11 and R13) are set up. LR does not contain a valid return address when control is passed to the run entry.

This function must be called by any client which calls LibInitAPCS_A or LibInitAPCS_R. Modules should call this entry in their run entry.

The words at offsets +04 and +08 from R0 describe an area containing at least one language description block. Any number of language description blocks may be present. The size field of each block must be the offset to the next language description block.

The command line is copied to an internal buffer at the top of the root stack chunk. To set a command line call SWI OS_WriteEnv. RISC OS sets up a command line before running your application or entering your module.

Exit, Error, CallBack, Escape, Event, UpCall, Illegal Instruction, Prefetch Abort, Data Abort and Address Exception handlers are set up.

Initial default alloc and free procs for use during stack extension are set up. These should be replaced with your own alloc and free procs as soon as possible.

The kernels workspace pointers are initialised to the values contained in R1 and R4. Note that it is assumed the root stack chunk resides at the base of the workspace area.

A small stack (159 words) for use during stack extension is claimed from the workspace following R2 (i.e. 159 words are claimed from R2 upwards).

Note: _kernel_init does not check that there is sufficient space in the workspace to claim this area. You must ensure there is sufficient space before calling _kernel_init.

The availability of floating point is determined (by calling SWI FPE_Version).

If executing under the desktop the initial wimpslot size is determined by reading the Application Space handler.

The initialisation for each language is called, then the run code if any is called. If no run code is present the error `No main program` is generated.

Entry no. 38: _kernel_moduleinit

On entry

R0 = pointer to kernel init block as described in _kernel_init on page 6-211
R1 = pointer to base of SVC stack (as returned by SWI LibInitModule)

On exit

This call does not obey the APCS.
On exit SL points to R1 on entry + 560.
R0, R1, R2 and R12 are indeterminate.

The kernel init block is copied for later use. The Image base is ignored.

The functions _kernel_RMAalloc and _kernel_RMAfree are established as the default alloc and free procs for use during stack extension.

You should call this function after calling SWI LibInitModule.

Entry no. 42: _kernel_entermodule

On entry

R0 = pointer to kernel init block as described in _kernel_init on page 6-211
R6 = requested root stack size
R8 = modules private word pointer

On exit

Does not return.
Control is regained through the procedure pointer returned in R0 by one of the language initialisation procedures.

The private word must point to the module workspace word which must contain the application base, the shared library static offset, and the client static offset in words 0, 1 and 2 (the application base is ignored for modules).

After claiming workspace from the application space and claiming a root stack from this _kernel_entermodule calls _kernel_init.

Stack management functions

Entry no. 27: _kernel_stkovf_split_0frame

This function is described in the section entitled *How the run-time stack is managed and extended* on page 6-185.

Entry no. 28: _kernel_stkovf_split

This function is described in the section entitled *How the run-time stack is managed and extended* on page 6-185.

Entry no. 29: _kernel_stkovf_copyargs

This function is described in the section entitled *How the run-time stack is managed and extended* on page 6-185.

Entry no. 30: _kernel_stkovf_copy0args

This function is described in the section entitled *How the run-time stack is managed and extended* on page 6-185.

```
typedef struct stack_chunk {
    unsigned long sc_mark;       /* == 0xf60690ff */
    struct stack_chunk *sc_next, *sc_prev;
    unsigned long sc_size;
    int (*sc_deallocate)()
} _kernel_stack_chunk;
```

Entry no. 44: _kernel_stack_chunk *_kernel_current_stack_chunk(void)

Returns a pointer to the current stack chunk.

```
typedef struct {
    int r4, r5, r6, r7, r8, r9;
    int fp, sp, pc, sl;
    int f4[3], f5[3], f6[3], f7[3];
} _kernel_unwindblock;
```

Entry no. 4: int _kernel_unwind(_kernel_unwindblock *inout, char **language)

Unwinds the call stack one level. Returns:
>0 if it succeeds
0 if it fails because it has reached the stack end or
<0 if it fails for any other reason (e.g. stack corrupt)

Input values for `fp`, `sl` and `pc` must be correct. r4-r9 and f4-f7 are updated if the frame addressed by the input value of `fp` contains saved values for the corresponding registers.

`fp`, `sp`, `sl` and `pc` are always updated, the word pointed to by language is updated to point to a string naming the language corresponding to the returned value of pc.

Program environment functions

Entry no. 5: char *_kernel_procname(int pc)

Returns a string naming the procedure containing the address pc (or 0 if no name for it can be found).

Entry no. 6: char *_kernel_language(int pc)

Returns a string naming the language in whose code the address pc lies (or 0 if it is in no known language).

Entry no. 7: char *_kernel_command_string(void)

Returns a pointer to a copy of the command string used to run the program.

Entry no. 2: void _kernel_setreturncode(unsigned code)

Sets the return code to be used by _kernel_exit.

Entry no. 1: void _kernel_exit(void)

Calls OS_Exit with the return code specified by a previous call to _kernel_setreturncode.

Entry no. 47: void _kernel_raise_error(_kernel_oserror *)

Generates an external error.

Entry no. 3: void _kernel_exittraphandler(void)

Resets the InTrapHandler flag which prevents recursive traps. Used in trap handlers which do not return directly but continue execution.

Entry no. 8: int _kernel_hostos(void)

Returns 6 for RISC OS.
(Returns the result of calling OS_Byte with R0 = 0 and R1 = 1.)

Entry no. 37: int _kernel_fpavailable(void)

Returns non-zero if floating point is available.

Entry no. 21: _kernel_oserror *_kernel_last_oserror(void)

Returns a pointer to an error block describing the last OS error since _kernel_last_oserror was last called (or since the program started if there has been no such call). If there has been no OS error it returns 0. Note that occurrence of a further error may overwrite the contents of the block. This can be used, for example, to determine the error which caused fopen to fail. If _kernel_swi caused the last OS error, the error already returned by that call gets returned by this too.

Entry no. 23: _kernel_oserror *_kernel_getenv(const char *name, char *buffer, unsigned size)

Reads the value of a system variable, placing the value string in the buffer (of size size).

Entry no. 24: _kernel_oserror *_kernel_setenv(const char *name,const char *value)

Updates the value of a system variable to be string valued, with the given value (value = 0 deletes the variable)

Entry no. 43: int _kernel_escape_seen(void)

Returns 1 if there has been an escape since the previous call of _kernel_escape_seen (or since the program start if there has been no previous call). Escapes are never ignored with this mechanism, whereas they may be with the language EventProc mechanism since there may be no stack to call the EventProc on.

Entry no. 39: void _kernel_irqs_on(void)

Enable interrupts. You should not disable interrupts unless absolutely necessary. If you disable interrupts you should re-enable them as soon as possible (preferably within 10uS).

This function can only be used from code running in SVC mode.

Entry no. 40: void _kernel_irqs_off(void)

Disable IRQ interrupts. You should not disable interrupts unless absolutely necessary. If you disable interrupts you should re-enable them as soon as possible (preferably within 10uS).

This function can only be used from code running in SVC mode.

Entry no. 41: int _kernel_irqs_disabled(void)

Returns non-zero if IRQ interrupts are disabled.

General utility functions

```
typedef struct {
   int r[10]; /* only r0 - r9 matter for swi's */
} _kernel_swi_regs;
```

Entry no. 9: _kernel_oserror *_kernel_swi(int no, _kernel_swi_regs *in, _kernel_swi_regs *out)

Call the SWI specified by `no`. The X bit is set by _kernel_swi unless bit31 is set. `in` and `out` are pointers to blocks for R0 - R9 on entry to and exit from the SWI.

Returns a pointer to an error block if an error occurred, otherwise 0.

Entry no. 45: _kernel_oserror *_kernel_swi_c(int no, _kernel_swi_regs *in, _kernel_swi_regs *out, int *carry)

Similar to _kernel_swi but returns the status of the carry flag on exit from the SWI in the word pointed to by `carry`.

Entry no. 10: int _kernel_osbyte(int op, int x, int y)

Performs an OS_Byte operation. If there is no error, the result contains:
the return value of R1 (x) in its bottom byte
the return value of R2 (y) in its second byte
1 in the third byte if carry is set on return, otherwise 0
0 in its top byte

Entry no. 11: int _kernel_osrdch(void)

Returns a character read from the currently selected OS input stream.

Entry no. 12: int _kernel_oswrch(int ch)

Writes a byte to all currently selected OS output streams. The return value just indicates success or failure.

Entry no. 13: int _kernel_osbget(unsigned handle);

Returns the next byte from the file identified by `handle`. (-1 ⇒EOF)

Entry no. 14: int _kernel_osbput(int ch, unsigned handle)

Writes a byte to the file identified by `handle`. The return value just indicates success or failure.

```
typedef struct {
   void * dataptr; /* memory address of data */
   int nbytes, fileptr;
   int buf_len; /* these fields for Arthur gpbp extensions */
   char * wild_fld; /* points to wildcarded filename to match */
} _kernel_osgbpb_block;
```

Entry no. 15: int _kernel_osgbpb(int op, unsigned handle, _kernel_osgbpb_block *inout);

Reads or writes a number of bytes from a filing system. The return value just indicates success or failure. Note that for some operations, the return value of C is significant, and for others it isn't. In all cases, therefore, a return value of -1 is possible, but for some operations it should be ignored.

Entry no. 16: int _kernel_osword(int op, int *data)

Performs an OS_Word operation. The size and format of the block pointed to by `data` depends on the particular OS_Word being used; it may be updated.

Entry no. 17: int _kernel_osfind(int op, char *name)

Opens or closes a file. Open returns a file handle (0 ⇒ open failed without error). For close the return value just indicates success or failure.

```
typedef struct {
  int load, exec; /* load, exec addresses */
  int start, end; /* start address/length, end address/attributes */
} _kernel_osfile_block;
```

Entry no. 18: int _kernel_osfile(int op, const char *name, _kernel_osfile_block *inout)

Performs an OS_File operation, with values of R2 - R5 taken from the osfile block. The block is updated with the return values of these registers, and the result is the return value of R0 (or an error indication).

Entry no. 19: int _kernel_osargs(int op, unsigned handle, int arg)

Performs an OS_Args operation. The result is the current filing system number (if op = 0) otherwise the value returned in R2 by the OS_Args operation.

Entry no. 20: int _kernel_oscli(char *s)

Calls OS_CLI with the specified string. If used to run another application the current application will be closed down. If you wish to return to the current application use _kernel_system. The return value just indicates whether there was an error or not.

Entry no. 22: int _kernel_system(char *string, int chain)

Calls OS_CLI with the specified string. If chain is 0, the current application is copied to the top of memory first, then handlers are installed so that if the command string causes an application to be invoked, control returns to _kernel_system, which then copies the calling application back into its proper place. Hence the command is executed as a sub-program. If chain is 1, all handlers are removed before calling the CLI, and if it returns (the command is built-in) _kernel_system Exits. The return value just indicates whether there was an error or not.

Memory allocation functions

Entry no. 26: unsigned _kernel_alloc(unsigned words, void **block)

Tries to allocate a block of size = `words` words. Failing that, it allocates the largest possible block (may be size zero). If `words` is < 2048 it is rounded up to 2048. Returns a pointer to the allocated block in the word pointed to by `block`. The return value gives the size of the allocated block.

```
typedef void freeproc(void *);
typedef void * allocproc(unsigned);
```

Entry no. 25: void _kernel_register_allocs(allocproc *malloc, freeproc *free)

Registers procedures to be used by the kernel when it requires to free or allocate storage. Currently this is only used to allocate and free stack chunks. Since allocproc and freeproc are called during stack extension, they must not check for stack overflow themselves or call any procedure which does stack checking and must guarantee to require no more than 41 words of stack.

The kernel provides default alloc and free procedures, however you should replace these with your own procedures since the default procedures are rather naive.

```
typedef int _kernel_ExtendProc(int /*n*/, void** /*p*/);
```

Entry no. 46: _kernel_ExtendProc *_kernel_register_slotextend (_kernel_ExtendProc *proc)

When the initial heap (supplied to _kernel_init) is full, the kernel is normally capable of extending it by extending the wimpslot. However, if the heap limit is not the same as the application limit, it is assumed that someone else has acquired the space between, and the procedure registered here is called to request n bytes from it.

Its return value is expected to be ≥ n, or 0 to indicate failure. If successful the word pointed to by p should be set to point to the space allocated.

Language support functions

Entry no. 31: unsigned _kernel_udiv(unsigned divisor, unsigned dividend);

Divide and remainder function, returns the remainder in R1.

Entry no. 32: unsigned _kernel_urem(unsigned divisor, unsigned dividend);

Remainder function.

Entry no. 33: unsigned _kernel_udiv10(unsigned dividend);

Divide and remainder function, returns the remainder in R1.

Entry no. 34: int _kernel_sdiv(int divisor, int dividend);

Signed divide and remainder function, returns the remainder in R1.

Entry no. 35: int _kernel_srem(int divisor, int dividend);

Signed remainder function.

Entry no. 36: int _kernel_sdiv10(int dividend);

Signed divide and remainder function, returns the remainder in R1.

C library functions

The C library functions are grouped under the following headings:

- *Language support functions*
  Provides functions for trap and event handling, initialisation and finalisation, and mathematical routines such as number conversion and multiplication.
- *assert*
  The assert module provides one function which is useful during program testing.
- *ctype*
  The `ctype` module provides several functions useful for testing and mapping characters.
- *errno*
  The word variable __errno at offset 800 in the library statics is set whenever certain error conditions arises.
- *locale*
  This module handles national characteristics, such as the different orderings month-day-year (USA) and day-month-year (UK).
- *math*
  This module contains the prototypes for 22 mathematical functions. All return the type `double`.
- *setjmp*
  This module provides two functions for bypassing the normal function call and return discipline.
- *signal*
  `Signal` provides two functions.
- *stdio*
  `stdio` provides many functions for performing input and output.
- *stdlib*
  `stdlib` provides several general purpose functions.
- *string*
  `string` provides several functions useful for manipulating character arrays and other objects treated as character arrays.
- *time*
  `time` provides several functions for manipulating time.

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Language support functions

Entry no. 0: TrapHandler

Entry no. 1: UncaughtTrapHandler

On entry:

R0 = error code
R1 = pointer to register dump

On exit:

Only exits if the trap was not handled

R0 = 0 (indicating that the trap was not handled).

These are the default TrapProc and UncaughtTrapProc handlers used by the C library in its kernel language description (see the section entitled *Interfacing a language run-time system to the Acorn library kernel* on page 6-184).

You may use these entries in your own kernel language description if you wish to have trap handling similar to that provided by the C library, or you may call these entries directly from your own trap handler if you wish to perform some pre-processing before passing the trap on.

The error code on entry is converted to a signal number as follows:

Signal no.	Error codes
2 (SIGFPE)	&80000020 (Error_DivideByZero), &80000200 (Error_FPBase) – &800002ff (Error_FPLimit – 1)
3 (SIGILL)	&80000000 (Error_IllegalInstruction), &80000001 (Error_PrefetchAbort), &80000005 (Error_BranchThroughZero)
5 (SIGSEGV)	&80000002 (Error_DataAbort), &80000003 (Error_AddressException), &80800ea0 (Error_ReadFail), &80800ea1 (Error_WriteFail)
7 (SIGSTAK)	&80000021 (Error_StackOverflow)
10 (SIGOSERROR)	All other errors

It then determines whether a signal handler has been set up for the converted signal handler. If no such handler has been set up (ie the signal handler is set to __SIG_DFL) it returns with R0 = 0.

Otherwise it calls the C library function `raise` with the derived signal number. If the raise function returns (ie the signal handler returns) a postmortem stack backtrace is generated.

Entry no. 2: EventHandler

Entry no. 3: UnhandledEventHandler

On entry:

R0 = event code
R1 = pointer to register dump

On exit:

R0 = 1 if the event was handled, else 0

These are the default EventProc and UnhandledEventProc handlers used by the C library in its kernel language description (see the section entitled *Interfacing a language run-time system to the Acorn library kernel* on page 6-184).

You may use these entries in your own kernel language description if you wish to have event handling similar to that provided by the C library or you may call these entries directly from your own event handler if you wish to perform some pre-processing before passing the event on.

The event code on entry is either a RISC OS event number as described in the chapter entitled *Events* on page 1-137, or −1 to indicate an escape event.

All events codes except −1 are currently ignored. The handler simply returns with R0 = 0 if R0 ≠ −1 on entry.

EventHandler then determines whether a SIGINT signal handler has been set up. If no handler is set up (ie the signal handler is set to __SIG_DFL) EventHandler returns with R0 = 0.

The C library function `raise` is then called with the signal number SIGINT. Note: `raise` is always called by UnhandledEventHandler even if the signal handler is set to __SIG_DFL.

If the signal handler returns the event handler returns with R0 = 1.

Certain sections of the C library are non-reentrant. When these sections are entered they set the variable _interrupts_off at offset 964 in the library statics is set to 1.

EventHandler and UnhandledEventHandler check this variable and, if it is set they set the variable _saved_interrupt at offset 968 in the library statics to SIGINT and returns immediately with R0 = 1 and without calling `raise`.

When the non-reentrant sections of code finish they reset the variable _interrupts_off and check the variable _saved_interrupts. If _saved_interrupts is non-zero it is reset to zero and the signal number stored in _saved_interrupts (before it was reset to 0) is raised.

Entry no. 4: x$stack_overflow

This entry branches directly to _kernel_stkovf_split_0frame which is described in the section entitled *How the run-time stack is managed and extended* on page 6-185.

Entry no. 5: x$stack_overflow_1

This entry branches directly to _kernel_stkovf_split which is described in the section entitled *How the run-time stack is managed and extended* on page 6-185.

Entry no. 6: x$udivide

This entry branches directly to _kernel_udiv described on page 6-219.

Entry no. 7: x$uremainder

This entry branches directly to _kernel_urem described on page 6-219.

Entry no. 8: x$divide

This entry branches directly to _kernel_sdiv described on page 6-219.

Entry no. 9: x$divtest

This function is used by the C compiler to test for division by zero when the result of the division is discarded.

If R0 is non-zero the function simply returns. Otherwise it generates a `Divide by zero` error.

Entry no. 10: x$remainder

This entry branches directly to _kernel_srem described on page 6-220.

Entry no. 11: x$multiply

On entry:

R0 = multiplicand
R1 = multiplier

On exit:

R0 = R0 * R1
R1, R2 scrambled.

Entry no. 12: _rd1chk

Entry no. 13: _rd2chk

Entry no. 14: _rd4chk

The functions `_rd1chk`, `_rd2chk` and `_rd4chk` check that the value of R0 passed to them is a valid address in the application space (&8000 ≤ R0 < &1000000). _rd2chk and _rd4chk also check that the value is properly aligned for a half-word / word access respectively.

If the value of R0 is a valid address the function just returns, otherwise it generates an `Illegal read` error.

These calls are used by the C compiler when compiling with memory checking enabled.

Entry no. 15: _wr1chk

Entry no. 16: _wr2chk

Entry no. 17: _wr4chk

The functions `_wr1chk`, `_wr2chk` and `_wr4chkcheck` that the value of R0 passed to them is a valid address in the application space (&8000 ≤ R0 < &1000000). _rd2chk and _rd4chk also check that the value is properly aligned for a half-word / word access respectively.

If the value of R0 is a valid address the function just returns, otherwise it generates an `Illegal write` error.

These calls are used by the C compiler when compiling with memory checking enabled.

Entry no. 18: _main

On entry:

R0 = pointer to copy of command line (the command line pointed to by R0 on return from OS_GetEnv should be copied to another buffer before calling _main).

R1 = address of routine at which execution will continue when _main has finished.

The following entry and exit conditions apply for this routine:

On entry:

R0 = count of argument `words`.
R1 = pointer to block containing R0 + 1 words, each word I in the block points to a zero terminated string which is the I'th word in the command line passed to _main. The last word in the block contains 0.

On exit:

R0 = exit condition (0 = success, else failure)

For C programs this argument will generally point at `main`.

On exit:

Does not return. Control is regained through the R1 argument on entry.

This function parses the command line pointed to by R0 and then calls the function pointed to by R1.

For C programs this function is called by the C library as a precursor to calling `main` to provide the C entry / exit requirements.

Entry no. 19: void _exit(void)

This function is identical in behaviour to the C library function `exit` described on page 6-263.

Entry no. 20: void _clib_initialise(void)

Performs various initialisation required before other C library functions can be called. You should call this function in your initialisation procedure.

Entry no. 21: void _backtrace(int why, int *address, _kernel_unwindblock *uwb)

Displays a stack backtrace and exits with the exit code 1.

The _kernel_unwindblock structure is described with the _kernel_unwind function on page 6-214. The argument `why` is an error code, if `why` is Error_ReadFail (&80800ea0) or Error_WriteFail (&80800ea1) the address given by the `address` argument is displayed at the top of the backtrace, otherwise the message `postmortem requested` is displayed.

Entry no. 22: _count

Entry no. 23: _count1

These entries are used by the C compiler when generating *profile* code.

Both _count and _count1 increment the word pointed to by R14 (after stripping the status bits), this will generally be the word immediately following a BL instruction to the relevant routine. _count then returns to the word immediately following the incremented word, _count1 returns to the word after that (the second word is used by the C compiler to record the position in a source file that this count-point refers to).

```
BL      _count
DCD     0               ; This word incremented each time _count is called
...                     ; Control returns here

BL      _count1
DCD     0               ; This word incremented each time _count1 is called
DCD     filepos         ; Offset into source file
...                     ; Control returns here
```

Entry no. 24: void _stfp(double d, void *x)

This function converts the double FP no. d to packed decimal and stores it at address x. Note that the double d is passed in R0, R1 (R0 containing the first word when a double is stored in memory, R1 containing the second word), the argument x is passed in R2. Three words should be reserved at x for the packed decimal number.

Entry no. 25: double _ldfp(void *x)

This function converts the packed decimal number stored at x to a double FP no. and returns this in F0.

Entry no. 169: void _memcpy(int *dest, int *source, int n)

This function performs a similar function to memcopy except that `dest` and `source` must be word aligned and the byte count n must be a multiple of 4.

It is used by the C compiler when copying structures.

Entry no. 170: void _memset(int *dest, int w, int n)

This function performs a similar function to memset except that `dest` must be word aligned, the byte value to be set must be copied into each of the four bytes of w (i.e. to initialise memory to &01 you must use &01010101 in w) and the byte count n must be a multiple of 4.

It is used by the C compiler when initialising structures.

Entry no. 179: _clib_finalisemodule

This entry must be called in the finalisation code of a module which uses the shared C library. Before calling it you must set up the static data relocation pointers on the base of the SVC stack and initialise the SL register to point to the base of the SVC stack + 512. The old static data relocation pointers on the base of the SVC stack must be saved around this call.

Entry no. 180: char *_clib_version(void)

This function returns a string giving version information on the Shared C Library.

Entry no. 181: Finalise

This function calls all the registered atexit functions and then performs some internal finalisation of the alloc and io subsystems.

This entry is called automatically by the C library on finalisation, you should not call it in your code.

assert

The assert module provides one function which is useful during program testing.

Entry no. 168: void __assert(char *reason, char *file, int line)

Displays the message:

```
*** assertion failed: 'reason', file 'file', line 'line'
```

and raises SIGABRT.

This function is generally used within a macro which calls __assert if a specified condition is false.

ctype

The `ctype` module provides several functions useful for testing and mapping characters. In all cases the argument is an int, the value of which is representable as an unsigned char or equal to the value –1. If the argument has any other value, the behaviour is undefined.

Entry no. 155: int isalnum(int c)

Returns true if c is alphabetic or numeric

Entry no. 156: int isalph(int c)

Returns true if c is alphabetic

Entry no. 157: int iscntrl(int c)

Returns true if c is a control character (in the ASCII locale)

Entry no. 158: int isdigit(int c)

Returns true if c is a decimal digit

Entry no. 159: int isgraph(int c)

Returns true if c is any printable character other than space

Entry no. 160: int islower(int c)

Returns true if c is a lower-case letter

Entry no. 161: int isprint(int c)

Returns true if c is a printable character (in the ASCII locale this means 0x20 (space) → 0x7E (tilde) inclusive).

Entry no. 162: int ispunct(int c)

Returns true if c is a printable character other than a space or alphanumeric character

Entry no. 163: int isspace(int c)

Returns true if c is a white space character viz: space, newline, return, linefeed, tab or vertical tab

Entry no. 164: int isupper(int c)

Returns true if c is an upper-case letter

Entry no. 165: int isxdigit(int c)

Returns true if c is a hexadecimal digit, ie in 0...9, a...f, or A...F

Entry no. 166: int tolower(int c)

Forces c to lower case if it is an upper-case letter, otherwise returns the original value

Entry no. 167: int toupper(int c)

Forces c to upper case if it is a lower-case letter, otherwise returns the original value

errno

The word variable __errno at offset 800 in the library statics is set whenever one of the error conditions listed below arises.

EDOM (__errno=1)

If a domain error occurs (an input argument is outside the domain over which the mathematical function is defined) the integer expression `errno` acquires the value of the macro EDOM and `HUGE_VAL` is returned. EDOM may be used by non-mathematical functions.

ERANGE (__errno=2)

A range error occurs if the result of a function cannot be represented as a double value. If the result overflows (the magnitude of the result is so large that it cannot be represented in an object of the specified type), the function returns the value of the macro `HUGE_VAL`, with the same sign as the correct value of the function; the integer expression `errno` acquires the value of the macro ERANGE. If the result underflows (the magnitude of the result is so small that it cannot be represented in an object of the specified type), the function returns zero; the integer expression `errno` acquires the value of the macro ERANGE. ERANGE may be used by non-mathematical functions.

ESIGNUM (__errno=3)

If an unrecognised signal is caught by the default signal handler, `errno` is set to `ESIGNUM`.

locale

This module handles national characteristics, such as the different orderings month-day-year (USA) and day-month-year (UK).

Entry no. 154: char *setlocale(int category, const char *locale)

Selects the appropriate part of the program's locale as specified by the `category` and `locale` arguments. The `setlocale` function may be used to change or query the program's entire current locale or portions thereof. Locale information is divided into the following types:

Type	Value	Description
LC_COLLATE	(1)	string collation
LC_CTYPE	(2)	character type
LC_MONETARY	(4)	monetary formatting
LC_NUMERIC	(8)	numeric string formatting
LC_TIME	(16)	time formatting
LC_ALL	(31)	entire locale

The locale string specifies which locale set of information is to be used. For example,

```
setlocale(LC_MONETARY,"uk")
```

would insert monetary information into the `lconv` structure. To query the current locale information, set the `locale` string to null and read the string returned.

Entry no. 171: struct lconv *localeconv(void)

Sets the components of an object with type struct `lconv` with values appropriate for the formatting of numeric quantities (monetary and otherwise) according to the rules of the current locale. The members of the structure with type `char *` are strings, any of which (except `decimal_point`) can point to `""`, to indicate that the value is not available in the current locale or is of zero length. The members with type `char` are non-negative numbers, any of which can be `CHAR_MAX` to indicate that the value is not available in the current locale. The members included are described above.

`localeconv` returns a pointer to the filled in object. The structure pointed to by the return value will not be modified by the program, but may be overwritten by a subsequent call to the `localeconv` function. In addition, calls to the `setlocale` function with categories `LC_ALL`, `LC_MONETARY`, or `LC_NUMERIC` may overwrite the contents of the structure.

math

This module contains the prototypes for 22 mathematical functions. All return the type `double`.

Entry no. 132: double acos(double x)

Returns arc cosine of x. A domain error occurs for arguments not in the range –1 to 1

Entry no. 133: double asin(double x)

Returns arc sine of x. A domain error occurs for arguments not in the range –1 to 1

Entry no. 134: double atan(double x)

Returns arc tangent of x

Entry no. 135: double atan2(double x, double y)

Returns arc tangent of y/x

Entry no. 136: double cos(double x)

Returns cosine of x (measured in radians)

Entry no. 137: double sin(double x)

Returns sine of x (measured in radians)

Entry no. 138: double tan(double x)

Returns tangent of x (measured in radians)

Entry no. 139: double cosh(double x)

Returns hyperbolic cosine of x

Entry no. 140: double sinh(double x)

Returns hyperbolic sine of x

Entry no. 141: double tanh(double x)

Returns hyperbolic tangent of x

Entry no. 142: double exp(double x)

Returns exponential function of x

Entry no. 143: double frexp(double *x*, int *exp)

Returns the value x, such that x is a double with magnitude in the interval 0.5 to 1.0 or zero, and value equals x times 2 raised to the power *exp

Entry no. 144: double ldexp(double *x*, int exp)

Returns x times 2 raised to the power of exp

Entry no. 145: double log(double *x*)

Returns natural logarithm of x

Entry no. 146: double log10(double *x*)

Returns log to the base 10 of x

Entry no. 147: double modf(double *x*, double *iptr)

Returns signed fractional part of x. Stores integer part of x in object pointed to by iptr.

Entry no. 148: double pow(double *x*, double *y*)

Returns x raised to the power of y

Entry no. 149: double sqrt(double *x*)

Returns positive square root of x

Entry no. 150: double ceil(double *x*)

Returns smallest integer not less than x (ie rounding up)

Entry no. 151: double fabs(double *x*)

Returns absolute value of x

Entry no. 152: double floor(double *x*)

Returns largest integer not greater than x (ie rounding down)

Entry no. 153: double fmod(double *x*, double *y*)

Returns floating-point remainder of x/y

setjmp

This module provides two functions for bypassing the normal function call and return discipline (useful for dealing with unusual conditions encountered in a low-level function of a program).

Entry no. 130: int setjmp(jmp_buf *env*)

The calling environment is saved in `env`, for later use by the `longjmp` function. If the return is from a direct invocation, the `setjmp` function returns the value zero. If the return is from a call to the `longjmp` function, the `setjmp` function returns a non-zero value.

Entry no. 131: void longjmp(jmp_buf *env*, int *val*)

The environment saved in `env` by the most recent call to `setjmp` is restored. If there has been no such call, or if the function containing the call to `setjmp` has terminated execution (eg with a return statement) in the interim, the behaviour is undefined. All accessible objects have values as at the time `longjmp` was called, except that the values of objects of automatic storage duration that do not have volatile type and that have been changed between the `setjmp` and `longjmp` calls are indeterminate.

As it bypasses the usual function call and return mechanism, the `longjmp` function executes correctly in contexts of interrupts, signals and any of their associated functions. However, if the `longjmp` function is invoked from a nested signal handler (that is, from a function invoked as a result of a signal raised during the handling of another signal), the behaviour is undefined.

After `longjmp` is completed, program execution continues as if the corresponding call to `setjmp` had just returned the value specified by *`val`*. The `longjmp` function cannot cause `setjmp` to return the value 0; if *`val`* is 0, `setjmp` returns the value 1.

signal

`Signal` provides two functions.

```
typedef void Handler(int);
```

Entry no. 128: Handler *signal(int, Handler *);

The following signal handlers are defined:

Type	value	description
SIG_DFL	(Handler*)-1	default routine
SIG_IGN	(Handler*)-2	ignore signal routine
SIG_ERR	(Handler*)-3	dummy routine to flag error return from signal

The following signals are defined:

Signal	value	description
SIGABRT	1	abort (ie call to abort())
SIGFPE	2	arithmetic exception
SIGILL	3	illegal instruction
SIGINT	4	attention request from user
SIGSEGV	5	bad memory access
SIGTERM	6	termination request
SIGSTAK	7	stack overflow
SIGUSR1	8	user definable
SIGUSR2	9	user definable
SIGOSERROR	10	operating system error

The 'signal' function chooses one of three ways in which receipt of the signal number `sig` is to be subsequently handled. If the value of `func` is `SIG_DFL`, default handling for that signal will occur. If the value of `func` is `SIG_IGN`, the signal will be ignored. Otherwise `func` points to a function to be called when that signal occurs.

When a signal occurs, if `func` points to a function, first the equivalent of `signal(sig, SIG_DFL)` is executed. (If the value of `sig` is `SIGILL`, whether the reset to `SIG_DFL` occurs is implementation-defined (under RISC OS the reset does occur)). Next, the equivalent of `(*func)(sig);` is executed. The function may terminate by calling the `abort`, `exit` or `longjmp` function. If `func` executes a return statement and the value of `sig` was `SIGFPE` or any other implementation-defined value corresponding to a computational exception, the behaviour is undefined. Otherwise, the program will resume execution at the point it was interrupted.

If the signal occurs other than as a result of calling the `abort` or `raise` function, the behaviour is undefined if the signal handler calls any function in the standard library other than the signal function itself or refers to any object with static storage duration other than by assigning a value to a volatile static variable of type `sig_atomic_t`. At program start-up, the equivalent of `signal(sig, SIG_IGN)` may be executed for some signals selected in an implementation-defined manner (under RISC OS this does not occur); the equivalent of `signal(sig, SIG_DFL)` is executed for all other signals defined by the implementation.

If the request can be honoured, the `signal` function returns the value of `func` for most recent call to `signal` for the specified signal `sig`. Otherwise, a value of `SIG_ERR` is returned and the integer expression `errno` is set to indicate the error.

Entry no. 129: int raise(int sig)

Sends the signal sig to the executing program. Returns zero if successful, non-zero if unsuccessful.

Entry no. 125: void __ignore_signal_handler(int sig)

This function is for compatibility with older versions of the shared C library stubs and should not be called in your code.

Entry no. 126: void __error_signal_marker(int sig)

This function is for compatibility with older versions of the shared C library stubs and should not be called in your code.

Entry no. 127: void __default_signal_handler(int sig)

This function is for compatibility with older versions of the shared C library stubs and should not be called in your code.

stdio

`stdio` provides many functions for performing input and output. For a discussion on Streams and Files refer to sections 4.9.2 and 4.9.3 in the ANSI standard.

The following two types are used by the stdio module:

```
typedef int fpos_t;
```

`fpos_t` is an object capable of recording all information needed to specify uniquely every position within a file.

```
typedef struct FILE{
   unsigned char *_ptr;     /* pointer to IO buffer */
   int _icnt;               /* character count for input */
   int _ocnt;               /* character count for output */
   int _flag;               /* flags, see below */
   int internal[6];
}FILE;
```

The following flags are defined in the flags field above:

Flag	Bit mask	Description
_IOEOF	&040	end-of-file reached
_IOERR	&080	error occurred on stream
_IOFBF	&100	fully buffered IO
_IOLBF	&200	line buffered IO
_IONBF	&400	unbuffered IO

`FILE` is an object capable of recording all information needed to control a stream, such as its file position indicator, a pointer to its associated buffer, an error indicator that records whether a read/write error has occurred and an end-of-file indicator that records whether the end-of-file has been reached.

Entry no. 81: int remove(const char * *filename*)

Causes the file whose name is the string pointed to by `filename` to be removed. Subsequent attempts to open the file will fail, unless it is created anew. If the file is open, the behaviour of the `remove` function is implementation-defined (under RISC OS the operation fails).

Returns: zero if the operation succeeds, non-zero if it fails.

Entry no. 82: int rename(const char * *old*, const char * *new*)

Causes the file whose name is the string pointed to by `old` to be henceforth known by the name given by the string pointed to by `new`. The file named `old` is effectively removed. If a file named by the string pointed to by `new` exists prior to the call of the `rename` function, the behaviour is implementation-defined (under RISC OS, the operation fails).

Returns: zero if the operation succeeds, non-zero if it fails, in which case if the file existed previously it is still known by its original name.

Entry no. 83: FILE *tmpfile(void)

Creates a temporary binary file that will be automatically removed when it is closed or at program termination. The file is opened for update.

Returns: a pointer to the stream of the file that it created. If the file cannot be created, a null pointer is returned.

Entry no. 182: char *tmpnam(char * *s*)

Generates a string that is not the same as the name of an existing file. The `tmpnam` function generates a different string each time it is called, up to `TMP_MAX` times. If it is called more than `TMP_MAX` times, the behaviour is implementation-defined (under RISC OS the algorithm for the name generation works just as well after `tmpnam` has been called more than `TMP_MAX` times as before; a name clash is impossible in any single half year period).

Returns: If the argument is a null pointer, the `tmpnam` function leaves its result in an internal static object and returns a pointer to that object. Subsequent calls to the `tmpnam` function may modify the same object. If the argument is not a null pointer, it is assumed to point to an array of at least `L_tmpnam` characters; the `tmpnam` function writes its result in that array and returns the argument as its value.

Entry no. 84: char *__old_tmpnam(char *s)

This function is included for backwards compatibility for binaries linked with older library stubs. You should not call this function in your code, call tmpnam (Entry no. 182) instead.

Entry no. 85: int fclose(FILE * *stream*)

Causes the stream pointed to by `stream` to be flushed and the associated file to be closed. Any unwritten buffered data for the stream are delivered to the host environment to be written to the file; any unread buffered data are discarded. The stream is disassociated from the file. If the associated buffer was automatically allocated, it is deallocated.

Returns: zero if the stream was successfully closed, or EOF if any errors were detected or if the stream was already closed.

Entry no. 86: int fflush(FILE * *stream*)

If the stream points to an output or update stream in which the most recent operation was output, the `fflush` function causes any unwritten data for that stream to be delivered to the host environment to be written to the file. If the stream points to an input or update stream, the `fflush` function undoes the effect of any preceding `ungetc` operation on the stream.

Returns: EOF if a write error occurs.

Entry no. 87: FILE *fopen(const char * *filename*, const char * *mode*)

Opens the file whose name is the string pointed to by `filename`, and associates a stream with it. The argument `mode` points to a string beginning with one of the following sequences:

`r`	open text file for reading
`w`	create text file for writing, or truncate to zero length
`a`	append; open text file or create for writing at eof
`rb`	open binary file for reading
`wb`	create binary file for writing, or truncate to zero length
`ab`	append; open binary file or create for writing at eof
`r+`	open text file for update (reading and writing)
`w+`	create text file for update, or truncate to zero length
`a+`	append; open text file or create for update, writing at eof
`r+b` or `rb+`	open binary file for update (reading and writing)
`w+b` or `wb+`	create binary file for update, or truncate to zero length
`a+b` or `ab+`	append; open binary file or create for update, writing at eof

- Opening a file with read mode (`r` as the first character in the `mode` argument) fails if the file does not exist or cannot be read.
- Opening a file with append mode (`a` as the first character in the `mode` argument) causes all subsequent writes to be forced to the current end of file, regardless of intervening calls to the `fseek` function.
- In some implementations, opening a binary file with append mode (`b` as the second or third character in the `mode` argument) may initially position the file position indicator beyond the last data written, because of null padding (but not under RISC OS).
- When a file is opened with update mode (`+` as the second or third character in the `mode` argument), both input and output may be performed on the associated stream. However, output may not be directly followed by input without an intervening call to the `fflush` function or to a file positioning function (`fseek`, `fsetpos`, or `rewind`), nor may input be directly followed by output without an intervening call to the `fflush` function or to a file positioning function, unless the input operation encounters end-of-file.
- Opening a file with update mode may open or create a binary stream in some implementations (but not under RISC OS). When opened, a stream is fully buffered if and only if it does not refer to an interactive device. The error and end-of-file indicators for the stream are cleared.

Returns: a pointer to the object controlling the stream. If the open operation fails, `fopen` returns a null pointer.

Entry no. 88: FILE *freopen(const char * *filename*, const char * *mode*, FILE * *stream*)

Opens the file whose name is the string pointed to by `filename` and associates the stream pointed to by `stream` with it. The `mode` argument is used just as in the `fopen` function. The `freopen` function first attempts to close any file that is associated with the specified stream. Failure to close the file successfully is ignored. The error and end-of-file indicators for the stream are cleared.

Returns: a null pointer if the operation fails. Otherwise, `freopen` returns the value of the stream.

Entry no. 89: void setbuf(FILE * *stream*, char * *buf*)

Except that it returns no value, the `setbuf` function is equivalent to the `setvbuf` function invoked with the values _IOFBF for `mode` and BUFSIZ for `size`, or if `buf` is a null pointer, with the value _IONBF for `mode`.

Returns: no value.

Entry no. 90: int setvbuf(FILE * *stream*, char * *buf*, int *mode*, size_t *size*)

This may be used after the stream pointed to by `stream` has been associated with an open file but before it is read or written. The argument `mode` determines how `stream` will be buffered, as follows:

- _IOFBF causes input/output to be fully buffered.
- _IOLBF causes output to be line buffered (the buffer will be flushed when a newline character is written, when the buffer is full, or when interactive input is requested).
- _IONBF causes input/output to be completely unbuffered.

If `buf` is not the null pointer, the array it points to may be used instead of an automatically allocated buffer (the buffer must have a lifetime at least as great as the open stream, so the stream should be closed before a buffer that has automatic storage duration is deallocated upon block exit). The argument `size` specifies the size of the array. The contents of the array at any time are indeterminate.

Returns: zero on success, or non-zero if an invalid value is given for mode or size, or if the request cannot be honoured.

Entry no. 92: int fprintf(FILE * *stream*, const char * *format*, ...)

writes output to the stream pointed to by `stream`, under control of the string pointed to by `format` that specifies how subsequent arguments are converted for output. If there are insufficient arguments for the format, the behaviour is undefined. If the format is exhausted while arguments remain, the excess arguments are evaluated but otherwise ignored. The `fprintf` function returns when the end of the format string is reached. The format must be a multibyte character sequence, beginning and ending in its initial shift state. The format is composed of zero or more directives: ordinary multibyte characters (not %), which are copied unchanged to the output stream; and conversion specifiers, each of which results in fetching zero or more subsequent arguments. Each conversion specification is introduced by the character %. For a complete description of the available conversion specifiers refer to section 4.9.6.1 in the ANSI standard. The minimum value for the maximum number of characters that can be produced by any single conversion is at least 509.

A brief and incomplete description of conversion specifications is:

`[flags][field width][.precision]specifier-char`

flags	is most commonly –, indicating left justification of the output item within the field. If omitted, the item will be right justified.
field width	is the minimum width of field to use. If the formatted item is longer, a bigger field will be used; otherwise, the item will be right (left) justified in the field.
precision	is the minimum number of digits to print for a d, i, o, u, x or X conversion, the number of digits to appear after the decimal digit for e, E and f conversions, the maximum number of significant digits for g and G conversions, or the maximum number of characters to be written from strings in an s conversion.

Either of both of *field width* and *precision* may be `*`, indicating that the value is an argument to `printf`.

The *specifier chars* are:

`d, i`	int printed as signed decimal
`o, u, x, X`	unsigned int value printed as unsigned octal, decimal or hexadecimal
`f`	double value printed in the style `[-]ddd.ddd`
`e, E`	double value printed in the style `[-]d.ddd...e dd`
`g, G`	double printed in f or e format, whichever is more appropriate
`c`	int value printed as unsigned char
`s`	`char *` value printed as a string of characters
`p`	`void *` argument printed as a hexadecimal address
`%`	write a literal %

Returns: the number of characters transmitted, or a negative value if an output error occurred.

Entry no. 91: int printf(const char * *format*, ...)

Equivalent to `fprintf` with the argument `stdout` interposed before the arguments to `printf`.

Returns: the number of characters transmitted, or a negative value if an output error occurred.

Entry no. 93: int sprintf(char * *s*, const char * *format*, ...)

Equivalent to `fprintf`, except that the argument *s* specifies an array into which the generated output is to be written, rather than to a stream. A null character is written at the end of the characters written; it is not counted as part of the returned sum.

Returns: the number of characters written to the array, not counting the terminating null character.

Entry no. 26: int _printf(const char *format, ...)

This function is identical in function to printf except that it does not handle floating point arguments.

It is used for space optimisation by the C compiler when using the non shared library and when a literal format string does not contain any floating point conversions.

It is included in the shared library for compatibility with the non shared library.

Entry no. 27: int _fprintf(FILE *stream, const char *format, ...)

This function is identical in function to fprintf except that it does not handle floating point arguments.

It is used for space optimisation by the C compiler when using the non shared library and when a literal format string does not contain any floating point conversions.

It is included in the shared library for compatibility with the non shared library.

Entry no. 28: int _sprintf(char *s, const char *format, ...)

This function is identical in function to sprintf except that it does not handle floating point arguments.

It is used for space optimisation by the C compiler when using the non shared library and when a literal format string does not contain any floating point conversions.

It is included in the shared library for compatibility with the non shared library.

Entry no. 100: int _vfprintf(FILE *stream, const char *format, va_list arg)

This function is identical in function to vfprintf except that it does not handle floating point arguments.

It is used for space optimisation by the C compiler when using the non shared library and when a literal format string does not contain any floating point conversions.

It is included in the shared library for compatibility with the non shared library.

Entry no. 95: int fscanf(FILE * *stream*, const char * *format*, ...)

Reads input from the stream pointed to by `stream`, under control of the string pointed to by `format` that specifies the admissible input sequences and how they are to be converted for assignment, using subsequent arguments as pointers to the objects to receive the converted input. If there are insufficient arguments for the format, the behaviour is undefined. If the format is exhausted while arguments remain, the excess arguments are evaluated but otherwise ignored. The format is composed of zero or more directives, one or more white-space characters, an ordinary character (not %), or a conversion specification. Each conversion specification is introduced by the character %. For a description of the available conversion specifiers refer to section 4.9.6.2 in the ANSI standard, or to any of the references listed in the chapter entitled *Introduction* on page 1 of the Acorn Desktop C Manual. A brief list is given above, under the entry for `fprintf`.

If end-of-file is encountered during input, conversion is terminated. If end-of-file occurs before any characters matching the current directive have been read (other than leading white space, where permitted), execution of the current directive terminates with an input failure; otherwise, unless execution of the current directive is terminated with a matching failure, execution of the following directive (if any) is terminated with an input failure.

If conversions terminate on a conflicting input character, the offending input character is left unread in the input stream. Trailing white space (including newline characters) is left unread unless matched by a directive. The success of literal matches and suppressed assignments is not directly determinable other than via the %n directive.

Returns: the value of the macro EOF if an input failure occurs before any conversion. Otherwise, the `fscanf` function returns the number of input items assigned, which can be fewer than provided for, or even zero, in the event of an early conflict between an input character and the format.

Entry no. 94: int scanf(const char * *format*, ...)

Equivalent to `fscanf` with the argument `stdin` interposed before the arguments to `scanf`.

Returns: the value of the macro EOF if an input failure occurs before any conversion. Otherwise, the `scanf` function returns the number of input items assigned, which can be fewer than provided for, or even zero, in the event of an early matching failure.

Entry no. 96: int sscanf(const char * *s*, const char * *format*, ...)

Equivalent to `fscanf` except that the argument *s* specifies a string from which the input is to be obtained, rather than from a stream. Reaching the end of the string is equivalent to encountering end-of-file for the `fscanf` function.

Returns: the value of the macro EOF if an input failure occurs before any conversion. Otherwise, the `scanf` function returns the number of input items assigned, which can be fewer than provided for, or even zero, in the event of an early matching failure.

Entry no. 97: int vprintf(const char * *format*, va_list *arg*)

Equivalent to `printf`, with the variable argument list replaced by `arg`, which has been initialised by the `va_start` macro (and possibly subsequent `va_arg` calls). The `vprintf` function does not invoke the va_end function.

Returns: the number of characters transmitted, or a negative value if an output error occurred.

Entry no. 98: int vfprintf(FILE * *stream*, const char * *format*, va_list *arg*)

Equivalent to `fprintf`, with the variable argument list replaced by *arg*, which has been initialised by the `va_start` macro (and possibly subsequent `va_arg` calls). The `vfprintf` function does not invoke the va_end function.

Returns: the number of characters transmitted, or a negative value if an output error occurred.

Entry no. 99: int vsprintf(char * *s*, const char * *format*, va_list *arg*)

Equivalent to `sprintf`, with the variable argument list replaced by *arg*, which has been initialised by the `va_start` macro (and possibly subsequent `va_arg` calls). The `vsprintf` function does not invoke the va_end function.

Returns: the number of characters written in the array, not counting the terminating null character.

Entry no. 101: int fgetc(FILE * *stream*)

Obtains the next character (if present) as an unsigned char converted to an int, from the input stream pointed to by `stream`, and advances the associated file position indicator (if defined).

Returns: the next character from the input stream pointed to by `stream`. If the stream is at end-of-file, the end-of-file indicator is set and `fgetc` returns EOF. If a read error occurs, the error indicator is set and `fgetc` returns EOF.

Entry no. 102: char *fgets(char * *s*, int *n*, FILE * *stream*)

Reads at most one less than the number of characters specified by *n* from the stream pointed to by `stream` into the array pointed to by *s*. No additional characters are read after a newline character (which is retained) or after end-of-file. A null character is written immediately after the last character read into the array.

Returns: *s* if successful. If end-of-file is encountered and no characters have been read into the array, the contents of the array remain unchanged and a null pointer is returned. If a read error occurs during the operation, the array contents are indeterminate and a null pointer is returned.

Entry no. 103: int fputc(int *c*, FILE * *stream*)

Writes the character specified by *c* (converted to an unsigned char) to the output stream pointed to by `stream`, at the position indicated by the associated file position indicator (if defined), and advances the indicator appropriately. If the file cannot support positioning requests, or if the stream was opened with append mode, the character is appended to the output stream.

Returns: the character written. If a write error occurs, the error indicator is set and `fputc` returns EOF.

Entry no. 104: int fputs(const char * *s*, FILE * *stream*)

Writes the string pointed to by *s* to the stream pointed to by `stream`. The terminating null character is not written.

Returns: EOF if a write error occurs; otherwise it returns a non-negative value.

Entry no. 106: int getc(FILE * *stream*)

Equivalent to `fgetc` except that it may be (and is under RISC OS) implemented as a macro. `stream` may be evaluated more than once, so the argument should never be an expression with side effects.

Returns: the next character from the input stream pointed to by `stream`. If the stream is at end-of-file, the end-of-file indicator is set and `getc` returns EOF. If a read error occurs, the error indicator is set and `getc` returns EOF.

Entry no. 107: int getchar(void)

Equivalent to `getc` with the argument `stdin`.

Returns: the next character from the input stream pointed to by `stdin`. If the stream is at end-of-file, the end-of-file indicator is set and `getchar` returns EOF. If a read error occurs, the error indicator is set and `getchar` returns EOF.

Entry no. 108: char *gets(char * *s*)

Reads characters from the input stream pointed to by `stdin` into the array pointed to by *s*, until end-of-file is encountered or a newline character is read. Any newline character is discarded, and a null character is written immediately after the last character read into the array.

Returns: *s* if successful. If end-of-file is encountered and no characters have been read into the array, the contents of the array remain unchanged and a null pointer is returned. If a read error occurs during the operation, the array contents are indeterminate and a null pointer is returned.

Entry no. 110: int putc(int *c*, FILE * *stream*)

Equivalent to `fputc` except that it may be (and is under RISC OS) implemented as a macro. `stream` may be evaluated more than once, so the argument should never be an expression with side effects.

Returns: the character written. If a write error occurs, the error indicator is set and `putc` returns EOF.

Entry no. 111: int putchar(int *c*)

Equivalent to `putc` with the second argument `stdout`.

Returns: the character written. If a write error occurs, the error indicator is set and `putc` returns EOF.

Entry no. 112: int puts(const char * *s*)

Writes the string pointed to by *s* to the stream pointed to by `stdout`, and appends a newline character to the output. The terminating null character is not written.

Returns: EOF if a write error occurs; otherwise it returns a non-negative value.

Entry no. 113: int ungetc(int *c*, FILE * *stream*)

Pushes the character specified by *c* (converted to an unsigned char) back onto the input stream pointed to by `stream`. The character will be returned by the next read on that stream. An intervening call to the `fflush` function or to a file positioning function (`fseek`, `fsetpos`, `rewind`) discards any pushed-back characters. The external storage corresponding to the stream is unchanged. One character pushback is guaranteed. If the `unget` function is called too many times on the same stream without an intervening read or file positioning operation on that stream, the operation may fail. If the value of *c* equals that of the macro `EOF`, the operation fails and the input stream is unchanged.

A successful call to the `ungetc` function clears the end-of-file indicator. The value of the file position indicator after reading or discarding all pushed-back characters will be the same as it was before the characters were pushed back. For a text stream, the value of the file position indicator after a successful call to the `ungetc` function is unspecified until all pushed-back characters are read or discarded. For a binary stream, the file position indicator is decremented by each successful call to the `ungetc` function; if its value was zero before a call, it is indeterminate after the call.

Returns: the character pushed back after conversion, or `EOF` if the operation fails.

Entry no. 114: size_t fread(void * *ptr*, size_t *size*, size_t *nmemb*, FILE * *stream*)

Reads into the array pointed to by `ptr`, up to *nmemb* members whose size is specified by `size`, from the stream pointed to by `stream`. The file position indicator (if defined) is advanced by the number of characters successfully read. If an error occurs, the resulting value of the file position indicator is indeterminate. If a partial member is read, its value is indeterminate. The `ferror` or `feof` function shall be used to distinguish between a read error and end-of-file.

Returns: the number of members successfully read, which may be less than *nmemb* if a read error or end-of-file is encountered. If `size` or *nmemb* is zero, `fread` returns zero and the contents of the array and the state of the stream remain unchanged.

Entry no. 115: size_t fwrite(const void * *ptr*, size_t *size*, size_t *nmemb*, FILE * *stream*)

Writes, from the array pointed to by `ptr` up to *nmemb* members whose size is specified by `size`, to the stream pointed to by `stream`. The file position indicator (if defined) is advanced by the number of characters successfully written. If an error occurs, the resulting value of the file position indicator is indeterminate.

Returns: the number of members successfully written, which will be less than nmemb only if a write error is encountered.

Entry no. 116: int fgetpos(FILE * *stream*, fpos_t * *pos*)

Stores the current value of the file position indicator for the stream pointed to by `stream` in the object pointed to by *pos*. The value stored contains unspecified information usable by the `fsetpos` function for repositioning the stream to its position at the time of the call to the `fgetpos` function.

Returns: zero, if successful. Otherwise non-zero is returned and the integer expression `errno` is set to an implementation-defined non-zero value (under RISC OS `fgetpos` cannot fail).

Entry no. 117: int fseek(FILE * *stream*, long int *offset*, int *whence*)

Sets the file position indicator for the stream pointed to by `stream`. For a binary stream, the new position is at the signed number of characters specified by `offset` away from the point specified by *whence*. The specified point is the beginning of the file for `SEEK_SET`, the current position in the file for `SEEK_CUR`, or end-of-file for `SEEK_END`. A binary stream need not meaningfully support `fseek` calls with a *whence* value of `SEEK_END`, though the Acorn implementation does. For a text stream, `offset` is either zero or a value returned by an earlier call to the `ftell` function on the same stream; *whence* is then `SEEK_SET`. The Acorn implementation also allows a text stream to be positioned in exactly the same manner as a binary stream, but this is not portable. The `fseek` function clears the end-of-file indicator and undoes any effects of the `ungetc` function on the same stream. After an `fseek` call, the next operation on an update stream may be either input or output.

Returns: non-zero only for a request that cannot be satisfied.

Entry no. 118: int fsetpos(FILE * *stream*, const fpos_t * *pos*)

Sets the file position indicator for the stream pointed to by `stream` according to the value of the object pointed to by pos, which is a value returned by an earlier call to the `fgetpos` function on the same stream. The `fsetpos` function clears the end-of-file indicator and undoes any effects of the `ungetc` function on the same stream. After an `fsetpos` call, the next operation on an update stream may be either input or output.

Returns: zero, if successful. Otherwise non-zero is returned and the integer expression `errno` is set to an implementation-defined non-zero value (under RISC OS the value is that of EDOM in `math.h`).

Entry no. 119: long int ftell(FILE * *stream*)

Obtains the current value of the file position indicator for the stream pointed to by `stream`. For a binary stream, the value is the number of characters from the beginning of the file. For a text stream, the file position indicator contains unspecified information, usable by the `fseek` function for returning the file position indicator to its position at the time of the `ftell` call; the difference between two such return values is not necessarily a meaningful measure of the number of characters written or read. However, for the Acorn implementation, the value returned is merely the byte offset into the file, whether the stream is text or binary.

Returns: if successful, the current value of the file position indicator. On failure, the `ftell` function returns -1L and sets the integer expression `errno` to an implementation-defined non-zero value (under RISC OS `ftell` cannot fail).

Entry no. 120: void rewind(FILE * *stream*)

Sets the file position indicator for the stream pointed to by `stream` to the beginning of the file. It is equivalent to `(void)fseek(stream, 0L, SEEK_SET)` except that the error indicator for the stream is also cleared.

Returns: no value.

Entry no. 121: void clearerr(FILE * *stream*)

Clears the end-of-file and error indicators for the stream pointed to by `stream`. These indicators are cleared only when the file is opened or by an explicit call to the `clearerr` function or to the `rewind` function.

Returns: no value.

Entry no. 122: int feof(FILE * *stream*)

Tests the end-of-file indicator for the stream pointed to by `stream`.

Returns: non-zero if the end-of-file indicator is set for `stream`.

Entry no. 123: int ferror(FILE * *stream*)

Tests the error indicator for the stream pointed to by `stream`.

Returns: non-zero if the error indicator is set for `stream`.

Entry no. 124: void perror(const char * *s*)

Maps the error number in the integer expression `errno` to an error message. It writes a sequence of characters to the standard error stream thus: first (if *s* is not a null pointer and the character pointed to by *s* is not the null character), the string pointed to by *s* followed by a colon and a space; then an appropriate error message string followed by a newline character. The contents of the error message strings are the same as those returned by the `strerror` function with argument `errno`, which are implementation-defined.

Returns: no value.

Entry no. 105: int __filbuf(FILE *stream)

This function is used by the C library to implement the 'getc' macro. The definition of the 'getc' macro is as follows:

```
#define getc(p) \
    (--((p)->__icnt) >= 0 ? *((p)->__ptr)++ : __filbuf(p))
```

where p is a pointer to a FILE structure.

`__filbuf` fills the buffer associated with p from a file stream and returns the first character of the buffer incrementing the buffer pointer and decrementing the input character count.

Entry no. 109: int __flsbuf(int ch, FILE *stream)

This function is used by the C library to implement the `putc` macro. The definition of the `putc` macro is as follows:

```
#define putc(ch, p) \
    (--((p)->__ocnt) >= 0 ? (*((p)->__ptr)++ = (ch)) : __flsbuf(ch,p))
```

where p is a pointer to a FILE structure.

`__flsbuf` flushes the buffer associated with p to a file stream and writes the character ch to the file stream. The buffer pointer and output character count are reset.

stdlib

`stdlib` provides several general purpose functions

Entry no. 58: double atof(const char * *nptr*)

Converts the initial part of the string pointed to by *nptr* to double * representation.

Returns: the converted value.

Entry no. 59: int atol(const char * *nptr*)

Converts the initial part of the string pointed to by `nptr` to int representation.

Returns: the converted value.

Entry no. 60: long int atol(const char * *nptr*)

Converts the initial part of the string pointed to by `nptr` to long int representation.

Returns: the converted value.

Entry no. 61: double strtod(const char * *nptr*, char ** *endptr*)

Converts the initial part of the string pointed to by `nptr` to double representation. First it decomposes the input string into three parts: an initial, possibly empty, sequence of white-space characters (as specified by the `isspace` function), a subject sequence resembling a floating point constant, and a final string of one or more unrecognised characters, including the terminating null character of the input string. It then attempts to convert the subject sequence to a floating point number, and returns the result. A pointer to the final string is stored in the object pointed to by `endptr`, provided that `endptr` is not a null pointer.

Returns: the converted value if any. If no conversion could be performed, zero is returned. If the correct value is outside the range of representable values, plus or minus HUGE_VAL is returned (according to the sign of the value), and the value of the macro ERANGE is stored in `errno`. If the correct value would cause underflow, zero is returned and the value of the macro ERANGE is stored in `errno`.

Entry no. 62: long int strtol(const char * *nptr*, char ***endptr*, int *base*)

Converts the initial part of the string pointed to by `nptr` to long int representation. First it decomposes the input string into three parts: an initial, possibly empty, sequence of white-space characters (as specified by the `isspace` function), a subject sequence resembling an integer represented in some radix determined by the value of base, and a final string of one or more unrecognised characters, including the terminating null character of the input string.

It then attempts to convert the subject sequence to an integer, and returns the result. If the value of base is 0, the expected form of the subject sequence is that of an integer constant (described precisely in the ANSI standard, section 3.1.3.2), optionally preceded by a + or – sign, but not including an integer suffix. If the value of base is between 2 and 36, the expected form of the subject sequence is a sequence of letters and digits representing an integer with the radix specified by

`base`, optionally preceded by a plus or minus sign, but not including an integer suffix. The letters from a (or A) through z (or Z) are ascribed the values 10 to 35; only letters whose ascribed values are less than that of the base are permitted. If the value of `base` is 16, the characters 0x or 0X may optionally precede the sequence of letters and digits following the sign if present. A pointer to the final string is stored in the object pointed to by `endptr`, provided that `endptr` is not a null pointer.

Returns: the converted value if any. If no conversion could be performed, zero is returned. If the correct value is outside the range of representable values, LONG_MAX or LONG_MIN is returned (according to the sign of the value), and the value of the macro ERANGE is stored in `errno`.

Entry no. 63: unsigned long int strtoul(const char * *nptr*, char ** *endptr*, int *base*)

Converts the initial part of the string pointed to by `nptr` to unsigned long int representation. First it decomposes the input string into three parts: an initial, possibly empty, sequence of white space characters (as determined by the `isspace` function), a subject sequence resembling an unsigned integer represented in some radix determined by the value of `base`, and a final string of one or more unrecognised characters, including the terminating null character of the input string.

It then attempts to convert the subject sequence to an unsigned integer, and returns the result. If the value of `base` is zero, the expected form of the subject sequence is that of an integer constant (described precisely in the ANSI Draft, section 3.1.3.2), optionally preceded by a + or – sign, but not including an integer suffix. If the value of `base` is between 2 and 36, the expected form of the subject sequence is a sequence of letters and digits representing an integer with the radix specified by base, optionally preceded by a + or – sign, but not including an integer suffix. The letters from a (or A) through z (or Z) stand for the values 10 to 35; only letters whose ascribed values are less than that of the base are permitted. If the value of `base` is 16, the characters 0x or 0X may optionally precede the sequence of letters and digits following the sign, if present. A pointer to the final string is stored in the object pointed to by `endptr`, provided that `endptr` is not a null pointer.

Returns: the converted value if any. If no conversion could be performed, zero is returned. If the correct value is outside the range of representable values, ULONG_MAX is returned, and the value of the * macro ERANGE is stored in `errno`.

Entry no. 64: int rand(void)

Computes a sequence of pseudo-random integers in the range 0 to RAND_MAX, where RAND_MAX = `0x7fffffff`.

Returns: a pseudo-random integer.

Entry no. 65: void srand(unsigned int *seed*)

Uses its argument as a seed for a new sequence of pseudo-random numbers to be returned by subsequent calls to `rand`. If `srand` is then called with the same seed value, the sequence of pseudo-random numbers will be repeated. If `rand` is called before any calls to `srand` have been made, the same sequence is generated as when `srand` is first called with a seed value of 1.

Entry no. 66: void *calloc(size_t *nmemb*, size_t *size*)

Allocates space for an array of *nmemb* objects, each of whose size is *size*. The space is initialised to all bits zero.

Returns: either a null pointer or a pointer to the allocated space.

Entry no. 67: void free(void * *ptr*)

Causes the space pointed to by *ptr* to be deallocated (made available for further allocation). If *ptr* is a null pointer, no action occurs. Otherwise, if *ptr* does not match a pointer earlier returned by `calloc`, `malloc` or `realloc` or if the space has been deallocated by a call to `free` or `realloc`, the behaviour is undefined.

Entry no. 68: void *malloc(size_t *size*)

Allocates space for an object whose size is specified by *size* and whose value is indeterminate.

Returns: either a null pointer or a pointer to the allocated space.

Entry no. 69: void *realloc(void * *ptr*, size_t *size*)

Changes the size of the object pointed to by *ptr* to the size specified by *size*. The contents of the object is unchanged up to the lesser of the new and old sizes. If the new size is larger, the value of the newly allocated portion of the object is indeterminate. If *ptr* is a null pointer, the `realloc` function behaves like a call to `malloc` for the specified size. Otherwise, if *ptr* does not match a pointer earlier returned by `calloc`, `malloc` or `realloc`, or if the space has been deallocated by a call to `free` or `realloc`, the behaviour is undefined. If the space cannot be allocated, the object pointed to by *ptr* is unchanged. If size is zero and *ptr* is not a null pointer, the object it points to is freed.

Returns: either a null pointer or a pointer to the possibly moved allocated space.

Entry no. 70: void abort(void)

Causes abnormal program termination to occur, unless the signal `SIGABRT` is being caught and the signal handler does not return. Whether open output streams are flushed or open streams are closed or temporary files removed is implementation-defined (under RISC OS all these occur). An implementation-defined form of the status 'unsuccessful termination' (1 under RISC OS) is returned to the host environment by means of a call to `raise(SIGABRT)`.

Entry no. 71: int atexit(void (* *func*)(void))

Registers the function pointed to by `func`, to be called without its arguments at normal program termination. It is possible to register at least 32 functions.

Returns: zero if the registration succeeds, non-zero if it fails.

Entry no. 72: void exit(int *status*)

Causes normal program termination to occur. If more than one call to the `exit` function is executed by a program (for example, by a function registered with `atexit`), the behaviour is undefined. First, all functions registered by the `atexit` function are called, in the reverse order of their registration. Next, all open output streams are flushed, all open streams are closed, and all files created by the `tmpfile` function are removed. Finally, control is returned to the host environment. If the value of *status* is zero or `EXIT_SUCCESS`, an implementation-defined form of the status 'successful termination' (0 under RISC OS) is returned. If the value of *status* is `EXIT_FAILURE`, an implementation-defined form of the status 'unsuccessful termination' (1 under RISC OS) is returned. Otherwise the status returned is implementation-defined (the value of *status* is returned under RISC OS).

Entry no. 73: char *getenv(const char * *name*)

Searches the environment list, provided by the host environment, for a string that matches the string pointed to by *name*. The set of environment names and the method for altering the environment list are implementation-defined.

Returns: a pointer to a string associated with the matched list member. The array pointed to is not modified by the program, but may be overwritten by a subsequent call to the `getenv` function. If the specified name cannot be found, a null pointer is returned.

Entry no. 74: int system(const char * *string*)

Passes the string pointed to by `string` to the host environment to be executed by a command processor in an implementation-defined manner. A null pointer may be used for `string`, to inquire whether a command processor exists. Under RISC OS, care must be taken, when executing a command, that the command does not overwrite the calling program. To control this, the string `chain:` or `call:` may immediately precede the actual command. The effect of `call:` is the same as if `call:` were not present. When a command is called, the caller is first moved to a safe place in application workspace. When the callee terminates, the caller is restored. This requires enough memory to hold caller and callee simultaneously. When a command is chained, the caller may be overwritten. If the caller is not overwritten, the caller exits when the caller terminates. Thus a transfer of control is effected and memory requirements are minimised.

Returns: If the argument is a null pointer, the `system` function returns non-zero only if a command processor is available. If the argument is not a null pointer, it returns an implementation-defined value (under RISC OS 0 is returned for success and -2 for failure to invoke the command; any other value is the return code from the executed command).

Entry no. 75: void *bsearch(const void **key*, const void * *base*, size_t *nmemb*, size_t *size*, int (* *compar*) (const void *, const void *))

Searches an array of *nmemb* objects, the initial member of which is pointed to by `base`, for a member that matches the object pointed to by `key`. The size of each member of the array is specified by `size`. The contents of the array must be in ascending sorted order according to a comparison function pointed to by `compar`, which is called with two arguments that point to the key object and to an array member, in that order. The function returns an integer less than, equal to, or greater than zero if the key object is considered, respectively, to be less than, to match, or to be greater than the array member.

Returns: a pointer to a matching member of the array, or a null pointer if no match is found. If two members compare as equal, which member is matched is unspecified.

Entry no. 76: void qsort(void * *base*, size_t *nmemb*, size_t *size*, int (* *compar*)(const void *, const void *))

Sorts an array of *nmemb* objects, the initial member of which is pointed to by `base`. The size of each object is specified by `size`. The contents of the array are sorted in ascending order according to a comparison function pointed to by `compar`, which is called with two arguments that point to the objects being compared. The function returns an integer less than, equal to, or greater than zero if the first argument is considered to be respectively less than, equal to, or greater than the second. If two members compare as equal, their order in the sorted array is unspecified.

Entry no. 77: int abs(int *j*)

Computes the absolute value of an integer `j`. If the result cannot be represented, the behaviour is undefined.

Returns: the absolute value.

Entry no. 78: div_t div(int *numer*, int *denom*)

Computes the quotient and remainder of the division of the numerator `numer` by the denominator `denom`. If the division is inexact, the resulting quotient is the integer of lesser magnitude that is the nearest to the algebraic quotient. If the result cannot be represented, the behaviour is undefined; otherwise, `quot * denom + rem equals numer`.

Returns: a structure of type `div_t`, comprising both the quotient and the remainder. The structure contains the following members: `int quot; int rem`. You may not rely on their order.

Entry no. 79: long int labs(long int *j*)

Computes the absolute value of an long integer `j`. If the result cannot be represented, the behaviour is undefined.

Returns: the absolute value.

Entry no. 80: ldiv_t ldiv(long int *numer*, long int *denom*)

Computes the quotient and remainder of the division of the numerator `numer` by the denominator `denom`. If the division is inexact, the sign of the resulting quotient is that of the algebraic quotient, and the magnitude of the resulting quotient is the largest integer less than the magnitude of the algebraic quotient. If the result cannot be represented, the behaviour is undefined; otherwise, `quot * denom + rem` equals `numer`.

Returns: a structure of type `ldiv_t`, comprising both the quotient and the remainder. The structure contains the following members: `long int quot; long int rem`. You may not rely on their order.

Multibyte character functions

The behaviour of the multibyte character functions is affected by the `LC_CTYPE` category of the current locale. For a state-dependent encoding, each function is placed into its initial state by a call for which its character pointer argument, `s`, is a null pointer. Subsequent calls with *s* as other than a null pointer cause the internal state of the function to be altered as necessary. A call with *s* as a null pointer causes these functions to return a non-zero value if encoding have state dependency, and a zero otherwise. After the `LC_CTYPE` category is changed, the shift state of these functions is indeterminate.

Entry no. 172: int mblen(const char * *s*, size_t *n*)

If *s* is not a null pointer, the `mblen` function determines the number of bytes comprising the multibyte character pointed to by *s*. Except that the shift state of the `mbtowc` function is not affected, it is equivalent to `mbtowc((wchar_t *)0, s, n)`.

Returns: If *s* is a null pointer, the `mblen` function returns a non-zero or zero value, if multibyte character encodings, respectively do or do not have state-dependent encodings. If *s* is not a null pointer, the `mblen` function either returns a 0 (if *s* points to a null character), or returns the number of bytes that comprise the multibyte character (if the next *n* or fewer bytes form a valid multibyte character), or returns –1 (if they do not form a valid multibyte character).

Entry no. 173: int mbtowc(wchar_t * *pwc*, const char * *s*, size_t *n*)

If *s* is not a null pointer, the `mbtowc` function determines the number of bytes that comprise the multibyte character pointed to by *s*. It then determines the code for value of type `wchar_t` that corresponds to that multibyte character. (The value of the code corresponding to the null character is zero). If the multibyte character is valid and *pwc* is not a null pointer, the `mbtowc` function stores the code in the object pointed to by *pwc*. At most *n* bytes of the array pointed to by *s* will be examined.

Returns: If *s* is a null pointer, the `mbtowc` function returns a non-zero or zero value, if multibyte character encodings, respectively do or do not have state-dependent encodings. If *s* is not a null pointer, the `mbtowc` function either returns a 0 (if *s* points to a null character), or returns the number of bytes that comprise the converted multibyte character (if the next *n* of fewer bytes form a valid multibyte character), or returns –1 (if they do not form a valid multibyte character).

Entry no. 174: int wctomb(char * *s*, wchar_t *wchar*)

Determines the number of bytes need to represent the multibyte character corresponding to the code whose value is *wchar* (including any change in shift state). It stores the multibyte character representation in the array object pointed to by *s* (if *s* is not a null pointer). At most `MB_CUR_MAX` characters are stored. If the value of *wchar* is zero, the `wctomb` function is left in the initial shift state).

Returns: If *s* is a null pointer, the `wctomb` function returns a non-zero or zero value, if multibyte character encodings, respectively do or do not have state-dependent encodings. If *s* is not a null pointer, the `wctomb` function returns a –1 if the value of *wchar* does not correspond to a valid multibyte character, or returns the number of bytes that comprise the multibyte character corresponding to the value of *wchar*.

Multibyte string functions

The behaviour of the multibyte string functions is affected by the `LC_CTYPE` category of the current locale.

Entry no. 175: size_t mbstowcs(wchar_t * *pwcs*, const char * *s*, size_t *n*)

Converts a sequence of multibyte characters that begins in the initial shift state from the array pointed to by *s* into a sequence of corresponding codes and stores not more than *n* codes into the array pointed to by *pwcs*. No multibyte character that follow a null character (which is converted into a code with value zero) will be examined or converted. Each multibyte character is converted as if by a call to the `mbtowc` function. If an invalid multibyte character is found, `mbstowcs` returns `(size_t)-1`. Otherwise, the `mbstowcs` function returns the number of array elements modified, not including a terminating zero code, if any.

Entry no. 176: size_t wcstombs(char * *s*, const wchar_t * *pwcs*, size_t *n*)

Converts a sequence of codes that correspond to multibyte characters from the array pointed to by *pwcs* into a sequence of multibyte characters that begins in the initial shift state and stores these multibyte characters into the array pointed to by *s*, stopping if a multibyte character would exceed the limit of *n* total bytes or if a null character is stored. Each code is converted as if by a call to the `wctomb` function, except that the shift state of the `wctomb` function is not affected. If a code is encountered which does not correspond to any valid multibyte character, the `wcstombs` function returns `(size_t)-1`. Otherwise, the `wcstombs` function returns the number of bytes modified, not including a terminating null character, if any.

string

`string` provides several functions useful for manipulating character arrays and other objects treated as character arrays. Various methods are used for determining the lengths of the arrays, but in all cases a `char *` or `void *` argument points to the initial (lowest addresses) character of the array. If an array is written beyond the end of an object, the behaviour is undefined.

Entry no. 38: void *memcpy(void * s1, const void * s2, size_t n)

Copies *n* characters from the object pointed to by *s2* into the object pointed to by *s1*. If copying takes place between objects that overlap, the behaviour is undefined.

Returns: the value of s1.

Entry no. 39: void *memmove(void * s1, const void * s2, size_t n)

Copies *n* characters from the object pointed to by *s2* into the object pointed to by *s1*. Copying takes place as if the *n* characters from the object pointed to by *s2* are first copied into a temporary array of *n* characters that does not overlap the objects pointed to by *s1* and s2, and then the *n* characters from the temporary array are copied into the object pointed to by *s1*.

Returns: the value of *s1*.

Entry no. 40: char *strcpy(char * s1, const char * s2)

Copies the string pointed to by *s2* (including the terminating null character) into the array pointed to by *s1*. If copying takes place between objects that overlap, the behaviour is undefined.

Returns: the value of *s1*.

Entry no. 41: char *strncpy(char * s1, const char * s2, size_t n)

Copies not more than *n* characters (characters that follow a null character are not copied) from the array pointed to by *s2* into the array pointed to by *s1*. If copying takes place between objects that overlap, the behaviour is undefined. If terminating `nul` has not been copied in chars, no term `nul` is placed in *s2*.

Returns: the value of *s1*.

Entry no. 42: char *strcat(char * s1, const char * s2)

Appends a copy of the string pointed to by *s2* (including the terminating null character) to the end of the string pointed to by *s1*. The initial character of *s2* overwrites the null character at the end of *s1*.

Returns: the value of *s1*.

Entry no. 43: char *strncat(char * s1, const char * s2, size_t n)

Appends not more than *n* characters (a null character and characters that follow it are not appended) from the array pointed to by *s2* to the end of the string pointed to by *s1*. The initial character of *s2* overwrites the null character at the end of *s1*. A terminating null character is always appended to the result.

Returns: the value of *s1*.

The sign of a non-zero value returned by the comparison functions is determined by the sign of the difference between the values of the first pair of characters (both interpreted as unsigned char) that differ in the objects being compared.

Entry no. 44: int memcmp(const void * s1, const void * s2, size_t n)

Compares the first *n* characters of the object pointed to by *s1* to the first *n* characters of the object pointed to by *s2*.

Returns: an integer greater than, equal to, or less than zero, depending on whether the object pointed to by *s1* is greater than, equal to, or less than the object pointed to by *s2*.

Entry no. 45: int strcmp(const char * s1, const char * s2)

Compares the string pointed to by *s1* to the string pointed to by *s2*.

Returns: an integer greater than, equal to, or less than zero, depending on whether the string pointed to by *s1* is greater than, equal to, or less than the string pointed to by *s2*.

Entry no. 46: int strncmp(const char * s1, const char * s2, size_t n)

Compares not more than *n* characters (characters that follow a null character are not compared) from the array pointed to by *s1* to the array pointed to by *s2*.

Returns: an integer greater than, equal to, or less than zero, depending on whether the string pointed to by *s1* is greater than, equal to, or less than the string pointed to by *s2*.

Entry no. 178: int strcoll(const char * s1, const char * s2)

Compares the string pointed to by *s1* to the string pointed to by *s2*, both interpreted as appropriate to the `LC_COLLATE` category of the current locale.

Returns: an integer greater than, equal to, or less than zero, depending on whether the string pointed to by *s1* is greater than, equal to, or less than the string pointed to by *s2* when both are interpreted as appropriate to the current locale.

Entry no. 177: size_t strxfrm(char * *s1*, const char * *s2*, size_t *n*)

Transforms the string pointed to by `s2` and places the resulting string into the array pointed to by `s1`. The transformation function is such that if the `strcmp` function is applied to two transformed strings, it returns a value greater than, equal to or less than zero, corresponding to the result of the `strcoll` function applied to the same two original strings. No more than *n* characters are placed into the resulting array pointed to by `s1`, including the terminating null character. If *n* is zero, `s1` is permitted to be a null pointer. If copying takes place between objects that overlap, the behaviour is undefined.

Returns: The length of the transformed string is returned (not including the terminating null character). If the value returned is *n* or more, the contents of the array pointed to by `s1` are indeterminate.

Entry no. 47: void *memchr(const void * *s*, int *c*, size_t *n*)

Locates the first occurrence of *c* (converted to an unsigned char) in the initial *n* characters (each interpreted as unsigned char) of the object pointed to by *s*.

Returns: a pointer to the located character, or a null pointer if the character does not occur in the object.

Entry no. 48: char *strchr(const char * *s*, int *c*)

Locates the first occurrence of *c* (converted to a char) in the string pointed to by *s* (including the terminating null character). The BSD UNIX name for this function is `index()`.

Returns: a pointer to the located character, or a null pointer if the character does not occur in the string.

Entry no. 49: size_t strcspn(const char * *s1*, const char * *s2*)

Computes the length of the initial segment of the string pointed to by `s1` which consists entirely of characters not from the string pointed to by `s2`. The terminating null character is not considered part of `s2`.

Returns: the length of the segment.

Entry no. 50: char *strpbrk(const char * *s1*, const char * *s2*)

Locates the first occurrence in the string pointed to by `s1` of any character from the string pointed to by `s2`.

Returns: returns a pointer to the character, or a null pointer if no character form `s2` occurs in `s1`.

Entry no. 51: char *strrchr(const char * *s*, int *c*)

Locates the last occurrence of *c* (converted to a char) in the string pointed to by *s*. The terminating null character is considered part of the string. The BSD UNIX name for this function is `rindex()`.

Returns: returns a pointer to the character, or a null pointer if *c* does not occur in the string.

Entry no. 52: size_t strspn(const char * *s1*, const char * *s2*)

Computes the length of the initial segment of the string pointed to by `s1` which consists entirely of characters from the string pointed to by `s2`.

Returns: the length of the segment.

Entry no. 53: char *strstr(const char * *s1*, const char * *s2*)

Locates the first occurrence in the string pointed to by `s1` of the sequence of characters (excluding the terminating null character) in the string pointed to by `s2`.

Returns: a pointer to the located string, or a null pointer if the string is not found.

Entry no. 54: char *strtok(char * *s1*, const char * *s2*)

A sequence of calls to the `strtok` function breaks the string pointed to by `s1` into a sequence of tokens, each of which is delimited by a character from the string pointed to by `s2`. The first call in the sequence has `s1` as its first argument, and is followed by calls with a null pointer as their first argument. The separator string pointed to by `s2` may be different from call to call. The first call in the sequence searches for the first character that is not contained in the current separator string `s2`. If no such character is found, then there are no tokens in `s1` and the `strtok` function returns a null pointer. If such a character is found, it is the start of the first token. The `strtok` function then searches from there for a character that is contained in the current separator string. If no such character is found, the current token extends to the end of the string pointed to by `s1`, and subsequent searches for a token will fail. If such a character is found, it is overwritten by a null character, which terminates the current token. The `strtok` function saves a pointer to the following character, from which the next search for a token will start. Each subsequent call, with a null pointer as the value for the first argument, starts searching from the saved pointer and behaves as described above.

Returns: pointer to the first character of a token, or a null pointer if there is no token.

Entry no. 55: void *memset(void * *s*, int *c*, size_t *n*)

Copies the value of *c* (converted to an unsigned char) into each of the first *n* characters of the object pointed to by *s*.

Returns: the value of *s*.

Entry no. 56: char *strerror(int *errnum*)

Maps the error number in `errnum` to an error message string.

Returns: a pointer to the string, the contents of which are implementation-defined. Under RISC OS and Arthur the strings for the given `errnums` are as follows:

• 0	No error (errno = 0)
• EDOM	EDOM – function argument out of range
• ERANGE	ERANGE – function result not representable
• ESIGNUM	ESIGNUM – illegal signal number to `signal()` or `raise()`
• others	Error code (errno) has no associated message.

The array pointed to may not be modified by the program, but may be overwritten by a subsequent call to the `strerror` function.

Entry no. 57: size_t strlen(const char * *s*)

Computes the length of the string pointed to by *s*.

Returns: the number of characters that precede the terminating null character.

time

`time` provides several functions for manipulating time. Many functions deal with a calendar time that represents the current date (according to the Gregorian calendar) and time. Some functions deal with local time, which is the calendar time expressed for some specific time zone, and with Daylight Saving Time, which is a temporary change in the algorithm for determining local time.

`struct tm` holds the components of a calendar time called the broken-down time. The value of `tm_isdst` is positive if Daylight Saving Time is in effect, zero if Daylight Saving Time is not in effect, and negative if the information is not available (as is the case under RISC OS).

```
struct tm {
  int tm_sec;     /* seconds after the minute, 0 to 60
                     (0-60 allows for the occasional leap
                     second) */
  int tm_min      /* minutes after the hour, 0 to 59 */
  int tm_hour     /* hours since midnight, 0 to 23 */
  int tm_mday     /* day of the month, 0 to 31 */
  int tm_mon      /* months since January, 0 to 11 */
  int tm_year     /* years since 1900 */
  int tm_wday     /* days since Sunday, 0 to 6 */
  int tm_yday     /* days since January 1, 0 to 365 */
  int tm_isdst    /* Daylight Saving Time flag */
};
```

Entry no. 29: clock_t clock(void)

Determines the processor time used.

Returns: the implementation's best approximation to the processor time used by the program since program invocation. The time in seconds is the value returned, divided by the value of the macro `CLOCKS_PER_SEC`. The value `(clock_t)-1` is returned if the processor time used is not available. In the desktop, `clock()` returns all processor time, not just that of the program.

Entry no. 30: double difftime(time_t *time1*, time_t *time0*)

Computes the difference between two calendar times: `time1 - time0`. Returns: the difference expressed in seconds as a double.

Entry no. 31: time_t mktime(struct tm * *timeptr*)

Converts the broken-down time, expressed as local time, in the structure pointed to by `timeptr` into a calendar time value with the same encoding as that of the values returned by the `time` function. The original values of the `tm_wday` and `tm_yday` components of the structure are ignored, and the original values of the other components are not restricted to the ranges indicated above. On successful completion, the values of the `tm_wday` and `tm_yday` structure components are set appropriately, and the other components are set to represent the specified calendar time, but with their values forced to the ranges indicated above; the final value of `tm_mday` is not set until `tm_mon` and `tm_year` are determined.

Returns: the specified calendar time encoded as a value of type `time_t`. If the calendar time cannot be represented, the function returns the value `(time_t)-1`.

Entry no. 32: time_t time(time_t * *timer*)

Determines the current calendar time. The encoding of the value is unspecified.

Returns: the implementation's best approximation to the current calendar time. The value `(time_t)-1` is returned if the calendar time is not available. If `timer` is not a null pointer, the return value is also assigned to the object it points to.

Entry no. 33: char *asctime(const struct tm * *timeptr*)

Converts the broken-down time in the structure pointed to by `timeptr` into a string in the style `Sun Sep 16 01:03:52 1973\n\0`.

Returns: a pointer to the string containing the date and time.

Entry no. 34: char *ctime(const time_t * *timer*)

Converts the calendar time pointed to by `timer` to local time in the form of a string. It is equivalent to `asctime(localtime(timer))`.

Returns: the pointer returned by the `asctime` function with that broken-down time as argument.

Entry no. 35: struct tm *gmtime(const time_t * *timer*)

Converts the calendar time pointed to by `timer` into a broken-down time, expressed as Greenwich Mean Time (GMT).

Returns: a pointer to that object or a null pointer if GMT is not available (it is not available under RISC OS).

Entry no. 36: struct tm *localtime(const time_t * *timer*)

Converts the calendar time pointed to by `timer` into a broken-down time, expressed a local time.

Returns: a pointer to that object.

Entry no. 37: size_t strftime(char * *s*, size_t *maxsize*, const char * *format*, const struct tm * *timeptr*)

Places characters into the array pointed to by *s* as controlled by the string pointed to by `format`. The format string consists of zero or more directives and ordinary characters. A directive consists of a `%` character followed by a character that determines the directive's behaviour. All ordinary characters (including the terminating null character) are copied unchanged into the array. No more than `maxsize` characters are placed into the array. Each directive is replaced by

appropriate characters as described in the following list. The appropriate characters are determined by the `LC_TIME` category of the current locale and by the values contained in the structure pointed to by `timeptr`.

Directive	Replaced by
`%a`	the locale's abbreviated weekday name
`%A`	the locale's full weekday name
`%b`	the locale's abbreviated month name
`%B`	the locale's full month name
`%c`	the locale's appropriate date and time representation
`%d`	the day of the month as a decimal number (01–31)
`%H`	the hour (24-hour clock) as a decimal number (00–23)
`%I`	the hour (12-hour clock) as a decimal number (01–12)
`%j`	the day of the year as a decimal number (001–366)
`%m`	the month as a decimal number (01–12)
`%M`	the minute as a decimal number (00–61)
`%p`	the locale's equivalent of either AM or PM designation associated with a 12-hour clock
`%S`	the second as a decimal number (00–61)
`%U`	the week number of the year (Sunday as the first day of week 1) as a decimal number (00–53)
`%w`	the weekday as a decimal number (0(Sunday)–6)
`%W`	the week number of the year (Monday as the first day of week 1) as a decimal number (00–53)
`%x`	the locale's appropriate date representation
`%X`	the locale's appropriate time representation
`%y`	the year without century as a decimal number (00–99)
`%Y`	the year with century as a decimal number
`%Z`	the time zone name or abbreviation, or by no character if no time zone is determinable
`%%`	`%`.

If a directive is not one of the above, the behaviour is undefined.

Returns: If the total number of resulting characters including the terminating null character is not more than `maxsize`, the `strftime` function returns the number of characters placed into the array pointed to by *s* not including the terminating null character. Otherwise, zero is returned and the contents of the array are indeterminate.

76 BASIC and BASICTrans

Introduction and Overview

Facilities were added to BASIC (and to BASIC64) in RISC OS 3 so that its messages can be translated for use in another territory. The BASIC interpreter issues calls to the BASICTrans module, which is responsible for providing messages appropriate to a particular territory. By replacing one BASICTrans module with another, you can change the language used by BASIC for its messages.

Both BASIC and BASIC64 issue the same calls to the same BASICTrans module, thus code and messages are shared between the two modules.

If you write a BASICTrans module, you can allocate memory for the translation from the RMA:

- Memory inside the SWI call is invulnerable to the task swapping problem found when BASIC itself attempts to use RMA memory. 'Task manager' swapping between two BASIC programs does not occur when in SWI mode.

Using BBC BASIC

For the sake of completeness, this chapter documents the *BASIC and *BASIC64 commands used to enter BBC BASIC. For full details of using BBC BASIC, see the BBC BASIC *Reference Manual*, available from your Acorn supplier.

SWI Calls

BASICTrans_HELP (SWI &42C80)

Interpret, translate if required, and print HELP messages

On entry

R0 = pointer to lexically analysed HELP text (terminated by &0D)
R1 = pointer to program's name (BASIC or BASIC64)
R2 = pointer to the lexical analyser's tables

On exit

R0 - R2 corrupted

Use

This call is made by BASIC to request that a BASICTrans module print a help message. BASIC lexically analyses the HELP text, converting keywords to tokens, before making this call. The currently loaded BASICTrans module then prints appropriate help text.

On entry R1 points to the program's name, and so is non-zero; if it is still non-zero on exit BASIC will print its own (short, English) Help text. Consequently, a BASICTrans module will normally set R1 to zero on exit – but the English version of BASICTrans sometimes preserves R1 so that its own help is followed by the default help.

In order to share the entirety of the HELP text between BASIC and BASIC64, this call is implemented for English, and both BASIC and BASIC64 are assembled without their own HELP text. About 15Kbytes are shared like this.

BASICTrans_Error (SWI &42C81)

Copy translated error string to buffer

On entry

R0 = unique error number (0 - 112)
R1 = pointer to buffer in which to place the error

On exit

R0 - R3 corrupted

Use

This call is made by BASIC to request that a BASICTrans module provide an error message. The currently loaded BASICTrans module places a null terminated error string for the given error number in the buffer pointed to by R1. The error string is null terminated. BASIC then prints the error message, and performs other actions necessary to smoothly integrate the error message with BASIC's normal provisions for error handling.

An error is generated if the BASICTrans module is not present (ie the SWI is not found), or if BASICTrans does not perform the translation. BASIC then prints a default (English) message explaining this.

In order to share the entirety of the error string text between BASIC and BASIC64, this call is implemented for English, and both BASIC and BASIC64 are assembled without their error messages. About 6Kbytes are shared like this. Correct error numbers are vital to the functioning of the interpreter, and so – rather than being shared – these are held in BASIC or BASIC64.

BASICTrans_Message (SWI &42C82)

Translate and print miscellaneous message

On entry

R0 = unique message number (0 - 25)
R1 - R3 = message dependent values

On exit

R0, R1 corrupted

Use

This call is made by BASIC to request that the BASICTrans module print a 'miscellaneous' message. Further parameters are passed that depend on the message you require to be printed.

An error is generated if the BASICTrans module is not present (ie the SWI is not found), or if BASICTrans does not perform the translation. BASIC then prints the full (English) version of the message that it holds internally.

The English BASICTrans module behaves as if this call does not exist, so that the default messages get printed. There are not many 'miscellaneous' messages, so no great saving is to be had in providing RISC OS 3 with a shared implementation.

The classic problem of the error handler's ' at line ' can now be handled as follows:

```
TRACE OFF
IF QUIT=TRUE THEN
 ERROR EXT,ERR,REPORT$
ELSE
 RESTORE:!(HIMEM-4)=@%
 SYS"BASICTrans_Message",21,ERL,REPORT$ TO ;@%
 IF (@% AND 1)<>0 THEN
  REPORT:@%=&900:IF ERL<>0 THEN PRINT" at line "ERL ELSE PRINT
 ENDIF
@%=!(HIMEM-4)
ENDIF
END
```

This allows the BASICTrans_Message code to print the string and optional ' at line ' ERL information in any order it likes.

* Commands

*BASIC
*BASIC64

Starts the ARM BBC BASIC interpreter

Syntax

`*BASIC [options]`

Parameters

options see below

Use

*BASIC starts the ARM BBC BASIC V interpreter.

*BASIC64 starts the ARM BBC BASIC VI interpreter – provided its module has already been loaded, or is in the library or some other directory on the run path.

For full details of BBC BASIC, see the BBC BASIC *Reference Manual*, available from your Acorn supplier.

The *options* control how the interpreter will behave when it starts, and when any program that it executes terminates. If no option is given, BASIC simply starts with a message of the form:

```
ARM BBC BASIC V version 1.05 (C) Acorn 1989

Starting with 643324 bytes free
```

The number of bytes free in the above message will depend on the amount of free RAM on your computer. The first line is also used for the default REPORT message, before any errors occur.

One of three options may follow the *BASIC command to cause a program to be loaded, and, optionally, executed automatically. Alternatively, you can use a program that is already loaded into memory by passing its address to the interpreter. Each of these possibilities is described in turn below.

In all cases where a program is specified, this may be a tokenised BASIC program, as created by a SAVE command, or a textual program, which will be tokenised (and possibly renumbered) automatically.

`*BASIC -help`

This command causes BASIC to print some help information describing the options documented here. Then BASIC starts as usual.

`*BASIC [-chain] filename`

If you give a *filename* after the *BASIC command, optionally preceded by the keyword `-chain`, then the named file is loaded and executed. When the program stops, BASIC enters immediate mode, as usual.

`*BASIC -quit filename`

This behaves in a similar way to the previous option. However, when the program terminates, BASIC quits automatically, returning to the environment from which the interpreter was originally called. It also performs a `CRUNCH %1111` on the program (for further details see the description of the CRUNCH command in the BBC BASIC *Reference Manual*). This is the default action used by BASIC programs that are executed as * commands. In addition, the function QUIT returns TRUE if BASIC is called in this fashion.

`*BASIC -load filename`

This option causes the file to be loaded automatically, but not executed. BASIC remains in immediate mode, from where the program can be edited or executed as required.

`*BASIC @start,end`

This acts in a similar way to the `-load` form of the command. However, the program that is 'loaded' automatically is not in a file, but already in memory. Following the @ are two addresses. These give, in hexadecimal, the address of the start of the in-core program, and the address of the byte after the last one. The program is copied to PAGE and tokenised if necessary. This form of the command is used by Twin when returning to BASIC.

Note that the in-core address description is fixed format. It should be in the form:

`@xxxxxxxx,xxxxxxxx`

where *x* means a hexadecimal digit. Leading zeros must be supplied. The command line terminator character must come immediately after the last digit. No spaces are allowed.

`*BASIC -chain @start,end`

This behaves like the previous option, but the program is executed as well. When the program terminates, BASIC enters immediate mode.

`*BASIC -quit @start,end`

This option behaves as the previous one, but when the BASIC program terminates, BASIC automatically quits. The function QUIT will return TRUE during the execution of the program.

Examples

```
*BASIC
*BASIC -quit shellProg
*BASIC @000ADF0C,000AE345
*BASIC -chain fred
```

Related commands

None

Related SWIs

None

Related vectors

None

77 Command scripts

Introduction

Command scripts are files of commands that you would normally type in at the Command Line prompt. There are two common reasons for using such a file:

- To set up the computer to the state you want, either when you switch on or when you start an application.
- To save typing in a set of commands you find yourself frequently using.

In the first case the file of commands is commonly known as a boot file.

You may find using an Alias$... variable to be better in some cases. The main advantage of these variables is that they are held in memory and so are quicker in execution; however, they are only really suitable for short commands. Even if you use these variables you are still likely to need to use a command file to set them up initially.

There are two types of file available for writing command scripts: Command files, and Obey files. The differences between these two file types are:

- An Obey file is read directly, whereas a Command file is treated as if it were typed at the keyboard (and hence usually appears on the screen).
- An Obey file sets the system variable Obey$Dir to the directory it is in.
- An Obey file can be passed parameters
- An Obey file stops when an error is returned to the Obey module (or when an error is generated and the exit handler is the Obey module – an untrapped error, not in an application).

Overview and Technical Details

Creating a command script

A command script can be created using any text or word processor. Normally you then have to use the command *SetType to set the type of the file to Command or Obey.

You should save it in one of the following:

- the directory from which the command script will be run (typically your root directory, or an application directory)
- the library (typically $.Library, but may be $.ArthurLib on a network; see *Configure Lib in the chapter entitled *FileSwitch*).

Running the script

Provided that you have set the file to have a filetype of Command or Obey it can then be run in the same ways as any other file:

- Type its name at the * prompt.
- Type its name preceded by a * at any other prompt (some applications may not support this).
- Double-click on its icon from the desktop.

The same restrictions apply as with any other file. If the file is not in either your current directory or the library, it will not be found if you just give the filename; you must give its full pathname. (This assumes you have not changed the value of the system variable Run$Path.)

You can force any text file to be treated as an obey file by using the command *Obey. This overrides the current file type, such as Text or Command. Obviously, this will only have meaning if the text in the file is valid to treat as an obey file.

Similarly, any file can be forced to be a command file by using *Exec. This is described in the chapter entitled *Character Input*.

Obey$Dir

When an obey file is run, by using any of the above techniques, the system variable Obey$Dir is set to the parent directory part of the pathname used. For example, if you were to type `*Obey a.b.c`, then `a.b` is the parent directory of the pathname.

Note that it is not set to the full parent name, only the part of the string passed to the command as the pathname. So if you change the current directory or filing system during the obey file, then it would not be valid any more.

Ideally, you should invoke Obey files (and applications, which are started by an Obey file named !Run) by using their full pathname, and preceding that by either a forward slash `/` or the word `Run`, for example:

```
/ adfs::MikeWinnie.$.Odds'nSods.MyConfig
```

```
Run adfs::MikeWinnie.$.Odds'nSods.MyConfig
```

This ensures that Obey$Dir is set to the full pathname of the Obey file.

Run$Path

The variable Run$Path also influences how this parent name is decoded. If you were to type:

```
*Set Run$Path adfs::Winnie.Flagstaff.
*obeyfile parl par2
```

Then it would be interpreted as:

```
*Run adfs::Winnie.Flagstaff.obeyfile parl par2
```

If the filetype of `obeyfile` was &FEB, an obey file, then the command would be interpreted as:

```
*Obey adfs::Winnie.Flagstaff.obeyfile parl par2
```

This can also apply to application directories, as follows:

```
*Set Alias$@RunType_FEB Obey %*0
*Set File$Type_FEB Obey
*Set Run$Path adfs::Winnie.Flagstaff.
*appdir parl par2
```

In this case, RISC OS would look for the !Run file within the application directory and run it. Note that in most cases, the first two lines above are already defined in your system. If !Run is an obey file, then it would be interpreted as:

```
*Obey adfs::Winnie.Flagstaff.appdir.!Run parl par2
```

Note that Obey files can also be nested to refer to other files to Obey; however, Command files cannot be nested. This is one of the reasons why it is better to set up your file as an Obey file rather than a Command file

Making a script run automatically

You can make scripts run automatically:

- From the network when you first log on.

  The file must be called !ArmBoot. (This is to distinguish a boot file for a machine running Arthur or RISC OS from an existing !Boot file already on the network for the use of BBC model A, model B or Master series computers.
- From a disc when you first switch the computer on.

  The file must be called !Boot.
- From an application directory when you first display the directory's icon under the desktop.

  The file must be called !Boot. It is run if RISC OS does not already know of a sprite having the same name as the directory, and is intended to load sprites for applications when they first need to be displayed. For further details see the chapter entitled *The Window Manager*.
- From an application directory when the application is run.

  The file must be called !Run. For further details see the chapter entitled *The Window Manager*.

In the first two cases you will need to use the *Opt command as well.

For an example of the latter two cases, you can look in any of the application directories in the Applications Suite. If you are using the desktop, you will need to hold down the Shift key while you open the application directory, otherwise the application will run.

Using parameters

An Obey file can have parameters passed to it, which can then be used by the command script. A Command file cannot have parameters passed to it. The first parameter is referred to as %0, the second as %1, and so on. You can refer to all the parameters after a particular one by putting a * after the %, so %*1 would refer to the all parameters from the second one onwards.

These parameters are substituted before the line is passed to the Command Line Interpreter. Thus if an Obey file called Display contained:

```
FileInfo %0
Type %0
```

then the command `*Display MyFile` would do this:

```
FileInfo MyFile
Type MyFile
```


Sometimes you do not want parameter substitution. For example, suppose you wish to include a *Set Alias$... command in your file, such as:

```
Set Alias$Mode echo |<22>|<%0>
```
Desired command

The effect of this is to create a new command 'Mode'. If you include the *Set Alias command in an Obey file, when you run the file the %0 will be replaced by the first parameter passed to the file. To prevent the substitution you need to change the % to %%:

```
Set Alias$Mode echo |<22>|<%%0>
```
Command needed in file

Now when the file is run, the '%%0' is changed to '%0'. No other substitution occurs at this stage, and the desired command is issued. See the *Set command in the chapter entitled *Program Environment*.

*Commands

*Obey

Executes a file of * commands

Syntax

```
*Obey [[-v] [-c] [filename [parameters]]]
```

Parameters

-v	echo each line before execution
-c	cache *filename*, and execute it from memory
filename	a valid pathname, specifying a file
parameters	strings separated by spaces

Use

*Obey executes a file of * commands. Argument substitution is performed on each line, using parameters passed in the command.

With the -v option, each line is displayed before execution. With the -c option, the file is cached and executed from memory. These options are not available in RISC OS 2.0.

Example

```
*Obey !commands myfile1 12
```

Related commands

*Exec

Related SWIs

None

Related vectors

None

Application Notes

These example files illustrate several of the important differences between Command and Obey files:

```
*BASIC
AUTO
FOR I = 1 TO 10
  PRINT "Hello"
NEXT I
END
```

If this were a command file, it would enter the BASIC interpreter, and input the file shown. The command script will end with the BASIC interpreter waiting for another line of input. You can then press Esc to get a prompt, type RUN to run the program, and then type QUIT to leave BASIC. This script shows how a command file is passed to the input, and can change what is accepting its input (in this case to the BASIC interpreter).

In contrast, if this were an Obey file it would be passed to the Command Line interpreter, and an attempt would be made to run these commands:

```
*BASIC
*AUTO
*FOR I = 1 TO 10
*  PRINT "Hello"
*NEXT I
*END
```

Only the first command is valid, and so as an Obey file all this does is to leave you in the BASIC interpreter. Type QUIT to leave BASIC; you will then get an error message saying File 'AUTO' not found, generated by the second line in the file.

The next example illustrates how control characters are handled:

```
echo <7>
echo |<7>
```

The control characters are represented in GSTrans format (see the chapter entitled *Conversions*). These are not interpreted until the echo command is run, and are only interpreted then because echo expects GSTrans format.

The first line sends an ASCII 7 to the VDU drivers, sounding a beep; see the chapter entitled VDU *drivers* for more information. In the second line, the | preceding the < changes it from the start of a GSTrans sequence to just representing the character <, so the overall effect is:

`echo <7>`	*Send ASCII 7 to VDU drivers – beeps*
`echo |<7>`	*Send <7> to the screen*

The last examples are a Command file:

```
*Set Alias$more %echo |<14>|m %type -tabexpand %*0|m %echo |<15>
```

and an Obey file that has the same effect:

```
Set Alias$more %echo |<14>|m %type -tabexpand %%*0|m %echo |<15>
```

The only differences between the two examples are that the Command file has a preceding * added, to ensure that the command is passed to the Command Line interpreter; and that the Obey file has the %*0 changed to %%*0 to delay the substitution of parameters.

The file creates a new command called 'more' – taking its name from the UNIX 'more' command – by setting the variable Alias$more:

- The % characters that precede `echo` and `type` ensure that the actual commands are used, rather than an aliased version of them.
- The sequence `|m` represents a carriage return in GSTrans format and is used to separate the commands, just as Return would if you were typing the commands.
- The two echo commands turn paged mode on, then off, by sending the control characters ASCII 14 and 15 respectively to the VDU drivers (see the chapter entitled VDU *drivers* for more information).
- The | before each < prevents the control characters from being interpreted until the aliased command 'more' is run.

The command turns paged mode on, types a file to the screen expanding tabs as it does so, and then turns paged mode off.

Appendices and tables

78 Appendix A: ARM assembler

Introduction

Assembly language is a programming language in which each statement translates directly into a single machine code instruction or piece of data. An assembler is a piece of software which converts these statements into their machine code counterparts.

Writing in assembly language has its disadvantages. The code is more verbose than the equivalent high-level language statements, more difficult to understand and therefore harder to debug. High-level languages were invented so that programs could be written to look more like English so we could talk to computers in our language rather than directly in its own.

There are two reasons why, in certain circumstances, assembly language is used in preference to high-level languages. The first reason is that the machine code program produced by it executes more quickly than its high-level counterparts, particularly those in languages such as BASIC which are interpreted. The second reason is that assembly language offers greater flexibility. It allows certain operating system routines to be called or replaced by new pieces of code, and it allows greater access to the hardware devices and controllers.

Available assemblers

The BASIC assembler

The BBC BASIC interpreter, supplied as a standard part of RISC OS, includes an ARM assembler. This supports the full instruction set of the ARM 2 processor. At present it neither supports extra instructions that were first implemented by the ARM 3 processor, nor does it support coprocessor instructions.

It is the BASIC assembler that is described below, serving as an introduction to ARM assembler.

The Acorn Desktop Assembler

The Acorn Desktop Assembler is a separate product that provides much more powerful facilities than the BASIC assembler. With it you can develop assembler programs under the desktop, in an environment common to all Acorn desktop languages. It contains two different assemblers:

- **AAsm** is an assembler that produces binary image files which can be executed immediately.
- **ObjAsm** is an assembler that creates object files that cannot be executed directly, but must first be linked to other object files. Object files linked with those produced by ObjAsm may be produced from some programming language other than assembler, for example C.

These assemblers are not described in this appendix, but use a broadly similar syntax the BASIC assembler described below. For full details, see the *Acorn Assembler Release 2* manual, which is supplied with Acorn Desktop Assembler, or is separately available.

The BASIC assembler

Using the BASIC assembler

The assembler is part of the BBC BASIC language. Square brackets '[' and ']' are used to enclose all the assembly language instructions and directives and hence to inform BASIC that the enclosed instructions are intended for its assembler. However, there are several operations which must be performed from BASIC itself to ensure that a subsequent assembly language routine is assembled correctly.

Initialising external variables

The assembler allows the use of BASIC variables as addresses or data in instructions and assembler directives. For example variables can be set up in BASIC giving the numbers of any SWI routines which will be called:

```
OS_WriteI = &100
...
[
...
SWI OS_WriteI+ASC">"
...
```

Reserving memory space for the machine code

The machine code generated by the assembler is stored in memory. However, the assembler does not automatically set memory aside for this purpose. You must reserve sufficient memory to hold your assembled machine code by using the DIM statement. For example:

```
1000 DIM code% 100
```

The start address of the memory area reserved is assigned to the variable code%. The address of the last memory location is code%+100. Hence, this example reserves a total of 101 bytes of memory. In future examples, the size of memory reserved is shown as *required_size*, to emphasise that you must substitute a value appropriate to the size of your code.

Memory pointers

You need to tell the assembler the start address of the area of memory you have reserved. The simplest way to do this is to assign P% to point to the start of this area. For example:

```
DIM code% required_size
...
P% = code%
```

P% is then used as the program counter. The assembler places the first assembler instruction at the address P% and automatically increments the value of P% by four so that it points to the next free location. When the assembler has finished assembling the code, P% points to the byte following the final location used. Therefore, the number of bytes of machine code generated is given by:

```
P% - code%
```

This method assumes that you wish subsequently to execute the code at the same location.

The position in memory at which you load a machine code program may be significant. For example, it might refer directly to data embedded within itself, or expect to find routines at fixed addresses. Such a program only works if it is loaded in the correct place in memory. However, it is often inconvenient to assemble the program directly into the place where it will eventually be executed. This memory may well be used for something else whilst you are assembling the program. The solution to this problem is to use a technique called 'offset assembly' where code is assembled as if it is to run at a certain address but is actually placed at another.

To do this, set O% to point to the place where the first machine code instruction is to be placed and P% to point to the address where the code is to be run.

To notify the assembler that this method of generating code is to be used, the directive OPT, which is described in more detail below, must have bit 2 set.

It is usually easy, and always preferable, to write ARM code that is position independent.

Implementing passes

Normally, when the processor is executing a machine code program, it executes one instruction and then moves on automatically to the one following it in memory. You can, however, make the processor move to a different location and start processing from there instead by using one of the 'branch' instructions. For example:

```
.result_was_0
...
        BEQ result_was_0
```

The fullstop in front of the name result_was_0 identifies this string as the name of a 'label'. This is a directive to the assembler which tells it to assign the current value of the program counter (P%) to the variable whose name follows the fullstop.

BEQ means 'branch if the result of the last calculation that updated the PSR was zero'. The location to be branched to is given by the value previously assigned to the label result_was_0.

The label can, however, occur after the branch instruction. This causes a slight problem for the assembler since when it reaches the branch instruction, it hasn't yet assigned a value to the variable, so it doesn't know which value to replace it with.

You can get around this problem by assembling the source code twice. This is known as two-pass assembly. During the first pass the assembler assigns values to all the label variables. In the second pass it is able to replace references to these variables by their values.

It is only when the text contains no forward references of labels that just a single pass is sufficient.

These two passes may be performed by a FOR...NEXT loop as follows:

```
DIM code% required_size
FOR pass% = 0 TO 3 STEP 3
   P% = code%
   [
   OPT pass%
   ...                    further assembly language statements and assembler directives
   ]
NEXT pass%
```

Note that the pointer(s), in this case just P%, must be set at the start of both passes.

The OPT directive

The OPT is an assembler directive whose bits have the following meaning:

Bit	Meaning
0	Assembly listing enabled if set
1	Assembler errors enabled
2	Assembled code placed in memory at O% instead of P%
3	Check that assembled code does not exceed memory limit L%

Bit 0 controls whether a listing is produced. It is up to you whether or not you wish to have one or not.

Bit 1 determines whether or not assembler errors are to be flagged or suppressed. For the first pass, bit 1 should be zero since otherwise any forward-referenced labels will cause the error 'Unknown or missing variable' and hence stop the assembly. During the second pass, this bit should be set to one, since by this stage all the labels defined are known, so the only errors it catches are 'real ones' – such as labels which have been used but not defined.

Bit 2 allows 'offset assembly', ie the program may be assembled into one area of memory, pointed to by O%, whilst being set up to run at the address pointed to by P%.

Bit 3 checks that the assembled code does not exceed the area of memory that has been reserved (ie none of it is held in an address greater than the value held in L%). When reserving space, L% might be set as follows:

```
DIM code% required_size
L% = code% + required_size
```

Saving machine code to file

Once an assembly language routine has been successfully assembled, you can then save it to file. To do so, you can use the *Save command. In our above examples, `code%` points to the start of the code; after assembly, `P%` points to the byte after the code. So we could use this BASIC command:

```
OSCLI "Save "+outfile$+" "+STR$~(code%)+" "+STR$~(P%)
```

after the above example to save the code in the file named by outfile$.

Executing a machine code program

From memory

From memory, the resulting machine code can be executed in a variety of ways:

```
CALL address
USR address
```

These may be used from inside BASIC to run the machine code at a given address. See the BBC BASIC Guide for more details on these statements.

From file

The commands below will load and run the named file, using either its filetype (such as &FF8 for absolute code) and the associated Alias$@LoadType_XXX and Alias$@RunType_XXX system variables, or the load and execution addresses defined when it was saved.

```
*name
*RUN name
*/name
```

We strongly advise you to use file types in preference to load and execution addresses.

Format of assembly language statements

The assembly language statements and assembler directives should be between the square brackets.

There are very few rules about the format of assembly language statements; those which exist are given below:

- Each assembly language statement comprises an assembler mnemonic of one or more letters followed by a varying number of operands.
- Instructions should be separated from each other by colons or newlines.
- Any text following a full stop '.' is treated as a label name.
- Any text following a semicolon ';', or backslash '\', or 'REM' is treated as a comment and so ignored (until the next end of line or ':').
- Spaces between the mnemonic and the first operand, and between the operands themselves are ignored.

The BASIC assembler contains the following directives:

EQUB *int*	Define 1 byte of memory from LSB of *int* (DCB, =)
EQUW *int*	Define 2 bytes of memory from *int* (DCW)
EQUD *int*	Define 4 bytes of memory from *int* (DCD)
EQUS *str*	Define 0 - 255 bytes as required by string expression *str* (DCS)
ALIGN	Align P% (and O%) to the next word (4 byte) boundary
ADR *reg, addr*	Assemble instruction to load *addr* into *reg*

- The first four operations initialise the reserved memory to the values specified by the operand. In the case of EQUS the operand field must be a string expression. In all other cases it must be a numeric expression. DCB (and =), DCW, DCD and DCS are synonyms for these directives.
- The ALIGN directive ensures that the next P% (and O%) that is used lies on a word boundary. It is used after, for example, an EQUS to ensure that the next instruction is word-aligned.
- ADR assembles a single instruction – typically but not necessarily an ADD or SUB – with reg as the destination register. It obtains addr in that register. It does so in a PC-relative (ie position independent) manner where possible.

Registers

At any particular time there are sixteen 32-bit registers available for use, R0 to R15. However, R15 is special since it contains the program counter and the processor status register.

R15 is split up with 24 bits used as the program counter (PC) to hold the word address of the next instruction. 8 bits are used as the processor status register (PSR) to hold information about the current values of flags and the current mode/register bank. These bits are arranged as follows:

The top six bits hold the following information:

Bit	Flag	Meaning
31	N	Negative flag
30	Z	Zero flag
29	C	Carry flag
28	V	Overflow flag
27	I	Interrupt request disable
26	F	Fast interrupt request disable

The bottom two bits can hold one of four different values:

M	Meaning
0	User mode
1	Fast interrupt processing mode (FIQ mode)
2	Interrupt processing mode (IRQ mode)
3	Supervisor mode (SVC mode)

User mode is the normal program execution state. SVC mode is a special mode which is entered when calls to the supervisor are made using software interrupts (SWIs) or when an exception occurs. From within SVC mode certain operations can be performed which are not permitted in user mode, such as writing to hardware devices and peripherals. SVC mode has its own private registers R13 and R14. So after changing to SVC mode, the registers R0 - R12 are the same, but new versions of R13 and R14 are available. The values contained by these registers in user mode are not overwritten or corrupted.

Similarly, IRQ and FIQ modes have their own private registers (R13 - R14 and R8 - R14 respectively).

Although only 16 registers are available at any one time, the processor actually contains a total of 27 registers.

For a more complete description of the registers, see the chapter entitled ARM *Hardware* on page 1-7.

Condition codes

All the machine code instructions can be performed conditionally according to the status of one or more of the following flags: N, Z, C, V. The sixteen available condition codes are:

AL	Always	*This is the default*
CC	Carry clear	C clear
CS	Carry set	C set
EQ	Equal	Z set
GE	Greater than or equal	(N set and V set) or (N clear and V clear)
GT	Greater than	((N set and V set) or (N clear and V clear)) and Z clear
HI	Higher (unsigned)	C set and Z clear
LE	Less than or equal	(N set and V clear) or (N clear and V set) or Z set
LS	Lower or same (unsigned)	C clear or Z set
LT	Less than	(N set and V clear) or (N clear and V set)

MI	Negative	N set
NE	Not equal	Z clear
NV	Never	
PL	Positive	N clear
VC	Overflow clear	V clear
VS	Overflow set	V set

Two of these may be given alternative names as follows:

LO	Lower unsigned	is equivalent to CC
HS	Higher / same unsigned	is equivalent to CS

You should not use the NV (never) condition code – see page 6-320.

The instruction set

The available instructions are introduced below in categories indicating the type of action they perform and their syntax. The description of the syntax obeys the following standards:

« » indicates that the contents of the brackets are optional (unlike all other chapters, where we have been using [ ] instead)

(x|y) indicates that either x or y but not both may be given

#exp indicates that a BASIC expression is to be used which evaluates to an immediate constant. An error is given if the value cannot be stored in the instruction.

Rn indicates that an expression evaluating to a register number (in the range 0 - 15) should be used, or just a register name, eg R0. PC may be used for R15.

shift indicates that one of the following shift options should be used:

ASL	(Rn|#exp)	Arithmetic shift left by contents of Rn or expression
LSL	(Rn|#exp)	Logical shift left
ASR	(Rn|#exp)	Arithmetic shift right
LSR	(Rn|#exp)	Logical shift right
ROR	(Rn|#exp)	Rotate right
RRX		Rotate right one bit with extend

In fact ASL and LSL are the same (because the ARM does not handle overflow for signed arithmetic shifts), and synonyms. LSL is the preferred form, as it indicates the functionality.

Moves

Syntax:

opcode«cond»«S» Rd, (#exp|Rm)«,shift»

There are two move instructions. 'Op2' means '(#exp|Rm)«,shift»':

Instruction		Calculation performed
MOV	Move	Rd = Op2
MOVN	Move NOT	Rd = NOT Op2

Each of these instructions produces a result which it places in a destination register (Rd). The instructions do not affect bytes in memory directly.

Again, all of these instructions can be performed conditionally. In addition, if the 'S' is present, they can cause the condition codes to be set or cleared. These instructions set N and Z from the ALU, C from the shifter (but only if it is used), and do not affect V.

Examples:

```
MOV R0, #10          ; Load R0 with the value 10.
```

Special actions are taken if the source register is R15; the action is as follows:

- If Rm=R15 all 32 bits of R15 are used in the operation ie the PC + PSR.

If the destination register is R15, then the action depends on whether the optional 'S' has been used:

- If S is not present only the 24 bits of the PC are set.
- If S is present the whole result is written to R15, the flags are updated from the result. (However the mode, I and F bits can only be changed when in non-user modes.)

Arithmetic and logical instructions

Syntax:

opcode«cond»«S» Rd, Rn, (#exp|Rm)«,shift»

The instructions available are given below; again, 'Op2' means '(#exp|Rm)«,shift»':

Instruction		Calculation performed
ADC	Add with carry	Rd = Rn + Op2 + C
ADD	Add without carry	Rd = Rn + Op2
SBC	Subtract with carry	Rd = Rn – Op2 – (1 – C)

SUB	Subtract without carry	Rd = Rn – Op2
RSC	Reverse subtract with carry	Rd = Op2 – Rn – (1 – C)
RSB	Reverse subtract without carry	Rd = Op2 – Rn
AND	Bitwise AND	Rd = Rn AND Op2
BIC	Bitwise AND NOT	Rd = Rn AND NOT (Op2)
ORR	Bitwise OR	Rd = Rn OR Op2
EOR	Bitwise EOR	Rd = Rn EOR Op2

Each of these instructions produces a result which it places in a destination register (Rd). The instructions do not affect bytes in memory directly.

As was seen above, all of these instructions can be performed conditionally. In addition, if the 'S' is present, they can cause the condition codes to be set or cleared. The condition codes N, Z, C and V are set by the arithmetic logic unit (ALU) in the arithmetic operations. The logical (bitwise) operations set N and Z from the ALU, C from the shifter (but only if it is used), and do not affect V.

Examples:

```
ADDEQ R1, R1, #7        ; If the zero flag is set then add 7
                        ; to the contents of register R1.

SBCS R2, R3, R4         ; Subtract with carry the contents of register R4 from
                        ; the contents of register R3 and place the result in
                        ; register R2. The flags will be updated.

AND R3, R1, R2, LSR #2  ; Perform a logical AND on the contents of register R1
                        ; and the contents of register R2 / 4, and place the
                        ; result in register R3.
```

Special actions are taken if any of the source registers are R15; the action is as follows:

- If Rm=R15 all 32 bits of R15 are used in the operation ie the PC + PSR.
- If Rn=R15 only the 24 bits of the PC are used in the operation.

If the destination register is R15, then the action depends on whether the optional 'S' has been used:

- If S is not present only the 24 bits of the PC are set.
- If S is present the whole result is written to R15, the flags are updated from the result. (However the mode, I and F bits can only be changed when in non-user modes.)

Comparisons

Syntax:

opcode«cond»«S|P» Rn, (#exp|Rm)«,shift»

There are four comparison instructions; again, 'Op2' means '(#exp|Rm)«,shift»':

Instruction		Calculation performed
CMN	Compare negated	Rn + Op2
CMP	Compare	Rn – Op2
TEQ	Test equal	Rn EOR Op2
TST	Test	Rn AND Op2

These are similar to the arithmetic and logical instructions listed above except that they do not take a destination register since they do not return a result. Also, they automatically set the condition flags (since they would perform no useful purpose if they didn't). Hence, the 'S' of the arithmetic instructions is implied. You can put an 'S' after the instruction to make this clearer.

These routines have an additional function which is to set the whole of the PSR to a given value. This is done by using a 'P' after the opcode, for example TEQP.

Normally the flags are set depending on the value of the comparison. The I and F bits and the mode and register bits are unaltered. The 'P' option allows the corresponding eight bits of the result of the calculation performed by the comparison to overwrite those in the PSR (or just the flag bits in user mode).

Example

```
TEQP    PC, #&80000000  ; Set N flag, clear all others. Also enable
                        ; IRQs, FIQs, select User mode if privileged
```

The above example (as well as setting the N flag and clearing the others) will alter the IRQ, FIQ and mode bits of the PSR – but only if you are in a privileged mode.

The 'P' option is also useful in user mode, for example to collect errors:

```
STMFD   sp!, {r0, r1, r14}
...
BL      routine1
STRVS   r0, [sp, #0]            ; save error block ptr in return r0
                                ; in stack frame if error
MOV     r1, pc                  ; save psr flags in r1
BL      routine2                ; called even if error from routine1
STRVS   r0, [sp, #0]            ; to do some tidy up action etc.
TEQVCP  r1, #0                  ; if routine2 didn't give error,
LDMFD   sp!, {r0, r1, pc}       ; restore error indication from r1
```

Multiply instructions

Syntax:

MUL«cond»«S» Rd,Rm,Rs
MLA«cond»«S» Rd,Rm,Rs,Rn

There are two multiply instructions:

Instruction		Calculation performed
MUL	Multiply	Rd = Rm × Rs
MLA	Multiply-accumulate	Rd = Rm × Rs + Rn

The multiply instructions perform integer multiplication, giving the least significant 32 bits of the product of two 32-bit operands.

The destination register must not be R15 or the same as Rm. Any other register combinations can be used.

If the 'S' is given in the instruction, the N and Z flags are set on the result, and the C and V flags are undefined.

Examples:

```
MUL     R1,R2,R3
MLAEQS  R1,R2,R3,R4
```

Branching instructions

Syntax:

B«cond» expression
BL«cond» expression

There are essentially only two branch instructions but in each case the branch can take place as a result of any of the 15 usable condition codes:

Instruction	
B	Branch
BL	Branch and link

The branch instruction causes the execution of the code to jump to the instruction given at the address to be branched to. This address is held relative to the current location.

Example:

```
BEQ label1   ; branch if zero flag set
BMI minus    ; branch if negative flag set
```


The branch and link instruction performs the additional action of copying the address of the instruction following the branch, and the current flags, into register R14. R14 is known as the 'link register'. This means that the routine branched to can be returned from by transferring the contents of R14 into the program counter and can restore the flags from this register on return. Hence instead of being a simple branch the instruction acts like a subroutine call.

Example:

```
BLEQ equal
          .........; address of this instruction
          .........; moved to R14 automatically

.equal    .........; start of subroutine
          .........

MOVS R15,R14      ; end ofsubroutine
```

Single register load/save instructions

Syntax:

opcode«cond»«B»«T» Rd, address

The single register load/save instructions are as follows:

Instruction	
LDR	Load register
STR	Store register

These instructions allow a single register to load a value from memory or save a value to memory at a given address.

The instruction has two possible forms:

- the address is specified by register(s), whose names are enclosed in square brackets
- the address is specified by an expression

Address given by registers

The simplest form of address is a register number, in which case the contents of the register are used as the address to load from or save to. There are two other alternatives:

- pre-indexed addressing (with optional write back)
- post-indexed addressing (always with write back)

With pre-indexed addressing the contents of another register, or an immediate value, are added to the contents of the first register. This sum is then used as the address. It is known as pre-indexed addressing because the address being used is calculated before the load/save takes place. The first register (Rn below) can be optionally updated to contain the address which was actually used by adding a '!' after the closing square bracket.

Address syntax	**Address**
[Rn]	Contents of Rn
[Rn,#m]«!»	Contents of Rn + m
[Rn,«–»Rm]«!»	Contents of Rn ± contents of Rm
[Rn,«–»Rm,shift #s]«!»	Contents of Rn ± (contents of Rm shifted by s places)

With post-indexed addressing the address being used is given solely by the contents of the register Rn. The rest of the instruction determines what value is written back into Rn. This write back is performed automatically; no '!' is needed. Post-indexing gets its name from the fact that the address that is written back to Rn is calculated after the load/save takes place.

Address syntax	**Value written back**
[Rn],#m	Contents of Rn + m
[Rn],«–»Rm	Contents of Rn ± contents of Rm
[Rn],«–»Rm,shift #s	Contents of Rn ± (contents of Rm shifted by s places)

Address given as an expression

If the address is given as a simple expression, the assembler will generate a pre-indexed instruction using R15 (the PC) as the base register. If the address is out of the range of the instruction (4095 bytes), an error is given.

Options

If the 'B' option is specified after the condition, only a single byte is transferred, instead of a whole word. The top 3 bytes of the destination register are cleared by an LDRB instruction.

If the 'T' option is specified after the condition, then the TRANs pin on the ARM processor will be active during the transfer, forcing an address translation. This allows you to access User mode memory from a privileged mode. This option is invalid for pre-indexed addressing.

Using the program counter

If you use the program counter (PC, or R15) as one of the registers, a number of special cases apply:

- the PSR is never modified, even when Rd or Rn is the PC

- the PSR flags are not used when the PC is used as Rn, and (because of pipelining) it will be advanced by eight bytes from the current instruction
- the PSR flags are used when the PC is used as Rm, the offset register.

Multiple load/save instructions

Syntax:

opcode«cond»type Rn«!», {Rlist}«^»

These instructions allow the loading or saving of several registers:

Instruction	
LDM	Load multiple registers
STM	Store multiple registers

The contents of register Rn give the base address from/to which the value(s) are loaded or saved. This base address is effectively updated during the transfer, but is only written back to if you follow it with a '!'.

Rlist provides a list of registers which are to be loaded or saved . The order the registers are given, in the list, is irrelevant since the lowest numbered register is loaded/saved first, and the highest numbered one last. For example, a list comprising {R5,R3,R1,R8} is loaded/saved in the order R1, R3, R5, R8, with R1 occupying the lowest address in memory. You can specify consecutive registers as a range; so {R0–R3} and {R0,R1,R2,R3} are equivalent.

The type is a two-character mnemonic specifying either how Rn is updated, or what sort of a stack results:

Mnemonic	**Meaning**
DA	Decrement Rn After each store/load
DB	Decrement Rn Before each store/load
IA	Increment Rn After each store/load
IB	Increment Rn Before each store/load
EA	Empty Ascending stack is used
ED	Empty Descending stack is used
FA	Full Ascending stack is used
FD	Full Descending stack is used

- an empty stack is one in which the stack pointer points to the first free slot in it
- a full stack is one in which the stack pointer points to the last data item written to it
- an ascending stack is one which grows from low memory addresses to high ones

- a descending stack is one which grows from high memory addresses to low ones

In fact these are just different ways of looking at the situation – the way Rn is updated governs what sort of stack results, and vice versa. So, for each type of instruction in the first group there is an equivalent in the second:

LDMEA	is the same as	LDMDB
LDMED	is the same as	LDMIB
LDMFA	is the same as	LDMDA
LDMFD	is the same as	LDMIA
STMEA	is the same as	STMIA
STMED	is the same as	STMDA
STMFA	is the same as	STMIB
STMFD	is the same as	STMDB

All Acorn software uses an FD (full, descending) stack. If you are writing code for SVC mode you should try to use a full descending stack as well – although you can use any type you like.

A '^' at the end of the register list has two possible meanings:

- For a load with R15 in the list, the '^' forces update of the PSR.
- Otherwise the '^' forces the load/store to access the User mode registers. The base is still taken from the current bank though, and if you try to write back the base it will be put in the User bank – probably not what you would have intended.

Examples:

```
LDMIA R5, {R0,R1,R2}        ; where R5 contains the value
                            ; &1484
                            ; This will load R0 from &1484
                            ;                R1 from &1488
                            ;                R2 from &148C
LDMDB R5, {R0-R2}           ; where R5 contains the value
                            ; &1484
                            ; This will load R0 from &1478
                            ;                R1 from &147C
                            ;                R2 from &1480
```

If there were a '!' after R5, so that it were written back to, then this would leave R5 containing &1490 and &1478 after the first and second examples respectively.

The examples below show directly equivalent ways of implementing a full descending stack. The first uses mnemonics describing how the stack pointer is handled:


```
STMDB Stackpointer!, {R0-R3}    ; push onto stack
...
LDMIA Stackpointer!, {R0-R3}    ; pull from stack
```

and the second uses mnemonics describing how the stack behaves:

```
STMFD Stackpointer!, {R0,R1,R2,R3} ; push onto stack
...
LDMFD Stackpointer!, {R0,R1,R2,R3} ; pull from stack
```

Using the base register

- You can always load the base register without any side effects on the rest of the LDM operation, because the ARM uses an internal copy of the base, and so will not be aware that it has been loaded with a new value.

  However, you should see *Appendix B: Warnings on the use of ARM assembler* on page 6-315 for notes on using writeback when doing so.

- You can store the base register as well. If you are not using write back then no problem will occur. If you are, then this is the order in which the ARM does the STM:

  1. write the lowest numbered register to memory
  2. do the write back
  3. write the other registers to memory in ascending order.

  So, if the base register is the lowest-numbered one in the list, its original value is stored:

  ```
  STMIA   R2!, {R2-R6}     ; R2 stored is value before write back
  ```

  Otherwise its written back value is stored:

  ```
  STMIA   R2!, {R1-R5}     ; R2 stored is value after write back
  ```

Using the program counter

If you use the program counter (PC, or R15) in the list of registers:

- the PSR is saved with the PC; and (because of pipelining) it will be advanced by twelve bytes from the current position
- the PSR is only loaded if you follow the register list with a '^'; and even then, only the bits you can modify in the ARM's current mode are loaded.

It is generally not sensible to use the PC as the base register. If you do:

- the PSR bits are used as part of the address, which will give an address exception unless all the flags are clear and all interrupts are enabled.

SWI instruction

Syntax:

SWI«cond» expression

SWI«cond» "SWIname"   (BBC BASIC assembler)

The SWI mnemonic stands for SoftWare Interrupt. On encountering a SWI, the ARM processor changes into SVC mode and stores the address of the next location in R14_svc – so the User mode value of R14 is not corrupted. The ARM then goes to the SWI routine handler via the hardware SWI vector containing its address.

The first thing that this routine does is to discover which SWI was requested. It finds this out by using the location addressed by (R14_svc – 4) to read the current SWI instruction. The opcode for a SWI is 32 bits long; 4 bits identify the opcode as being for a SWI, 4 bits hold all the condition codes and the bottom 24 bits identify which SWI it is. Hence 2^{24} different SWI routines can be distinguished.

When it has found which particular SWI it is, the routine executes the appropriate code to deal with it and then returns by placing the contents of R14_svc back into the PC, which restores the mode the caller was in.

This means that R14_svc will be corrupted if you execute a SWI in SVC mode – which can have disastrous consequences unless you take precautions.

The most common way to call this instruction is by using the SWI name, and letting the assembler translate this to a SWI number. The BBC BASIC assembler can do this translation directly:

```
SWINE   "OS_WriteC"
```

See the chapter entitled *An introduction to SWIs* on page 1-21 for a full description of how RISC OS handles SWIs, and the index of SWIs for a full list of the operating system SWIs.

79 Appendix B: Warnings on the use of ARM assembler

Introduction

The ARM processor family uses Reduced Instruction Set (RISC) techniques to maximise performance; as such, the instruction set allows some instructions and code sequences to be constructed that will give rise to unexpected (and potentially erroneous) results. These cases must be avoided by all machine code writers and generators if correct program operation across the whole range of ARM processors is to be obtained.

In order to be upwards compatible with future versions of the ARM processor family **never** use any of the undefined instruction formats:

- those shown in the *Acorn* RISC *Machine family Data Manual* as 'Undefined' which the processor traps;
- those which are not shown in the manual and which don't trap (for example, a Multiply instruction where bit 5 or 6 of the instruction is set).

In addition the 'NV' (never executed) instruction class should not be used (it is recommended that the instruction 'MOV R0,R0' be used as a general purpose NOP).

This chapter lists the instructions and code sequences to be avoided. It is **strongly** recommended that you take the time to familiarise yourself with these cases because some will only fail under particular circumstances which may not arise during testing.

For more details on the ARM chip see the *Acorn* RISC *Machine family Data Manual*. VLSI Technology Inc. (1990) Prentice-Hall, Englewood Cliffs, NJ, USA: ISBN 0-13-781618-9.

Restrictions to the ARM instruction set

There are three main reasons for restricting the use of certain parts of the instruction set:

- **Dangerous instructions**

  Such instructions can cause a program to fail unexpectedly, for example:

  ```
  LDM R15,Rlist
  ```

  uses PC+PSR as the base and so can cause an unexpected address exception.

- **Useless instructions**

  It is better to reserve the instruction space occupied by existing 'useless' instructions for instruction expansion in future processors. For example:

  ```
  MUL R15,Rm,Rs
  ```

  only serves to scramble the PSR.

  This category also includes ineffective instructions, such as a PC relative LDC/STC with writeback; the PC cannot be written back in these instructions, so the writeback bit is ineffective (and an attempt to use it should be flagged as an error).

  Note: LDC/STC are instructions to load/store a coprocessor register from/to memory; since they are not supported by the BASIC assembler, they were not described in *Appendix A: ARM assembler*.

- **Instructions with undesirable side-effects**

  It is hard to guarantee the side-effects of instructions across different processors. If, for example, the following is used:

  ```
  LDR Rd,[R15,#expression]!
  ```

  the PC writeback will produce different results on different types of processor.

Instructions and code sequences to avoid

The instructions and code sequences are split into a number of categories. Each category starts with an indication of which of the two main ARM variants (ARM2, ARM3) it applies to, and is followed by a recommendation or warning. The text then goes on to explain the conditions in more detail and to supply examples where appropriate.

Unless a program is being targeted **specifically** for a single version of the ARM processor family, all of these recommendations should be adhered to.

TSTP/TEQP/CMPP/CMNP: Changing mode

Applicability: ARM2

When the processor's mode is changed by altering the mode bits in the PSR using a data processing operation, care must be taken not to access a banked register (R8-R14) in the following instruction. Accesses to the unbanked registers (R0-R7, R15) are safe.

The following instructions are affected, but note that mode changes can only be made when the processor is in a non-user mode:

```
TSTP Rn,Op2
TEQP Rn,Op2
MPP  Rn,Op2
CMNP Rn,Op2
```

These are the only operations that change all the bits in the PSR (including the mode bits) without affecting the PC (thereby forcing a pipeline refill during which time the register bank select logic settles).

The following examples assume the processor starts in Supervisor mode:

	Code	Comment

a)	TEQP PC,#0
	MOV R0,R0
	ADD R0,R1,R13_usr
		Safe: NOP added between mode change and access to a banked register (R13_usr)

b)	TEQP PC,#0 ADD R0,R1,R2	**Safe:** No access made to a banked register
c)	TEQP PC,#0 ADD R0,R1,R13_usr	**Fails:** Data **not** read from Register R13_usr!

The safest default is always to add a NOP (e.g. MOV R0,R0) after a mode changing instruction; this will guarantee correct operation regardless of the code sequence following it.

LDM/STM: Forcing transfer of the user bank (Part 1)

Applicability: ARM2, ARM3

Do not use write back when forcing user bank transfer in LDM/STM.

For STM instructions the S bit is redundant as the PSR is always stored with the PC whenever R15 is in the transfer list. In user mode programs the S bit is ignored, but in other modes it has a second interpretation; S=1 is used to force transfers to take values from the user register bank instead of from the current register bank. This is useful for saving the user state on process switches.

Similarly, in LDM instructions the S bit is redundant if R15 is not in the transfer list. In user mode programs, the S bit is ignored, but in non-usermode programs where R15 is not in the transfer list, S=1 is used to force loaded values to go to the user registers instead of the current register bank.

In both cases where the processor is in a non-user mode and transfer to or from the user bank is forced by setting the S bit, write back of the base will also be to the user bank though the base will be fetched from the current bank. Therefore don't use write back when forcing user bank transfer in LDM/STM.

The following examples assume the processor to be in a non-user mode and `Rlist` not to include R15:

`STMxx Rn!,Rlist`	**Safe:** Storing non-user registers with write back to the non-user base register
`LDMxx Rn!,Rlist`	**Safe:** Loading non-user registers with write back to the non-user base register
`STMxx Rn,Rlist^`	**Safe:** Storing user registers, but no base write-back
`STMxx Rn!,Rlist^`	**Fails:** Base fetched from non-user register, but written back into user register
`LDMxx Rn!,Rlist^`	**Fails:** Base fetched from non-user register, but written back into user register

LDM: Forcing transfer of the user bank (Part 2)

Applicability: ARM2, ARM3

When loading user bank registers with an LDM in a non-user mode, care must be taken not to access a banked register (R8-R14) in the following instruction. Accesses to the unbanked registers (R0-R7,R15) are safe.

Because the register bank switches from user mode to non-user mode during the first cycle of the instruction following an `LDM Rn,Rlist^`, an attempt to access a banked register in that cycle may cause the wrong register to be accessed.

The following examples assume the processor to be in a non-user mode and `Rlist` not to include R15:

```
LDM Rn Rlist^
ADD R0,R1,R2
```

Safe: Access to unbanked registers after LDM^


```
LDM Rn,Rlist^
MOV R0,R0
ADD R0,R1,R13_svc
```

Safe: NOP inserted before banked register used following an LDM^

```
LDM Rn,Rlist^
ADD R0,R1,R13_svc
```

Fails: Accessing a banked register immediately after an LDM^ returns the wrong data

```
ADR    R14_svc, saveblock
LDMIA  R14_svc, {R0 - R14_usr}^
LDR    R14_svc, [R14_svc,#15*4]
MOVS   PC, R14_svc (R14_svc)
```

Fails: Banked base register used immediately after the LDM^

```
ADR    R14_svc, saveblock
LDMIA  R14_svc, {R0 - R14_usr}^
MOV    R0,R0
LDR    R14_svc, [R14_svc,#15*4]
MOVS   PC, R14_svc
```

Safe: NOP inserted before banked register (R14_svc) used

Note: The ARM2 and ARM3 processors **usually** give the expected result, but cannot be guaranteed to do so under all circumstances, therefore this code sequence should be avoided in future.

SWI/Undefined instruction trap interaction

Applicability: ARM2

Care must be taken when writing an undefined instruction handler to allow for an unexpected call from a SWI instruction. The erroneous SWI call should be intercepted and redirected to the software interrupt handler.

The implementation of the CDP instruction on ARM2 causes a Software Interrupt (SWI) to take the Undefined Instruction trap if the SWI was the next instruction after the CDP. For example:

```
SIN F0
SWI &11
```

Fails: ARM2 will take the undefined instruction trap instead of software interrupt trap.

All Undefined Instruction handler code should check the failed instruction to see if it is a SWI, and if so pass it over to the software interrupt handler.

Note: CDP is a Coprocessor Data Operation instruction; since it is not supported by the BASIC assembler, it was not described in *Appendix A: ARM assembler*.

Undefined instruction/Prefetch abort trap interaction

Applicability: ARM2, ARM3

Care must be taken when writing the Prefetch abort trap handler to allow for an unexpected call due to an undefined instruction.

When an undefined instruction is fetched from the last word of a page, where the next page is absent from memory, the undefined instruction will cause the undefined instruction trap to be taken, and the following (aborted) instructions will cause a prefetch abort trap. One might expect the undefined instruction trap to be taken first, then the return to the succeeding code will cause the abort trap. In fact the prefetch abort has a higher priority than the undefined instruction trap, so the prefetch abort handler is entered before the undefined instruction trap, indicating a fault at the address of the undefined instruction (which is in a page which is actually present). A normal return from the prefetch abort handler (after loading the absent page) will cause the undefined instruction to execute and take the trap correctly. However the indicated page is already present, so the prefetch abort handler may simply return control, causing an infinite loop to be entered.

Therefore, the prefetch abort handler should check whether the indicated fault is in a page which is actually present, and if so it should suspect the above condition and pass control to the undefined instruction handler. This will restore the expected sequential nature of the execution sequence. A normal return from the undefined instruction handler will cause the next instruction to be fetched (which will abort), the prefetch abort handler will be re-entered (with an address pointing to the absent page), and execution can proceed normally.

Single instructions to avoid

Applicability: ARM2, ARM3

The following single instructions and code sequences should be avoided in writing any ARM code.

Any instruction that uses the 'NV' condition flag

Avoid using the NV (execute never) condition code:

```
opcodeNV ...
```

i.e. any operation where {cond}= NV

By avoiding the use of the 'NV' condition code, 2^{28} instructions become free for future expansion.

Note: It is recommended that the instruction `MOV R0,R0` be used as a general purpose NOP.

Data processing

Avoid using R15 in the Rs position of a data processing instruction:

```
MOV|MVN{cond}{S} Rd,Rm,shiftname R15

CMP|CMN|TEQ|TST{cond}{P} Rn,Rm,shiftname R15

AND|EOR|SUB...|BIC{cond}{S} Rd,Rn,shiftname R15
```

Shifting a register by an amount dependent upon the code position should be avoided.

Multiply and multiply-accumulate

Do not specify R15 as the destination register as only the PSR will be affected by the result of the operation:

```
MUL{cond}{S} R15,Rm,Rs
MLA{cond}{S} R15,Rm,Rs,Rn
```

Do not use the same register in the Rd and Rm positions, as the result of the operation will be incorrect:

```
MUL{cond}{S} Rd,Rd,Rs
MLA{cond}{S} Rd,Rd,Rs
```

Single data transfer

Do not use a PC relative load or store with base writeback as the effects may vary in future processors:

```
LDR|STR{cond}{B}{T} Rd,[R15,#expression]!
LDR|STR{cond}{B}{T} Rd,[R15,{-}Rm{,shift}]!

LDR|STR{cond}{B}{T} Rd,[R15],#expression
LDR|STR{cond}{B}{T} Rd,[R15],{-}Rm{,shift}
```

Note: It is safe to use pre-indexed PC relative loads and stores **without** base writeback.

Avoid using R15 as the register offset (Rm) in single data transfers as the value used will be PC+PSR which can lead to address exceptions:

```
LDR|STR{cond}{B}{T} Rd,[Rn,{-}R15{,shift}]{!}
LDR|STR{cond}{B}{T} Rd,[Rn],{-}R15{,shift}
```

A byte load or store operation on R15 must not be specified, as R15 contains the PC, and should always be treated as a 32 bit quantity:

```
LDR|STR{cond}B{T} R15,Address
```

A post-indexed LDR|STR where Rm=Rn must not be used (this instruction is very difficult for the abort handler to unwind when late aborts are configured – which do not prevent base writeback):

```
LDR|STR{cond}{B}{T} Rd,[Rn],{-}Rn{,shift}
```

Do not use the same register in the Rd and Rm positions of an LDR which specifies (or implies) base writeback; such an instruction is ambiguous, as it is not clear whether the end value in the register should be the loaded data or the updated base:

```
LDR{cond}{B}{T} Rn,[Rn,#expression]!
LDR{cond}{B}{T} Rn,[Rn,{-}Rm{,shift}]!

LDR{cond}{B}{T} Rn,[Rn],#expression
LDR{cond}{B}{T} Rn,[Rn],{-}Rm{,shift}
```

Block data transfer

Do not specify base writeback when forcing user mode block data transfer as the writeback may target the wrong register:

```
STM{cond}<FD|ED...|DB> Rn!,Rlist^
LDM{cond}<FD|ED...|DB> Rn!,Rlist^
```

where `Rlist` does not include R15.

Note: The instruction:

```
LDM{cond}<FD|ED...|DB> Rn!,<Rlist,R15>^
```

does **not** force user mode data transfer, and can be used safely.

Do not perform a PC relative block data transfer, as the PC+PSR is used to form the base address which can lead to address exceptions:

```
LDM|STM{cond}<FD|ED...|DB> R15{!},Rlist{^}
```

Single data swap

Do not perform a PC relative swap as its behaviour may change in the future:

```
SWP{cond}{B} Rd,Rm,[R15]
```

Avoid specifying R15 as the source or destination register:

```
SWP{cond}{B} R15,Rm,[Rn]
SWP{cond}{B} Rd,R15,[Rn]
```

Note: SWP is a Single Data Swap instruction, typically used to implement semaphores, and introduced in the ARM3; since it is not supported by the BASIC assembler, it was not described in *Appendix A: ARM assembler*.

Coprocessor data transfers

When performing a PC relative coprocessor data transfer, writeback to R15 is prevented so the W bit should not be set:

```
LDC|STC{cond}{L} CP#,CRd,[R15]!

LDC|STC{cond}{L} CP#,CRd,[R15,#expression]!

LDC|STC{cond}{L} CP#,CRd,[R15]#expression!
```

Undefined instructions

ARM2 has two undefined instructions, and ARM3 has only one (the other ARM2 undefined instruction has been defined as the Single data swap operation).

Undefined instructions should not be used in programs, as they may be defined as a new operation in future ARM variants.

Register access after an in-line mode change

Care must be taken not to access a banked register (R8-R14) in the cycle following an in-line mode change. Thus the following code sequences should be avoided:

1 `TSTP|TEQP|CMPP|CMNP{cond} Rn,Op2`
2 any instruction that uses R8-R14 in its first cycle.

Register access after an LDM that forces user mode data transfer

The banked registers (R8-R14) should not be accessed in the cycle immediately after an LDM that forces user mode data transfer. Thus the following code sequence should be avoided:

1 `LDM{cond}<FD|ED...|DB> Rn,Rlist^`
where `Rlist` does **not** include R15
2 any instruction that uses R8-R14 in its first cycle.

Other points to note

This section highlights some obscure cases of ARM operation which should be borne in mind when writing code.

Use of R15

Applicability: ARM2, ARM3

Warning: When the PC is used as a destination, operand, base or shift register, different results will be obtained depending on the instruction and the exact usage of R15.

Full details of the value derived from or written into R15+PSR for each instruction class is given in the *Acorn RISC Machine family Data Manual*. Care must be taken when using R15 because small changes in the instruction can yield significantly different results. For example, consider data operations of the type:-

```
    opcode{cond}{S} Rd,Rn,Rm
or  opcode{cond}{S} Rd,Rn,Rm,shiftname Rs
```

- When R15 is used in the Rm position, it will give the value of the PC together with the PSR flags.
- When R15 is used in the Rn or Rs positions, it will give the value of the PC without the PSR flags (PSR bits replaced by zeros).

```
MOV R0,#0
ORR R1,R0,R15      ;R1:=PC+PSR    (bits 31:26,1:0 reflect PSR flags)
ORR R2,R15,R0      ;R2:=PC        (bits 31:26,1:0 set to zero)
```

Note: The relevant instruction description in the ARM *Acorn RISC Machine family Data Manual* should be consulted for full details of the behaviour of R15.

STM: Inclusion of the base in the register list

Applicability: ARM2, ARM3

Warning: In the case of a STM with writeback that includes the base register in the register list, the value of the base register stored depends upon its position in the register list.

During an STM, the first register is written out at the start of the second cycle of the instruction. When writeback is specified, the base is written back at the end of the second cycle. An STM which includes storing the base, with the base as the first register to be stored, will therefore store the unchanged value, whereas with the base second or later in the transfer order, it will store the modified value.

For example:

```
MOV    R5,#&1000
STMIA  R5!,{R5-R6}    ;Stores value of R5=&1000

MOV    R5,#&1000
STMIA  R5!,{R4-R5}    ;Stores value of R5=&1008
```

MUL/MLA: Register restrictions

Applicability: ARM2, ARM3

```
Given   MUL Rd,Rm,Rs
 or     MLA Rd,Rm,Rs,Rn

Then    Rd & Rm must be different registers
        Rd must not be R15
```


Due to the way the Booth's algorithm has been implemented, certain combinations of operand registers should be avoided. (The assembler will issue a warning if these restrictions are overlooked.)

The destination register (Rd) should not be the same as the Rm operand register, as Rd is used to hold intermediate values and Rm is used repeatedly during the multiply. A MUL will give a zero result if Rm=Rd, and a MLA will give a meaningless result.

The destination register (Rd) should also not be R15. R15 is protected from modification by these instructions, so the instruction will have no effect, except that it will put meaningless values in the PSR flags if the S bit is set.

All other register combinations will give correct results, and Rd, Rn and Rs may use the same register when required.

LDM/STM: Address Exceptions

Applicability: ARM2, ARM3

Warning: Illegal addresses formed during a LDM or STM operation will not cause an address exception.

Only the address of the first transfer of a LDM or STM is checked for an address exception; if subsequent addresses over-flow or under-flow into illegal address space they will be truncated to 26 bits but will not cause an address exception trap.

The following examples assume the processor is in a non-user mode and MEMC is being accessed:

```
MOV    R0,#&04000000  ;R0=&04000000
STMIA  R0,{R1-R2}     ;Address exception reported
                      ;    (base address illegal)

MOV    R0,#&04000000
SUB    R0,R0,#4       ;R0=&03FFFFFC
STMIA  R0,{R1-R2}     ;No address exception reported
                      ;    (base address legal)
                      ;code will overwrite data at address &00000000
```

Note: The exact behaviour of the system depends upon the memory manager to which the processor is attached; in some cases, the wraparound may be detected and the instruction aborted.

LDC/STC: Address Exceptions

Applicability: ARM2, ARM3

Warning: Illegal addresses formed during a LDC or STC operation will not cause an address exception (affects LDF/STF).

The coprocessor data transfer operations act like STM and LDM with the processor generating the addresses and the coprocessor supplying/reading the data. As with LDM/STM, only the address of the first transfer of a LDC or STC is checked for an address exception; if subsequent addresses over-flow or under-flow into illegal address space they will be truncated to 26 bits but will not cause an address exception trap.

Note that the floating point LDF/STF instructions are forms of LDC and STC.

The following examples assume the processor is in a non-user mode and MEMC is being accessed:

```
MOV  R0,#&04000000   ; R0=&04000000
STC  CP1,CR0,[R0]    ; Address exception reported
                     ;     (base address illegal)

MOV  R0,#&04000000
SUB  R0,R0,#4        ; R0=&03FFFFFC
STFD F0,[R0]         ; No address exception reported
                     ;     (base address legal)
                     ; code will overwrite data at address &00000000
```

Note: The exact behaviour of the system depends upon the memory manager to which the processor is attached; in some cases, the wraparound may be detected and the instruction aborted.

LDC: Data transfers to a coprocessor fetch more data than expected

Applicability: ARM3

Data to be transferred to a coprocessor with the LDC instruction should never be placed in the last word of an addressable chunk of memory, nor in the word of memory immediately preceding a read-sensitive memory location.

Due to the pipelining introduced into the ARM3 coprocessor interface, an LDC operation will cause one extra word of data to be fetched from the internal cache or external memory by ARM3 and then discarded; if the extra data is fetched from an area of external memory marked as cacheable, a whole line of data will be fetched and placed in the cache.

A particular case in point is that an LDC whose data ends at the last word of a memory page will load and then discard the first word (and hence the first cache line) of the next page. A minor effect of this is that it may occasionally cause an unnecessary page swap in a virtual memory system. The major effect of it is that (whether in a virtual memory system or not), the data for an LDC should never be placed in the last word of an addressable chunk of memory: the LDC will attempt to read the immediately following non-existent location and thus produce a memory fault.

The following example assumes the processor is in a non-user mode, FPU hardware is attached and MEMC is being accessed:

```
MOV  R13,#&03000000  ; R13=Address of I/O space
STFD F0,[R13,#-8]!   ; Store F.P. register 0 at top of physical memory
                     ; (two words of data transferred)
LDFD F1,[R13],#8     ; Load F.P. register 1 from top of physical
                     ; memory, but three words of data are
                     ; transferred, and the third access will read
                     ; from I/O space which may be read sensitive
```

Static ARM problems

The static ARM is a variant of the ARM processor designed for low power consumption, that is built using static CMOS technology. (The difference between it and the standard ARM is similar to that between SRAM and DRAM.)

The static ARM exhibits different behaviour to ARM2 and ARM3 when executing a PC relative LDR with base write-back. This class of instruction has very limited application, so the discrepancy should not be a problem, but if you wish to use any of the following instructions in your code you are advised to contact Acorn Computers.

```
LDR Rd,[PC,#expression]!
LDR Rd,[PC],#expression
LDR Rd,[PC,{-}Rm{,shift}]!
LDR Rd,[PC],{-}Rm{,shift}
```

Note: A PC relative LDR **without** write-back works exactly as expected.

Provided that this instruction class is unused, it is likely that write-back to the PC on LDR and STR will be disabled completely in the future. The fewer incidental ways there are to modify the PC the better.

Unexpected Static ARM2 behaviour when executing a PC relative LDR with writeback

The instructions affected are:-

- `LDR Rd,[PC,#expression]!`
- `LDR Rd,[PC],#expression`

Case 1: LDR Rd,[PC,#expression]!

Expected result: Rd ← (PC+8+expression)
PC ← PC+8+expression
...so execution continues from PC+8+expression

Actual ARM2 result:	Rd ← Rd (no change)
	PC ← PC+8+expression+4
	...so execution continues from PC+12+expression

Case 2: LDR Rd,[PC],#expression

Expected result:	Rd ← (PC+8)
	PC ← PC+8+expression
	...so execution continues from PC+8+expression
Actual ARM2 result:	Rd ← Rd (no change)
	PC ← PC+8+expression+4
	...so execution continues from PC+12+expression

80 Appendix C: ARM procedure call standard

This appendix relates to the implementation of compiler code-generators and language run-time library kernels for the Advanced RISC Machine (ARM) but is also a useful reference when interworking assembly language with high level language code.

The reader should be familiar with the ARM's instruction set, floating-point instruction set and assembler syntax before attempting to use this information to implement a code-generator. In order to write a run-time kernel for a language implementation, additional information specific to the relevant ARM operating system will be needed (some information is given in the sections describing the standard register bindings for this procedure-call standard).

The main topics covered in this appendix are the procedure call and stack disciplines. These disciplines are observed by Acorn's C language implementation for the ARM and, eventually, will be observed by other high level language compilers too. Because C is the first-choice implementation language for RISC OS applications and the implementation language of Acorn's UNIX product RISC iX, the utility of a new language implementation for the ARM will be related to its compatibility with Acorn's implementation of C.

At the end of this appendix are several examples of the usage of this standard, together with suggestions for generating effective code for the ARM.

The purpose of APCS

The ARM Procedure Call Standard is a set of rules, designed:

- to facilitate calls between program fragments compiled from different source languages (eg to make subroutine libraries accessible to all compiled languages)
- to give compilers a chance to optimise procedure call, procedure entry and procedure exit (following the reduced instruction set philosophy of the ARM). This standard defines the use of registers, the passing of arguments at an external procedure call, and the format of a data structure that can be used by stack backtracing programs to reconstruct a sequence of outstanding calls. It does so in terms of *abstract register names*. The binding of some register names to

register numbers and the precise meaning of some aspects of the standard are somewhat dependent on the host operating system and are described in separate sections.

Formally, this standard only defines what happens when an external procedure call occurs. Language implementors may choose to use other mechanisms for internal calls and are not required to follow the register conventions described in this appendix except at the instant of an external call or return. However, other system-specific invariants may have to be maintained if it is required, for example, to deliver reliably an asynchronous interrupt (eg a `SIGINT`) or give a stack backtrace upon an abort (eg when dereferencing an invalid pointer). More is said on this subject in later sections.

Design criteria

This procedure call standard was defined after a great deal of experimentation, measurement, and study of other architectures. It is believed to be the best compromise between the following important requirements:

- Procedure call must be extremely fast.
- The call sequence must be as compact as possible. (In typical compiled code, calls outnumber entries by a factor in the range 2:1 to 5:1.)
- Extensible stacks and multiple stacks must be accommodated. (The standard permits a stack to be extended in a non-contiguous manner, in stack chunks. The size of the stack does not have to be fixed when it is created, avoiding a fixed partition of the available data space between stack and heap. The same mechanism supports multiple stacks for multiple threads of control.)
- The standard should encourage the production of re-entrant programs, with writable data separated from code.
- The standard must support variation of the procedure call sequence, other than by conventional return from procedure (eg in support of C's `longjmp`, Pascal's `goto-out-of-block`, Modula-2+'s exceptions, UNIX's signals, etc) and tracing of the stack by debuggers and run-time error handlers. Enough is defined about the stack's structure to ensure that implementations of these are possible (within limits discussed later).

The Procedure Call Standard

This section defines the standard.

Register names

The ARM has 16 visible general registers and 8 floating-point registers. In interrupt modes some general registers are shadowed and not all floating-point operations are available, depending on how the floating-point operations are implemented.

This standard is written in terms of the register names defined in this section. The binding of certain register names (the **call frame registers**) to register numbers is discussed separately. We do this so that:

- Diverse needs can be more easily accommodated, as can conflicting historical usage of register numbers, yet the underlying structure of the procedure call standard – on which compilers depend critically – remains fixed.
- Run-time support code written in assembly language can be made portable between different register bindings, if it obeys the rules given in the section entitled *Defined bindings of the procedure call standard* on page 6-338.

The register names and fixed bindings are given immediately below.

General Registers

First, the four argument registers:

```
a1   RN   0    ; argument 1/integer result
a2   RN   1    ; argument 2
a3   RN   2    ; argument 3
a4   RN   3    ; argument 4
```

Then the six 'variable' registers:

```
v1   RN   4    ; register variable
v2   RN   5    ; register variable
v3   RN   6    ; register variable
v4   RN   7    ; register variable
v5   RN   8    ; register variable
v6   RN   9    ; register variable
```

Then the call-frame registers, the bindings of which vary (see the section entitled *Defined bindings of the procedure call standard* on page 6-338 for details):

```
sl             ; stack limit / stack chunk handle
fp             ; frame pointer
ip             ; temporary workspace, used in
                 procedure entry
sp   RN   13   ; lower end of current stack frame
```

Finally, lr and pc, which are determined by the ARM's hardware:

```
lr   RN   14   ; link address on calls/temporary workspace
pc   RN   15   ; program counter and processor status
```

In the obsolete APCS-A register bindings described below, sp is bound to r12; in all other APCS bindings, sp is bound to r13.

Notes

Literal register names are given in lower case, eg v1, sp, lr. In the text that follows, symbolic values denoting 'some register' or 'some offset' are given in upper case, eg R, R+N.

References to 'the stack' denoted by sp assume a stack that grows from high memory to low memory, with sp pointing at the top or front (ie lowest addressed word) of the stack.

At the instant of an external procedure call there must be nothing of value to the caller stored below the current stack pointer, between sp and the (possibly implicit, possibly explicit) stack (chunk) limit. Whether there is a single stack chunk or multiple chunks, an explicit stack limit (in sl) or an implicit stack limit, is determined by the register bindings and conventions of the target operating system.

Here and in the text that follows, for any register R, the phrase 'in R' refers to the contents of R; the phrase 'at [R]' or 'at [R, #N]' refers to the word pointed at by R or R+N, in line with ARM assembly language notation.

Floating-point Registers

The floating-point registers are divided into two sets, analogous to the subsets a1-a4 and v1-v6 of the general registers. Registers f0-f3 need not be preserved by a called procedure; f0 is used as the floating-point result register. In certain restricted circumstances (noted below), f0-f3 may be used to hold the first four floating-point arguments. Registers f4-f7, the so called 'variable' registers, must be preserved by callees.

The floating-point registers are:

```
f0   FN   0   ; floating point result (or 1st FP argument)
f1   FN   1   ; floating point scratch register (or 2nd FP arg)
f2   FN   2   ; floating point scratch register (or 3rd FP arg)
f3   FN   3   ; floating point scratch register (or 4th FP arg)
f4   FN   4   ; floating point preserved register
f5   FN   5   ; floating point preserved register
f6   FN   6   ; floating point preserved register
f7   FN   7   ; floating point preserved register
```


Data representation and argument passing

The APCS is defined in terms of N (≥ 0) word-sized arguments being passed from the caller to the callee, and a single word or floating-point result passed back by the callee. The standard does not describe the layout in store of records, arrays and so forth, used by ARM-targeted compilers for C, Pascal, Fortran-77, and so on. In other words, the mapping from language-level objects to APCS words is defined by each language's implementation, not by APCS, and, indeed, there is no formal reason why two implementations of, say, Pascal for the ARM should not use different mappings and, hence, not be cross-callable.

Obviously, it would be very unhelpful for a language implementor to stand by this formal position and implementors are strongly encouraged to adopt not just the letter of APCS but also the obviously natural mappings of source language objects into argument words. Strong hints are given about this in later sections which discuss (some) language specifics.

Register usage and argument passing to external procedures

Control Arrival

We consider the passing of N (≥ 0) actual argument words to a procedure which expects to receive either exactly N argument words or a variable number V (≥ 1) of argument words (it is assumed that there is at least one argument word which indicates in a language-implementation-dependent manner how many actual argument words there are: for example, by using a format string argument, a count argument, or an argument-list terminator).

At the instant when control arrives at the target procedure, the following shall be true (for any M, if a statement is made about argM, and M > N, the statement can be ignored):

```
arg1  is  in  a1
arg2  is  in  a2
arg3  is  in  a3
arg4  is  in  a4
for all I >= 5, argI is at [sp, #4*(I-5)]
```

fp contains 0 or points to a stack backtrace structure (as described in the next section).

The values in sp, sl, fp are all multiples of four.

lr contains the pc+psw value that should be restored into r15 on exit from the procedure. This is known as the *return link value* for this procedure call.

pc contains the entry address of the target procedure.

Now, let us call the lower limit to which sp may point **in this stack chunk** `SP_LWM` (Stack-Pointer Low Water Mark). Remember, it is unspecified whether there is one stack chunk or many, and whether `SP_LWM` is implicit, or explicitly derived from `sl`; these are binding-specific details. Then:

> Space between `sp` and `SP_LWM` shall be (or shall be on demand) readable, writable memory which can be used by the called procedure as temporary workspace and overwritten with any values before the procedure returns.

```
sp >= SP_LWM + 256.
```

This condition guarantees that a stack extension procedure, if used, will have a reasonable amount – 256 bytes – of work space available to it, probably sufficient to call two or three procedure invocations further.

Control Return

At the instant when the return link value for a procedure call is placed in the pc+psw, the following statements shall be true:

`fp`, `sp`, `sl`, `v1-v6`, and `f4-f7` shall contain the same values as they did at the instant of the call. If the procedure returns a word-sized result, R, which is not a floating-point value, then R shall be in `a1`. If the procedure returns a floating-point result, FPR, then FPR shall be in `f0`.

Notes

The definition of control return means that this is a 'callee saves' standard.

The requirement to pass a variable number of arguments to a procedure (as in old-style C) precludes the passing of floating-point arguments in floating-point registers (as the ARM's fixed point registers are disjoint from its floating-point registers). However, if a callee is defined to accept a fixed number K of arguments and its interface description declares it to accept exactly K arguments of matching types, then it is permissible to pass the first four floating-point arguments in floating-point registers `f0-f3`. However, Acorn's C compiler for the ARM does not yet exploit this latitude.

The values of `a2-a4`, `ip`, `lr` and `f1-f3` are not defined at the instant of return.

The Z, N, C and V flags are set from the corresponding bits in the return link value on procedure return. For procedures called using a `BL` instruction, these flag values will be preserved across the call.

The flag values from `lr` at the instant of entry must be restored; it is not sufficient merely to preserve the flag values across the call. (Consider a procedure `ProcA` which has been 'tail-call optimised' and does: `CMPS a1, #0; MOVLT a2, #255; MOVGE a2, #0; B ProcB`. If `ProcB` merely preserves the flags it sees on entry, rather than restoring those from `lr`, the wrong flags may be set when `ProcB` returns direct to `ProcA`'s caller).

This standard does not define the values of `fp`, `sp` and `sl` at arbitrary moments during a procedure's execution, but only at the instants of (external) call and return. Further standards and restrictions may apply under particular operating systems, to aid event handling or debugging. In general, you are strongly encouraged to preserve `fp`, `sp` and `sl`, at all times.

The minimum amount of stack defined to be available is not particularly large, and as a general rule a language implementation should not expect much more, unless the conventions of the target operating system indicate otherwise. For example, code generated by the Arthur/RISC OS C compiler is able, if there is inadequate local workspace, to allocate more stack space from the C heap before continuing. Any language unable to do this may have its interaction with C impaired. That `sl` contains a stack chunk handle is important in achieving this. (See the section entitled *Defined bindings of the procedure call standard* on page 6-338 for further details).

The statements about `sp` and `SP_LWM` are designed to optimise the testing of the one against the other. For example, in the RISC OS user-mode binding of APCS, `sl` contains `SL_LWM+512`, allowing a procedure's entry sequence to include something like:

```
CMP  sp, sl
BLLT |x$stack_overflow|
```

where `x$stack_overflow` is a part of the run-time system for the relevant language. If this test fails, and `x$stack_overflow` is not called, there are at least 512 bytes free on the stack.

This procedure should only call other procedures when `sp` has been dropped by 256 bytes or less, guaranteeing that there is enough space for the called procedure's entry sequence (and, if needed, the stack extender) to work in.

If 256 bytes are not enough, the entry sequence has to drop `sp` before comparing it with `sl` in order to force stack extension (see later sections on implementation specifics for details of how the RISC OS C compiler handles this problem).

The stack backtrace data structure

At the instant of an external procedure call, the value in `fp` is zero or it points to a data structure that gives information about the sequence of outstanding procedure calls. This structure is in the format shown below:

```
fp points to here:  | save mask pointer   |  [fp]
                    | return link value   |  [fp, #-4]
                    | return sp value     |  [fp, #-8]
                    | fp value            |  [fp, #-12]
                    |  saved v6 value     |
                    |  saved v5 value     |
                    |  saved v4 value     |
                    |  saved v3 value     |
                    |  saved v2 value     |
                    |  saved v1 value     |
         Optional { |  saved a4 value     |
           values   |  saved a3 value     |
                    |  saved a2 value     |
                    |  saved a1 value     |
                    |  saved f7 value     |  three words
                    |  saved f6 value     |  three words
                    |  saved f5 value     |  three words
                    |  saved f4 value     |  three words
```

This picture shows between four and 26 words of store, with those words higher on the page being at higher addresses in memory. The presence of any of the optional values does not imply the presence of any other. The floating-point values are in extended format and occupy three words each.

At the instant of procedure call, all of the following statements about this structure shall be true:

- The **return fp value** is either 0 or contains a pointer to another stack backtrace data structure of the same form. Each of these corresponds to an active, outstanding procedure invocation. The statements listed here are also true of this next stack backtrace data structure and, indeed, hold true for each structure in the chain.
- The **save mask pointer** value, when bits 0, 1, 26, 27, 28, 29, 30, 31 have been cleared, points twelve bytes beyond a word known as the **return data save instruction**.

- The return data save instruction is a word that corresponds to an ARM instruction of the following form:

```
STMDB   sp!, {[a1], [a2], [a3], [a4],
             [v1], [v2], [v3], [v4], [v5], [v6],
             fp, ip, lr, pc}
```

  Note the square brackets in the above denote optional parts: thus, there are 12 x 1024 possible values for the return data save instruction, corresponding to the following bit patterns:

```
      1110 1001 0010 1101 1101 10xx xxxx xxxx     APCS-R, APCS-U
 or                  !    ! !
      1110 1001 0010 1100 1100 11xx xxxx xxxx     APCS-A (obsolete)
```

  The least significant 10 bits represent argument and variable registers: if bit N is set, then register N will be transferred.

  The optional parts `a1`, `a2`, `a3`, `a4`, `v1`, `v2`, `v3`, `v4`, `v5` and `v6` in this instruction correspond to those optional parts of the stack backtrace data structure that are present such that: for all M, if vM or aM is present then so is `saved vM value` or `saved aM value`, and if vM or aM is absent then so is `saved vM value` or `saved aM value`. This is as if the stack backtrace data structure were formed by the execution of this instruction, following the loading of `ip` from `sp` (as is very probably the case).

- The sequence of up to four instructions following the return data save instruction determines whether saved floating-point registers are present in the backtrace structure. The four optional instructions allowed in this sequence are:

```
STFE f7, [sp, #-12]! ; 1110 1101 0110 1101 0111 0001 0000 0011
STFE f6, [sp, #-12]! ; 1110 1101 0110 1101 0110 0001 0000 0011
STFE f5, [sp, #-12]! ; 1110 1101 0110 1101 0101 0001 0000 0011
STFE f4, [sp, #-12]! ; 1110 1101 0110 1101 0100 0001 0000 0011
                                           !
```

  Any or all of these instructions may be missing, and any deviation from this order or any other instruction terminates the sequence.

  (A historical bug in the C compiler (now fixed) inserted a single arithmetic instruction between the return data save instruction and the first STFE. Some Acorn software allows for this.)

  The bit patterns given are for APCS-R/APCS-U register bindings. In the obsolete APCS-A bindings, the bit indicated by ! is 0.

  The optional instructions saving `f4`, `f5`, `f6` and `f7` correspond to those optional parts of the stack backtrace data structure that are present such that: for all M, if `STFE fM` is present then so is `saved fM value`; if `STFE fM` is absent then so is `saved fM value`.

- At the instant when procedure A calls procedure B, the stack backtrace data structure pointed at by `fp` contains exactly those elements `v1, v2, v3, v4, v5, v6, f4, f5, f6, f7, fp, sp` and `pc` which must be restored into the corresponding ARM registers in order to cause a correct exit from procedure A, albeit with an incorrect result.

Notes

The following example suggests what the entry and exit sequences for a procedure are likely to look like (though entry and exit are not defined in terms of these instruction sequences because that would be too restrictive; a good compiler can often do better than is suggested here):

```
entry   MOV     ip, sp
        STMDB   sp!, {argRegs, workRegs, fp, ip, lr, pc}
        SUB     fp, ip, #4
exit    LDMDB   fp, {workRegs, fp, sp, pc}^
```

Many apparent idiosyncrasies in the standard may be explained by efforts to make the entry sequence work smoothly. The example above is neither complete (no stack limit checking) nor mandatory (making arguments contiguous for C, for instance, requires a slightly different entry sequence; and storing `argRegs` on the stack may be unnecessary).

The `workRegs` registers mentioned above correspond to as many of `v1` to `v6` as this procedure needs in order to work smoothly. At the instant when procedure A calls any other, those workspace registers not mentioned in A's return data save instruction will contain the values they contained at the instant A was entered. Additionally, the registers `f4-f7` not mentioned in the floating-point save sequence following the return data save instruction will also contain the values they contained at the instant A was entered.

This standard does not require anything of the values found in the optional parts `a1, a2, a3, a4` of a stack backtrace data structure. They are likely, if present, to contain the saved arguments to this procedure call; but this is not required and should not be relied upon.

Defined bindings of the procedure call standard

APCS-R and APCS-U: The RISC OS and RISC IX PCSs

These bindings of the APCS are used by:

- RISC OS applications running in ARM user-mode
- compiled code for RISC OS modules and handlers running in ARM SVC-mode
- RISC iX applications (which make no use of `sl`) running in ARM user mode
- RISC iX kernels running in ARM SVC mode.

The call-frame register bindings are:

```
sl    RN    10      ; stack limit / stack chunk handle
                    ;   unused by RISC iX applications
fp    RN    11      ; frame pointer
ip    RN    12      ; used as temporary workspace
sp    RN    13      ; lower end of current stack frame
```

Although not formally required by this standard, it is considered good taste for compiled code to preserve the value of `sl` everywhere.

The invariants `sp > ip > fp` have been preserved, in common with the obsolete APCS-A (described below), allowing symbolic assembly code (and compiler code-generators) written in terms of register names to be ported between APCS-R, APCS-U and APCS-A merely by relabelling the call-frame registers provided:

- When call-frame registers appear in LDM, LDR, STM and STR instructions they are named symbolically, never by register numbers or register ranges.
- No use is made of the ordering of the four call-frame registers (eg in order to load/save `fp` or `sp` from a full register save).

APCS-R: Constraints on `sl` (For RISC OS applications and modules)

In SVC and IRQ modes (collectively called module mode) `SL_LWM` is implicit in `sp`: it is the next megabyte boundary below `sp`. Even though the SVC-mode and IRQ-mode stacks are not extensible, `sl` still points 512 bytes above a skeleton stack-chunk descriptor (stored just above the megabyte boundary). This is done for compatibility with use by applications running in ARM user-mode and to facilitate module-mode stack-overflow detection. In other words:

```
sl = SL_LWM + 512.
```

When used in user-mode, the stack is segmented and is extended on demand. Acorn's language-independent run-time kernel allows language run-time systems to implement stack extension in a manner which is compatible with other Acorn languages. `sl` points 512 bytes above a full stack-chunk structure and, again:

```
sl = SL_LWM + 512.
```

Mode-dependent stack-overflow handling code in the language-independent run-time kernel faults an overflow in module mode and extends the stack in application mode. This allows library code, including the run-time kernel, to be shared between all applications and modules written in C.

In both modes, the value of `sl` must be valid immediately before each external call **and each return from an external call**.

Deallocation of a stack chunk may be performed by intercepting returns from the procedure that caused it to be allocated. Tail-call optimisation complicates the relationship, so, in general, `sl` is required to be valid immediately before every return from external call.

APCS-U: Constraints on `sl` (For RISC iX applications and RISC iX kernels)

In this binding of the APCS the user-mode stack auto-extends on demand so `sl` is unused and there is no stack-limit checking.

In kernel mode, `sl` is reserved by Acorn.

APCS-A: The obsolete Arthur application PCS

This obsolete binding of the procedure-call standard is used by Arthur applications running in ARM user-mode. The applicable call-frame register bindings are as follows:

```
sl    RN    13    ; stack limit/stack chunk handle
fp    RN    10    ; frame pointer
ip    RN    11    ; used as temporary workspace
sp    RN    12    ; lower end of current stack frame
```

(Use of `r12` as `sp`, rather than the architecturally more natural `r13`, is historical and predates both Arthur and RISC OS.)

In this binding of the APCS, the stack is segmented and is extended on demand. Acorn's language-independent run-time kernel allows language run-time systems to implement stack extension in a manner which is compatible with other Acorn languages.

The stack limit register, `sl`, points 512 bytes above a stack-chunk descriptor, itself located at the low-address end of a stack chunk. In other words:

```
sl = SL_LWM + 512.
```

The value of `sl` must be valid immediately before each external call and each return from an external call.

Although not formally required by this standard, it is considered good taste for compiled code to preserve the value of `sl` everywhere.

Notes on APCS bindings

Invariants and APCS-M

In all future supported bindings of APCS `sp` shall be bound to `r13`. In all supported bindings of APCS the invariant `sp > ip > fp` shall hold. This means that the only other possible binding of APCS is APCS-M:


```
sl    RN    12    ; stack limit/stack chunk handle
fp    RN    10    ; frame pointer
ip    RN    11    ; used as temporary workspace
sp    RN    13    ; lower end of current stack frame
```

This binding of APCS is unlikely to be used (by Acorn).

Further Restrictions in SVC Mode and IRQ Mode

There are some consequences of the ARM's architecture which, while not formally acknowledged by the ARM Procedure Call Standard, need to be understood by implementors of code intended to run in the ARM's SVC and IRQ modes.

An IRQ corrupts `r14_irq`, so IRQ-mode code must run with IRQs off until `r14_irq` has been saved. Acorn's preferred solution to this problem is to enter and exit IRQ handlers written in high-level languages via hand-crafted 'wrappers' which on entry save `r14_irq`, change mode to SVC, and enable IRQs and on exit return to the saved `r14_irq` (which also restores IRQ mode and the IRQ-enable state). Thus the handlers themselves run in SVC mode, avoiding this problem in compiled code.

Both SWIs and aborts corrupt `r14_svc`. This means that care has to be taken when calling SWIs or causing aborts in SVC mode.

In high-level languages, SWIs are usually called out of line so it suffices to save and restore `r14` in the calling veneer around the SWI. If a compiler can generate in-line SWIs, then it should, of course, also generate code to save and restore `r14` in-line, around the SWI, unless it is known that the code will not be executed in SVC mode.

An abort in SVC mode may be symptomatic of a fatal error or it may be caused by page faulting in SVC mode. Acorn expects SVC-mode code to be correct, so these are the only options. Page faulting can occur because an instruction needs to be fetched from a missing page (causing a prefetch abort) or because of an attempted data access to a missing page (causing a data abort). The latter may occur even if the SVC-mode code is not itself paged (consider an unpaged kernel accessing a paged user-space).

A data abort is completely recoverable provided `r14` contains nothing of value at the instant of the abort. This can be ensured by:

- saving R14 on entry to every procedure and restoring it on exit
- not using R14 as a temporary register in any procedure
- avoiding page faults (stack faults) in procedure entry sequences.

A prefetch abort is harder to recover from and an aborting BL instruction cannot be recovered, so special action has to be taken to protect page faulting procedure calls.

For Acorn C, R14 is saved in the second or third instruction of an entry sequence. Aligning all procedures at addresses which are 0 or 4 modulo 16 ensures that the critical part of the entry sequence cannot prefetch-abort. A compiler can do this by padding all code sections to a multiple of 16 bytes in length and being careful about the alignment of procedures within code sections.

Data-aborts early in procedure entry sequences can be avoided by using a software stack-limit check like that used in APCS-R.

Finally, the recommended way to protect BL instructions from prefetch-abort corruption is to precede each BL by a `MOV ip, pc` instruction. If the BL faults, the prefetch abort handler can safely overwrite `r14` with `ip` before resuming execution at the target of the BL. If the prefetch abort is not caused by a BL then this action is harmless, as R14 has been corrupted anyway (and, by design, contained nothing of value at any instant a prefetch abort could occur).

Examples from Acorn language implementations

Example procedure calls in C

Here is some sample assembly code as it might be produced by the C compiler:

```
; gggg is a function of 2 args that needs one register variable (v1)
gggg    MOV     ip, sp
        STMFD   sp!, {a1, a2, v1, fp, ip, lr, pc}
        SUB     fp, ip, #4                  ; points at saved PC
        CMPS    sp, sl
        BLLT    |x$stack_overflow|          ; handler procedure
        ...
        MOV     v1, ...                     ; use a register variable
        ...
        BL      ffff
        ...
        MOV     ..., v1                     ; rely on its value after ffff()
```

Within the body of the procedure, arguments are used from registers, if possible; otherwise they must be addressed relative to `fp`. In the two argument case shown above, `arg1` is at `[fp, #-24]` and `arg2` is at `[fp, #-20]`. But as discussed below, arguments are sometimes stacked with positive offsets relative to `fp`.

Local variables are never addressed offset from `fp`; they always have positive offsets relative to `sp`. In code that changes `sp` this means that the offsets used may vary from place to place in the code. The reason for this is that it permits the procedure `x$stack_overflow` to recover by setting `sp` (and `sl`) to some new stack segment. As part of this mechanism, `x$stack_overflow` may alter memory offset from `fp` by negative amounts, eg `[fp, #-64]` and downwards, provided that it adjusts `sp` to provide workspace for the called routine.

If the function is going to use more than 256 bytes of stack it must do:

```
SUB     ip, sp, #<my stack size>
CMPS    ip, sl
BLLT    |x$stack_overflow_1|
```

instead of the two-instruction test shown above.

If a function expects no more than four arguments it can push all of them onto the stack at the same time as saving its old `fp` and its return address (see the example above); arguments are then saved contiguously in memory with `arg1` having the lowest address. A function that expects more than four arguments has code at its head as follows:

```
MOV     ip, sp
STMFD   sp!, {a1, a2, a3, a4}       ; put arg1-4 below stacked args
STMFD   sp!, {v1, v2, fp, ip, lr, pc}  ; v1-v6 saved as necessary
SUB     fp, ip, #20                 ; point at newly created call-frame
CMPS    sp, sl
BLLT    |x$stack_overflow|
...
...
LDMEA   fp, {v1, v2, fp, sp, pc}^  ; restore register vars & return
```

The store of the argument registers shown here is not mandated by APCS and can often be omitted. It is useful in support of debuggers and run-time trace-back code and required if the address of an argument is taken.

The entry sequence arranges that arguments (however many there are) lie in consecutive words of memory and that on return `sp` is always the lowest address on the stack that still contains useful data.

The time taken for a call, enter and return, with no arguments and no registers saved, is about 22 S-cycles.

Although not required by this standard, the values in `fp`, `sp` and `sl` are maintained while executing code produced by the C compiler. This makes it much easier to debug compiled code.

Multi-word results other than double precision reals in C programs are represented as an implicit first argument to the call, which points to where the caller would like the result placed. It is the first, rather than the last, so that it works with a C function that is not given enough arguments.

Procedure calls in other language implementations

Assembler

The procedure call standard is reasonably easy and natural for assembler programmers to use. The following rules should be followed:

- Call-frame registers should always be referred to explicitly by symbolic name, never by register number or implicitly as part of a register range.
- The offsets of the call-frame registers within a register dump should not be wired into code. Always use a symbolic offset so that you can easily change the register bindings.

Fortran

The Acorn/TopExpress Arthur/RISC OS Fortran-77 compiler violates the APCS in a number of ways that preclude inter-working with C, except via assembler veneers. This may be changed in future releases of the Fortran-77 product.

Pascal

The Acorn/3L Arthur/RISC OS ISO-Pascal compiler violates the APCS in a number of ways that preclude inter-working with C, except via assembler veneers. This may be changed in future releases of the ISO-Pascal product.

Lisp, BCPL and BASIC

These languages have their own special requirements which make it inappropriate to use a procedure call of the form described here. Naturally, all are capable of making external calls of the given form, through a small amount of assembler 'glue' code.

General

Note that there is no requirement specified by the standard concerning the production of re-entrant code, as this would place an intolerable strain on the conventional programming practices used in C and Fortran. The behaviour of a procedure in the face of multiple overlapping invocations is part of the specification of that procedure.

Various lessons

This appendix is not intended as a general guide to the writing of code-generators, but it is worth highlighting various optimisations that appear particularly relevant to the ARM and to this standard.

The use of a callee-saving standard, instead of a caller-saving one, reduces the size of large code images by about 10% (with compilers that do little or no interprocedural optimisation).

In order to make effective use of the APCS, compilers must compile code a procedure at a time. Line-at-a-time compilation is insufficient.

The preservation of condition codes over a procedure call is often useful because any short sequence of instructions (including calls) that forms the body of a short `IF` statement can be executed without a branch instruction. For example:

```
if (a < 0) b = foo();
```

can compile into:

```
CMP     a, #0
BLLT    foo
MOVLT   b, a1
```

In the case of a **leaf** or **fast** procedure – one that calls no other procedures –much of the standard entry sequence can be omitted. In very small procedures, such as are frequently used in data abstraction modules, the cost of the procedure can be very small indeed. For instance, consider:

```
typedef struct {...; int a; ...} foo;
int get_a(foo* f) {return(f->a);}
```

The procedure `get_a` can compile to just:

```
LDR     a1, [a1, #aOffset]
MOVS    pc, lr
```

This is also useful in procedures with a conditional as the top level statement, where one or other arm of the conditional is fast (ie calls no procedures). In this case there is no need to form a stack frame there. For example, using this, the C program:

```
int sum(int i)
{
   if (i <= 1)
      return(i);
   else
      return(i + sum(i-1));
}
```

could be compiled into:

```
sum     CMP     a1, #1 ; try fast case
        MOVSLE  pc, lr ; and if appropriate, handle quickly!
        ; else, form a stack frame and handle the rest as normal code.
        MOV     ip, sp
        STMDB   sp!, {v1, fp, ip, lr, pc}
        CMP     sp, sl
        BLLT    overflow
        MOV     v1, a1                   ; register to hold i
        SUB     a1, a1, #1               ; set up argument for call
        BL      sum                      ; do the call
        ADD     a1, a1, v1               ; perform the addition
        LDMEA   fp, {v1, fp, sp, pc}^    ; and return
```

This is only worthwhile if the test can be compiled using only `ip`, and any spare of `a1-a4`, as scratch registers. This technique can significantly speed up certain speed-critical routines, such as read and write character. At the present time, this optimisation is not performed by the C compiler.

Finally, it is often worth applying the tail call optimisation, especially to procedures which need to save no registers. For example, the code fragment:

```
extern void *malloc(size_t n)
{
    return primitive_alloc(NOTGCABLEBIT, BYTESTOWORDS(n));
}
```

is compiled by the C compiler into:

```
malloc  ADD     a1, a1, #3              ; 1S
        MOV     a2, a1, LSR #2          ; 1S
        MOV     a1, #1073741824         ; 1S
        B       primitive_alloc         ; 1N+2S = 4S
```

This avoids saving and restoring the call-frame registers and minimises the cost of interface 'sugaring' procedures. This saves five instructions and, on a 4/8MHz ARM, reduces the cost of the malloc sugar from 24S to 7S.

81 Appendix D: Code file formats

This appendix defines three file formats used by DDE tools to store processed code and the format of debugging data used by DDT:

- AOF – Arm Object Format
- ALF – Acorn Library Format
- AIF – RISC OS Application Image Format
- ASD – ARM Symbolic Debugging Format.

DDE language processors such as CC and ObjAsm generate processed code output as AOF files. An ALF file is a collection of AOF files constructed from a set of AOF files by the LibFile tool. The Link tool accepts a set of AOF and ALF files as input, and by default produces an executable program file as output in AIF.

Terminology

Throughout this appendix the terms *byte*, *half word*, *word*, and *string* are used to mean the following:

Byte: 8 bits, considered unsigned unless otherwise stated, usually used to store flag bits or characters.

Half word: 16 bits, or 2 bytes, usually unsigned. The least significant byte has the lowest address (DEC/Intel *byte sex*, sometimes called *little endian*). The address of a half word (ie of its least significant byte) must be divisible by 2.

Word: 32 bits, or 4 bytes, usually used to store a non-negative value. The least significant byte has the lowest address (DEC/Intel byte sex, sometimes called little endian). The address of a word (ie of its least significant byte) must be divisible by 4.

String: A sequence of bytes terminated by a NUL (0X00) byte. The NUL is part of the string but is not counted in the string's length. Strings may be aligned on any byte boundary.

For emphasis: a word consists of 32 bits, 4-byte aligned; within a word, the least significant byte has the lowest address. This is DEC/Intel, or little endian, byte sex, **not** IBM/Motorola byte sex.

Undefined Fields

Fields not explicitly defined by this appendix are implicitly reserved to Acorn. It is required that all such fields be zeroed. Acorn may ascribe meaning to such fields at any time, but will usually do so in a manner which gives no new meaning to zeroes.

Overall structure of AOF and ALF files

An object or library file contains a number of separate but related pieces of data. In order to simplify access to these data, and to provide for a degree of extensibility, the object and library file formats are themselves layered on another format called **Chunk File Format**, which provides a simple and efficient means of accessing and updating distinct chunks of data within a single file. The object file format defines five chunks:

- header
- areas
- identification
- symbol table
- string table.

The library file format defines four chunks:

- directory
- time-stamp
- version
- data.

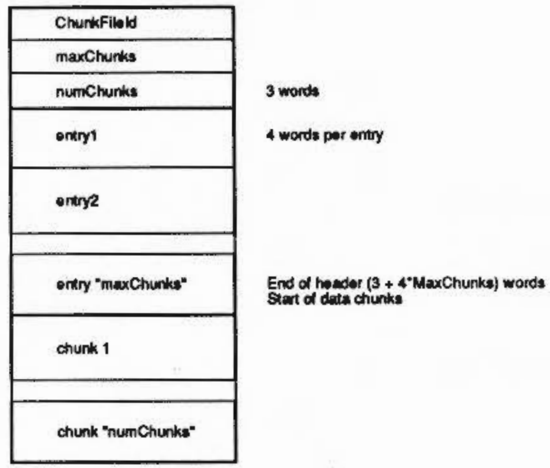
There may be many data chunks in a library.

The minimum size of a piece of data in both formats is four bytes or one word. Each word is stored in a file in little-endian format; that is the least significant byte of the word is stored first.

Chunk file format

A chunk is accessed via a header at the start of the file. The header contains the number, size, location and identity of each chunk in the file. The size of the header may vary between different chunk files but is fixed for each file. Not all entries in a header need be used, thus limited expansion of the number of chunks is permitted without a wholesale copy. A chunk file can be copied without knowledge of the contents of the individual chunks.

Graphically, the layout of a chunk file is as follows:



`ChunkFileId` marks the file as a chunk file. Its value is C3CBC6C5 hex. The `maxChunks` field defines the number of the entries in the header, fixed when the file is created. The `numChunks` field defines how many chunks are currently used in the file, which can vary from 0 to `maxChunks`. The value of `numChunks` is redundant as it can be found by scanning the entries.

Each entry in the header comprises four words in the following order:

`chunkId`	a two word field identifying what data the chunk file contains
`Offset`	a one word field defining the byte offset within the file of the chunk (which must be divisible by four); an entry of zero indicates that the corresponding chunk is unused
`size`	a one word field defining the exact byte size of the chunk (which need not be a multiple of four).

The `chunkId` field provides a conventional way of identifying what type of data a chunk contains. It is split into two parts. The first four characters (in the first word) contain a universally unique name allocated by a central authority (Acorn). The remaining four characters (in the second word) can be used to identify component chunks within this universal domain. In each part, the first character of the name is stored first in the file, and so on.

For AOF files, the first part of each chunk's name is `OBJ_`; the second components are defined later. For ALF files, the first part is `LIB_`.

AOF

ARM object format files are output by language processors such as CC and ObjAsm.

Object file format

Each piece of an object file is stored in a separate, identifiable, chunk. AOF defines five chunks as follows:

Chunk	Chunk Name
Header	OBJ_HEAD
Areas	OBJ_AREA
Identification	OBJ_IDFN
Symbol Table	OBJ_SYMT
String Table	OBJ_STRT

Only the `header` and `areas` chunks must be present, but a typical object file will contain all five of the above chunks.

A feature of chunk file format is that chunks may appear in any order in the file. However, language processors which must also generate other object formats – such as UNIX's `a.out` format – should use this flexibility cautiously.

A language translator or other system utility may add additional chunks to an object file, for example a language-specific symbol table or language-specific debugging data, so it is conventional to allow space in the chunk header for additional chunks; space for eight chunks is conventional when the AOF file is produced by a language processor which generates all five chunks described here.

The `header` chunk should not be confused with the chunk file's header.

Format of the AOF header chunk

The AOF header is logically in two parts, though these appear contiguously in the header chunk. The first part is of fixed size and describes the contents and nature of the object file. The second part is variable in length (specified in the fixed part) and is a sequence of `area` declarations defining the code and data areas within the OBJ_AREA chunk.

The AOF header chunk has the following format:

Object file type	
Version Id	
Number of areas	
Number of Symbols	
Entry Address area	
Entry Address Offset	6 words in the fixed part
1st Area Header	5 words per area header
2nd Area Header	
...	
nth Area Header	(6 + 5*Number of Areas) words in the AOF header

Object file type

C5E2D080 (hex) marks an object file as being in relocatable object format

Version ID

This word encodes the version of AOF to which the object file complies: AOF 1.xx is denoted by 150 decimal; AOF 2.xx by 200 decimal.

Number of areas

The code and data of the object file is presented as a number of separate areas, in the OBJ_AREA chunk, each with a name and some attributes (see below). Each area is declared in the (variable-length) part of the header which immediately follows the fixed part. The value of the `Number of Areas` field defines the number of areas in the file and consequently the number of area declarations which follow the fixed part of the header.

Number of symbols

If the object file contains a symbol table chunk OBJ_SYMT, then this field defines the number of symbols in the symbol table.

Entry address area/ entry address offset

One of the areas in an object file may be designated as containing the start address for any program which is linked to include this file. If so, the entry address is specified as an `<area-index, offset>` pair, where `area-index` is in the range 1 to `Number of Areas`, specifying the nth area declared in the area declarations part of the header. The entry address is defined to be the base address of this area plus `offset`.

A value of 0 for `area-index` signifies that no program entry address is defined by this AOF file.

Format of area headers

The area headers follow the fixed part of the AOF header. Each area header has the following form:

Area name			(offset into string variable)
zeros	AT	AL	
Area size			
Number of relocations			
Unused - must be zero			5 words in total

Area name

Each name in an object file is encoded as an offset into the string table, which stored in the OBJ_STRT chunk. This allows the variable-length characteristics of names to be factored out from primary data formats. Each area within an object file must be given a name which is unique amongst all the areas in that object file.

AL

This byte must be set to 2; all other values are reserved to Acorn.

AT (Area attributes)

Each area has a set of attributes encoded in the AT byte. The least-significant bit of AT is numbered 0.

Link orders areas in a generated image first by attributes, then by the (case-significant) lexicographic order of area names, then by position of the containing object module in the link-list. The position in the link-list of an object module loaded from a library is not predictable.

When ordered by attributes, Read-Only areas precede Read-Write areas which precede Debug areas; within Read-Only and Read-Write Areas, Code precedes Data which precedes Zero-Initialised data. Zero-Initialised data may not have the Read-Only attribute.

Bit 0

This bit must be set to 0.

Bit 1

If this bit is set, the area contains code, otherwise it contains data.

Bit 2

Bit 2 specifies that the area is a common block definition.

Bit 3

Bit 3 defines the area to be a (reference to a) common block and precludes the area having initialising data (see Bit 4, below). In effect, the setting of Bit 3 implies the setting of Bit 4.

Common areas with the same name are overlaid on each other by Link. The `Size` field of a common definition defines the size of a common block. All other references to this common block must specify a size which is smaller or equal to the definition size. In a link step there may be at most one area of the given name with bit 2 set. If none of these have bit 2 set, the actual size of the common area will be size of the largest common block reference (see also the section entitled *Linker defined symbols* on page 6-361).

Bit 4

This bit specifies that the area has no initialising data in this object file and that the area contents are missing from the OBJ_AREA chunk. This bit is typically used to denote large uninitialised data areas. When an uninitialised area is included in an image, Link either includes a read-write area of binary zeroes of appropriate size or maps a read-write area of appropriate size that will be zeroed at image start-up time. This attribute is incompatible with the read-only attribute (see the section on Bit 5, below).

Note: Whether or not a zero-initialised area is re-zeroed if the image is re-entered is a property of Link and the relevant image format. The definition of AOF neither requires nor precludes re-zeroing.

Bit 5

This bit specifies that the area is read-only. Link groups read-only areas together so that they may be write protected at run-time, hardware permitting. Code areas and debugging tables should have this bit set. The setting of this bit is incompatible with the setting of bit 4.

Bit 6

This bit must be set to 0.

Bit 7

This bit specifies that the area contains symbolic debugging tables. Link groups these areas together so they can be accessed as a single contiguous chunk at run-time. It is usual for debugging tables to be read-only and, therefore, to have bit 5 set too. If bit 7 is set, bit 1 is ignored.

Area size

This field specifies the size of the area in bytes, which must be a multiple of 4. Unless the `Not Initialised` bit (bit 4) is set in the area attributes, there must be this number of bytes for this area in the OBJ_AREA chunk.

Number of relocations

This specifies the number of relocation records which apply to this area.

Format of the areas chunk

The areas chunk (OBJ_AREA) contains the actual areas (code, data, zero- initialised data, debugging data, etc.) plus any associated relocation information. Its chunkId is OBJ_AREA. Both an area's contents and its relocation data must be word-aligned. Graphically, an area's layout is:

Area 1
Area 1 relocation
Area n
Area n relocation

An area is simply a sequence of byte values, the order following that of the addressing rules of the ARM, that is the least significant byte of a word is first. An area is followed by its associated relocation table (if any). An area is either completely initialised by the values from the file or not initialised at all (ie it is initialised to zero in any loaded program image, as specified by bit 4 of the area attributes).

Relocation directives

If no relocation is specified, the value of a byte/half word/word in the preceding area is exactly the value that will appear in the final image.

Bytes and half words may only be relocated by constant values of suitably small size. They may not be relocated by an area's base address.

A field may be subject to more than one relocation.

There are 2 types of relocation directive, termed here type-1 and type-2. Type-2 relocation directives occur only in AOF versions 1.50 and later.

Relocation can take two basic forms: *Additive* and *PCRelative*.

Additive relocation specifies the modification of a byte/half word/word, typically containing a data value (ie constant or address).

PCRelative relocation always specifies the modification of a branch (or branch with link) instruction and involves the generation of a program- counter-relative, signed, 24-bit word-displacement.

Additive relocation directives and type-2 PC-relative relocation directives have two variants: `Internal` and `Symbol`.

Additive internal relocation involves adding the allocated base address of an area to the field to be relocated. With Type-1 internal relocation directives, the value by which a location is relocated is always the base of the area with which the relocation directive is associated (the Symbol IDentification field (SID) is ignored). In a type-2 relocation directive, the SID field specifies the index of the area relative to which relocation is to be performed. These relocation directives are analogous to the TEXT-, DATA- and BSS-relative relocation directives found in the a.out object format.

Symbol relocation involves adding the value of the symbol quoted.

A type-1 PCRelative relocation directive always references a symbol. The relocation offset added to any pre-existing in the instruction is the offset of the target symbol from the PC current at the instruction making the PCRelative reference. Link takes into account the fact that the PC is eight bytes beyond that instruction.

In a type-2 PC-relative relocation directive (only in AOF version 1.50 and later) the offset bits of the instruction are initialised to the offset from the base of the area of the PC value current at the instruction making the reference – thus the language

translator, not Link, compensates for the difference between the address of the instruction and the PC value current at it. This variant is introduced in direct support of compilers that must also generate UNIX's `a.out` format.

For a type-2 PC-relative symbol-type relocation directive, the offset added into the instruction making the PC-relative reference is the offset of the target symbol from the base of the area containing the instruction. For a type-2, PC-relative, internal relocation directive, the offset added into the instruction is the offset of the base of the area identified by the SID field from the base of the area containing the instruction.

Link itself may generate type-2, PC-relative, internal relocation directives during the process of partially linking a set of object modules.

Format of Type 1 relocation directives

Diagrammatically:

Offset				
O	A	R	FT	SID

Offset

Offset is the byte offset in the preceding area of the field to be relocated.

SID

If a symbol is involved in the relocation, this 16-bit field specifies the index within the symbol table (see below) of the symbol in question.

FT (Field Type)

This 2-bit field (bits 16 – 17) specifies the size of the field to be relocated:

00	byte
01	half word
10	word
11	*illegal value*

R (relocation type)

This field (bit 18) has the following interpretation:

0	Additive relocation
1	PC-Relative relocation

A (Additive type)

In a type-1 relocation directive, this 1-bit field (bit 19) is only interpreted if bit 18 is a zero.

A=0 specifies Internal relocation, meaning that the base address of the area (with which this relocation directive is associated) is added into the field to be relocated. A=1 specifies Symbol relocation, meaning that the value of the given symbol is added to the field being relocated.

Bits 20 - 31

Bits 20-31 are reserved by Acorn and should be written as zeroes.

Format of Type 2 relocation directives

These are available from AOF 1.50 onwards.

Offset				
1000	A	R	FT	24-bit SID

The interpretation of Offset, FT and SID is exactly the same as for type-1 relocation directives except that SID is increased from 16 to 24 bits and has a different meaning – described below – if A=0).

The second word of a type-2 relocation directive contains 1 in its most significant bit; bits 28 - 30 must be written as 0, as shown.

The different interpretation of the R bit in type-2 directives has already been described in the section entitled *Relocation directives* on page 6-356.

If A=0 (internal relocation type) then SID is the index of the area, in the OBJ_AREA chunk, relative to which the value at Offset in the current area is to be relocated. Areas are indexed from 0.

Format of the symbol table chunk

The `Number of Symbols` field in the header defines how many entries there are in the symbol table. Each symbol table entry has the following format:

Name	
	AT
Value	
Area name	

Name

This value is an index into the string table (in chunk OBJ_STRT) and thus locates the character string representing the symbol.

AT

This is a 7 bit field specifying the attributes of a symbol as follows:

Bits 1 and 0

(10 means bit 1 set, bit 0 unset).

01 The symbol is defined in this object file and has scope limited to this object file (when resolving symbol references, Link will only match this symbol to references from other areas within the same object file).

10 The symbol is a reference to a symbol defined in another area or another object file. If no defining instance of the symbol is found then Link attempts to match the name of the symbol to the names of common blocks. If a match is found it is as if there were defined an identically-named symbol of global scope, having as value the base address of the common area.

11 The symbol is defined in this object file and has global scope (ie when attempting to resolve unresolved references, Link will match this symbol to references from other object files).

00 Reserved by Acorn.

Bit 2

This attribute is only meaningful if the symbol is a defining occurrence (bit 0 set). It specifies that the symbol has an absolute value, for example, a constant. Otherwise its value is relative to the base address of the area defined by the `Area Name` field of the symbol table entry.

Bit 3

This bit is only meaningful if bit 0 is unset (that is, the symbol is an external reference). Bit 3 denotes that the reference is case-insensitive. When attempting to resolve such an external reference, Link will ignore character case when performing the match.

Bit 4

This bit is only meaningful if the symbol is an external reference (bits 1,0 = 10). It denotes that the reference is **weak**, that is that it is acceptable for the reference to remain unsatisfied and for any fields relocated via it to remain unrelocated.

Note: A weak reference still causes a library module satisfying that reference to be auto-loaded.

Bit 5

This bit is only meaningful if the symbol is a defining, external occurrence (ie if bits 1,0 = 11). It denotes that the definition is **strong** and, in turn, this is only meaningful if there is a non-strong, external definition of the same symbol in another object file. In this scenario, all references to the symbol from outside of the file containing the strong definition are resolved to the strong definition. Within the file containing the strong definition, references to the symbol resolve to the non-strong definition.

This attribute allows a kind of link-time indirection to be enforced. Usually, strong definitions will be absolute and will be used to implement an operating system's entry vector which must have the **forever binary** property.

Bit 6

This bit is only meaningful if bits 1,0 = 10. Bit 6 denotes that the symbol is a common symbol – in effect, a reference to a common area with the symbol's name. The length of the common area is given by the symbol's value field (see below). Link treats common symbols much as it treats areas having the common reference bit set – all symbols with the same name are assigned the same base address and the length allocated is the maximum of all specified lengths.

If the name of a common symbol matches the name of a common area then these are merge and symbol identifies the base of the area.

All common symbols for which there is no matching common area (reference or definition) are collected into an anonymous linker pseudo-area.

Value

This field is only meaningful if the symbol is a defining occurrence (ie bit 0 of AT set) or a common symbol (ie bit 6 of AT set). If the symbol is absolute (bit 2 of AT set), this field contains the value of the symbol. Otherwise, it is interpreted as an offset from the base address of the area defined by `Area Name`, which must be an area defined in this object file.

Area name

This field is only meaningful if the symbol is not absolute (ie if bit 2 of AT is unset) and the symbol is a defining occurrence (ie bit 0 of AT is set). In this case it gives the index into the string table of the character string name of the (logical) area relative to which the symbol is defined.

String table chunk (OBJ_STRT)

The string table chunk contains all the print names referred to within the areas and symbol table chunks. The separation is made to factor out the variable length characteristic of print names. A print name is stored in the string table as a sequence of ISO8859 non-control characters terminated by a NUL (0) byte and is identified by an offset from the table's beginning. The first 4 bytes of the string table contain its length (including the length word – so no valid offset into the table is less than 4 and no table has length less than 4). The length stored at the start of the string table itself is identically the length stored in the OBJ_STRT chunk header.

Identification chunk (OBJ_IDFN)

This chunk should contain a printable character string (characters in the range [32 - 126]), terminated by a NUL (0) byte, giving information about the name and version of the language translator which generated the object file.

Linker defined symbols

Though not part of the definition of AOF, the definitions of symbols which the AOF linker defines during the generation of an image file are collected here. These may be referenced from AOF object files, but must not be redefined.

Linker pre-defined symbols

The pre-defined symbols occur in Base/Limit pairs. A Base value gives the address of the first byte in a region and the corresponding Limit value gives the address of the first byte beyond the end of the region. All pre-defined symbols begin `Image$$` and the space of all such names is reserved by Acorn.

None of these symbols may be redefined. The pre-defined symbols are:

`Image$$RO$$Base` `Image$$RO$$Limit`	Address and limit of the Read-Only section of the image.
`Image$$RW$$Base` `Image$$RW$$Limit`	Address and limit of the Read-Write section of the image.
`Image$$ZI$$Base` `Image$$ZI$$Limit`	Address and limit of the Zero-initialised data section of the image (created from areas having bit 4 of their area attributes set and from common symbols which match no area name).

If a section is absent, the Base and Limit values are equal but unpredictable.

`Image$$RO$$Base`	includes any image header prepended by Link.
`Image$$RW$$Limit`	includes (at the end of the RW section) any zero-initialised data created at run-time.

The `Image$$xx$${Base,Limit}` values are intended to be used by language run-time systems. Other values which are needed by a debugger or by part of the pre-run-time code associated with a particular image format are deposited into the relevant image header by Link.

Common area symbols

For each common area, Link defines a global symbol having the same name as the area, except where this would clash with the name of an existing global symbol definition (thus a symbol reference may match a common area).

Obsolescent and obsolete features

The following subsections describe features that were part of revision 1.xx of AOF and/or that were supported by the 59x releases of the AOF linker, which are no longer supported. In each case, a brief rationale for the change is given.

Object file type

AOF used to define three image types as well as a relocatable object file type. Image types 2 and 3 were never used under Arthur/RISC OS and are now obsolete. Image type 1 is used only by the obsolete Dbug (DDT has Dbug's functionality and uses Application Image Format).

AOF Image type 1	C5E2D081 hex	(obsolescent)
AOF Image type 2	C5E2D083 hex	(obsolete)
AOF Image type 3	C5E2D087 hex	(obsolete)

AL (Area alignment)

AOF used to allow the alignment of an area to be any specified power of 2 between 2 and 16. By convention, relocatable object code areas always used minimal alignment (AL=2) and only the obsolete image formats, types 2 and 3, specified values other than 2. From now on, all values other than 2 are reserved by Acorn.

AT (Area attributes)

Two attributes have been withdrawn: the Absolute attribute (bit 0 of AT) and the Position Independent attribute (bit 6 of AT).

The Absolute attribute was not supported by the RISC OS linker and therefore had no utility. Link in any case allows the effect of the Absolute attribute to be simulated.

The Position Independent bit used to specify that a code area was position independent, meaning that its base address could change at run-time without any change being required to its contents. Such an area could only contain internal, PC-relative relocations and must make all external references through registers. Thus only code and pure data (containing no address values) could be position-independent.

Few language processors generated the PI bit which was only significant to the generation of the obsolete image types 2 and 3 (in which it affected AREA placement). Accordingly, its definition has been withdrawn.

Fragmented areas

The concept of fragmented areas was introduced in release 0.04 of AOF, tentatively in support of Fortran compilers. To the best of our knowledge, fragmented areas were never used. (Two warnings against use were given with the original definition on the grounds of: structural incompatibility with UNIX's `a.out` format; and likely inefficient handling by Link. And use was hedged around with curious restrictions). Accordingly, the definition of fragmented areas is withdrawn.

ALF

ALF is the format of linkable libraries (such as the C RISC OS library RISC_OSLib).

Library file format types

There are two library file formats described here, termed *new-style* and *old-style*. Link can read both formats, though no tool will actually generate an old-style library.

Currently, only the Acorn/Topexpress Fortran-77 compiler generates old-style libraries (which it does instead of generating AOF object files). Link handles these libraries specially, including every member in the output image unless explicitly instructed otherwise.

Old-style libraries are obsolescent and should no longer be generated.

Library file chunks

Each piece of a library file is stored in a separate, identifiable, chunk, named as follows:

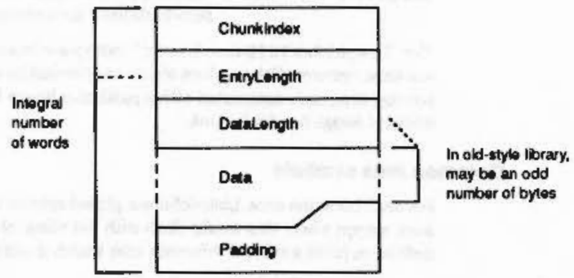
Chunk	Chunk Name	
Directory	LIB_DIRY	
Time-stamp	LIB_TIME	
Version	LIB_VSRN	– new-style libraries only
Data	LIB_DATA	
Symbol table	OFL_SYMT	– object code libraries only
Time-stamp	OFL_TIME	– object code libraries only

There may be many LIB_DATA chunks in a library, one for each library member.

LIB_DIRY

The LIB_DIRY chunk contains a directory of all modules in the library each of which is stored in a LIB_DATA chunk. The directory size is fixed when the library is created. The directory consists of a sequence of variable length entries, each an integral number of words long. The number of directory entries is determined by the size of the LIB_DIRY chunk.

This is shown pictorially in the following diagram:



ChunkIndex

The ChunkIndex is a 0 origin index within the chunk file header of the corresponding LIB_DATA chunk. The LIB_DATA chunk entry gives the offset and size of the library module in the library file. A ChunkIndex of 0 means the directory entry is not in use.

EntryLength

The number of bytes in this LIB_DIRY entry, always a multiple of 4.

DataLength

The number of bytes used in the Data section of this LIB_DIRY entry. This need not be a multiple of 4, though it always is in new-style libraries.

Data

The data section consists of a 0 terminated string followed by any other information relevant to the library module. Strings should contain only ISO-8859 non-control characters (ie codes [0-31], 127 and 128+[0-31] are excluded). The string is the name used by the library management tools to identify this library module. Typically this is the name of the file from which the library member was created.

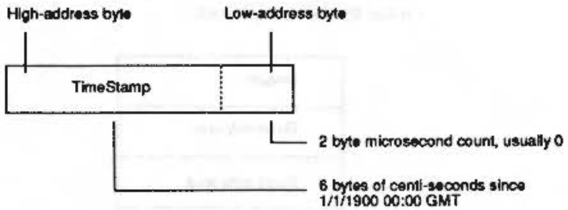
In new-style libraries, an 8-byte, word-aligned time-stamp follows the member name. The format of this time-stamp is described in the section entitled LIB_TIME on page 6-366. Its value is (an encoded version of) the time-stamp (ie the last modified time) of the file from which the library member was created.

Applications which create libraries or library members should ensure that the LIB_DIRY entries they create contain valid time-stamps. Applications which read LIB_DIRY entries should not rely on any data beyond the end of the name-string being present unless the difference between the DataLength field and the name-string length allows for it. Even then, the contents of a time-stamp should be treated cautiously and not assumed to be sensible.

Applications which write LIB_DIRY or OFL_SYMT entries should ensure that padding is done with NUL (0) bytes; applications which read LIB_DIRY or OFL_SYMT entries should make no assumptions about the values of padding bytes beyond the first, string-terminating NUL byte.

LIB_TIME

The LIB_TIME chunk contains a 64 bit time-stamp recording when the library was last modified, in the following format:



LIB_VSRN

In new-style libraries, this chunk contains a 4-byte version number. The current version number is 1. Old-style libraries do not contain this chunk.

LIB_DATA

A LIB_DATA chunk contains one of the library members indexed by the LIB_DIRY chunk. No interpretation is placed on the contents of a member by the library management tools. A member could itself be a file in chunk file format or even another library.

Object code libraries

An object code library is a library file whose members are files in AOF. All libraries you are likely to use with the DDE are object code libraries.

Additional information is stored in two extra chunks, OFL_SYMT and OFL_TIME.

OFL_SYMT contains an entry for each external symbol defined by members of the library, together with the index of the chunk containing the member defining that symbol.

The OFL_SYMT chunk has exactly the same format as the LIB_DIRY chunk except that the Data section of each entry contains only a string, the name of an external symbol (and between 1 and 4 bytes of NUL padding). OFL_SYMT entries do not contain time-stamps.

The OFL_TIME chunk records when the OFL_SYMT chunk was last modified and has the same format as the LIB_TIME chunk (see above).

AIF

AIF is the format of executable program files produced by linking AOF files. Example AIF files are !RunImage files of applications coded in C or assembler.

Properties of AIF

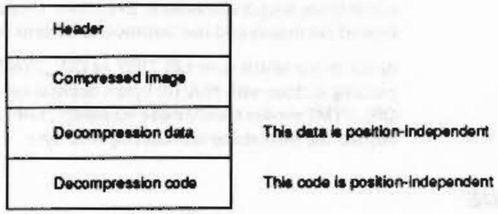
- An AIF image is loaded into memory at its load address and entered at its first word (compatible with old-style Arthur/Brazil ADFS images).
- An AIF image may be compressed and can be self-decompressing (to support faster loading from floppy discs, and better use of floppy-disc space).
- If created with suitable linker options, an AIF image may relocate itself at load time. Self-relocation is supported in two, distinct senses:-
    - One-time Position-Independence: A relocatable image can be loaded at any address (not just its load address) and will execute there (compatible with version 0.03 of AIF).
    - Specified Working Space Relocation: A suitably created relocatable image will copy itself from where it is loaded to the high address end of applications memory, leaving space above the copied image as noted in the AIF header (see below).

  In addition, similar relocation code and similar linker options support many-time position independence of RISC OS Relocatable Modules.
- AIF images support being debugged by the Desktop Debugging Tool (DDT), for C, assembler and other languages. Version 0.04 of AIF (and later) supports debugging at the symbolic assembler level (hitherto done by Dbug). Low-level and source-level debugging support are orthogonal (capabilities of debuggers notwithstanding, both, either, or neither kind of debugging support may be present in an AIF image).

  Debugging tables have the property that all references from them to code and data (if any) are in the form of relocatable addresses. After loading an image at its load address these values are effectively absolute. All references between debugger table entries are in the form of offsets from the beginning of the debugging data area. Thus, following relocation of a whole image, the debugging data area itself is position independent and can be copied by the debugger.

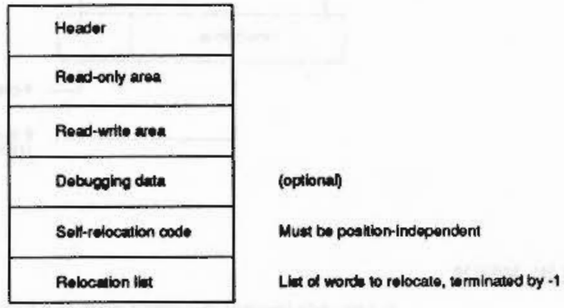
Layout of an AIF image

The layout of an AIF image is as follows:



The header is small, fixed in size, and described below. In a compressed AIF image, the header is NOT compressed.

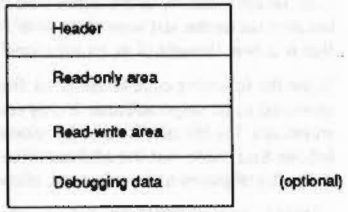
Once an image has been decompressed – or if it is uncompressed in the first place – it has the following layout:



Debugging data are absent unless the image has been linked appropriately and, in the case of source-level debugging, unless the constituent components of the image have been compiled appropriately.

The relocation list is a list of byte offsets from the beginning of the AIF header, of words to be relocated, followed by a word containing -1. The relocation of non-word values is not supported.

After the execution of the self-relocation code – or if the image is not self-relocating – the image has the following layout:



At this stage a debugger is expected to copy the debugging data (if present) somewhere safe, otherwise they will be overwritten by the zero-initialised data and/or the heap/stack data of the program. A debugger can seize control at the appropriate moment by copying, then modifying, the third word of the AIF header (see below).

AIF header layout

BL DecompressedCode	BLNV 0 if the image is not compressed
BL SelfRelocCode	BLNV 0 if the image is not self-relocating
BL ZeroInitCode	BLNV 0 if the image has none
BL ImageEntryPoint	BL to make header addressable via R14
SWI OS_Exit	Just in case silly enough to return
Image ReadOnly size	Includes header size and any padding Exact size - a multiple of 4 bytes
Image ReadWrite size	Exact size - a multiple of 4 bytes
Image Debug size	Exact size - a multiple of 4 bytes
Image zero-init size	Exact size - a multiple of 4 bytes
Image debug type	0,1,2 or 3 (see below)
Image base	Address of the AIF header - set by link a self-moving relocatable image
Work space	Min work space - in bytes - to be reserved by
Four reserved words (0)	
Zero-init code (16 words)	Header is 32 words long

BL is used everywhere to make the header addressable via R14 (but beware the PSR bits) in a position-independent manner and to ensure that the header will be position-independent.

It is required that an image be re-enterable at its first instruction. Therefore, after decompression, the decompression code must reset the first word of the header to BLNV 0. Similarly, following self-relocation, the second word of the header must be reset to BLNV 0. This causes no additional problems with the read-only nature of the code segment – both decompression and relocation code must write to it anyway. So, on systems with memory protection, both the decompression code and the self-relocation code must be bracketed by system calls to change the access status of the read-only section (first to writable, then back to read-only).

The image debug type has the following meaning:

- 0: No debugging data are present.
- 1: Low-level debugging data are present.
- 2: Source level (ASD) debugging data are present.
- 3: 1 and 2 are present together.

All other values are reserved by Acorn.

Zero-initialisation code

The Zero-initialisation code is as follows:

```
    BIC     IP,     LR,     #&FC000003  ; clear status bits -> header + &C
    ADD     IP,     IP,     #8          ; -> Image ReadOnly size
    LDMIA   IP,     {R0,R1,R2,R3}       ; various sizes
    CMPS    R3,     #0
    MOVLES  PC,     LR                  ; nothing to do
    SUB     IP,     IP,     #&14        ; image base
    ADD     IP,     IP,     R0          ; + RO size
    ADD     IP,     IP,     R1          ; + RW size = base of 0-init area
    MOV     R0,     #0
    MOV     R1,     #0
    MOV     R2,     #0
    MOV     R4,     #0
ZeroLoop
    STMIA   IP!,    {R0,R1,R2,R4}
    SUBS    R3,     R3,     #16
    BGT     ZeroLoop
    MOVS    PC,     LR                  ; 16 words in total.
```

Relationship between header sizes and linker pre-defined symbols

```
AIFHeader.ImageBase            = Image$$RO$$Base

AIFHeader.ImageBase +
  AIFHeader.ROSize             = Image$$RW$$Base

AIFHeader.ImageBase +
AIFHeader.ROSize +
  AIFHeader.RWSize             = Image$$ZI$$Base

AIFHeader.ImageBase +
  AIFHeader.ROSize +
    AIFHeader.RWSize +
      AIFHeader.ZeroInitSize   = Image$$RW$$Limit
```

Self relocation

Two kinds of self-relocation are supported by AIF and one by AMF; for completeness, all three are described here.

One-time position independence is supported by relocatable AIF images. Many-time position independence is required for AMF Relocatable Modules. And only AIF images can self-move to a location which leaves a requested amount of workspace.

Why are there three different kinds of self-relocation?

- The rules for constructing RISC OS applications do not forbid acquired position-dependence. Once an application has begun to run, it is not, in general, possible to move it, as it isn't possible to find all the data locations which are being used as position-dependent pointers. So, AIF images can be relocated only once. Afterwards, the relocation table is over-written by the application's zero-initialised data, heap, or stack.
- In contrast, the rules for constructing a RISC OS Relocatable Modules (RM) require that it be prepared to shut itself down, be moved in memory, and start itself up again. Shut-down and start-up are notified to a RM by special service calls to it. Clearly, a RM must be relocatable many times so its relocation table is not overwritten after first use.
- Relocatable Modules are loaded under the control of a Relocatable Module Area (RMA) manager which decides where to load a module initially and where to move each module to whenever the RMA is reorganised. In contrast, an application is loaded at its load address and is then on its own until it exits or faults. An application can only be moved by itself (and then only once, before it begins execution proper).

Self-relocation code for relocatable modules

In this case there is no AIF header, the code must be executable many times, and it must be symbolically addressable from the Relocatable Module header. The code below must be the last area of the RMF image, following the relocation list. Note that it is best thought of as an additional area.

When the following code is executed, the module image has already been loaded at/moved to its target address. It only remains to relocate location-dependent addresses. The list of offsets to be relocated, terminated by (-1), immediately follows End. Note that the address values here (eg |__RelocCode|) will appear in the list of places to be relocated, allowing the code to be re-executed.

```
  IMPORT  |Image$$RO$$Base|          ; where the image is linked at...
  EXPORT  |__RelocCode|              ; referenced from the RM header

|__RelocCode|
  LDR     R1,     RelocCode          ; value of __RelocCode (before relocation)
  SUB     IP,     PC,    #12         ; value of __RelocCode now
  SUBS    R1,     IP,    R1          ; relocation offset
  MOVEQS  PC,     LR                 ; relocate by 0 so nothing to do
  LDR     IP,     ImageBase          ; image base prior to relocation...
  ADD     IP,     IP,    R1          ; ...where the image really is
  ADR     R2,     End
RelocLoop
  LDR     R0,     [R2], #4
  CMNS    R0,     #1                 ; got list terminator?
  MOVLES  PC,     LR                 ; yes => return
  LDR R3, [IP, R0]                   ; word to relocate
  ADD     R3,     R3,    R1          ; relocate it
  STR     R3,     [IP, R0]           ; store it back
  B       RelocLoop                  ; and do the next one
RelocCode DCD     |__RelocCode|
ImageBase DCD     |Image$$RO$$Base|
End                                  ; the list of locations to relocate
                                     ; starts here (each is an offset from the
                                     ; base of the module) and is terminated
                                     ; by -1.
```

Note that this code, and the associated list of locations to relocate, is added automatically to a relocatable module image by Link (as a consequence of using Link with the SetUp option Module enabled).

Self-move and self-relocation code for AIF

This code is added to the end of an AIF image by Link, immediately before the list of relocations (terminated by -1). Note that the code is entered via a BL from the second word of the AIF header so, on entry, R14 points to AIFHeader + 8.

```
RelocCode ROUT
  BIC    IP,    LR,   #&FC000003 ;clear flag bits; -> AIF header + &08
  SUB    IP,    IP,   #8          ; -> header address
  MOV    R0,    #&FB000000        ; BLNV #0
  STR    R0,    [IP,  #4]         ; won't be called again on image re-entry
;does the code need to be moved?
  LDR    R9,    [IP, #&2C]        ; min free space requirement
  CMPS   R9,    #0                ; 0 => no move, just relocate
  BEQ    RelocateOnly
;calculate the amount to move by...
  LDR    R0,    [IP,  #&20]       ; image zero-init size
  ADD    R9,    R9,   R0          ; space to leave = min free + zero init
  SWI    GetEnv                   ; MemLimit -> R1
  ADR    R2,    End               ; -> End
01 LDR   R0,    [R2], #4          ; load relocation offset, increment R2
  CMNS   R0,    #1                ; terminator?
  BNE    %B01                     ; No, so loop again
  SUB    R3,    R1,   R9          ; MemLimit - freeSpace
  SUBS   R0,    R3,   R2          ; amount to move by
  BLE    RelocateOnly             ; not enough space to move...
  BIC    R0,    R0,   #15         ; a multiple of 16...
  ADD    R3,    R2,   R0          ; End + shift
  ADR    R8,    %F01              ; intermediate limit for copy-up
;
; copy everything up memory, in descending address order, branching
; to the copied copy loop as soon as it has been copied.
;
02 LDMDB R2!,   {R4-R7}
  STMDB  R3!,   {R4-R7}
  CMP    R2,    R8                ; copied the copy loop?
  BGT    %B02                     ; not yet
  ADD    R4,    PC,   R0
  MOV    PC,    R4                ; jump to copied copy code
03 LDMDB R2!,   {R4-R7}
  STMDB  R3!,   {R4-R7}
  CMP    R2,    IP                ; copied everything?
  BGT    %B03                     ; not yet
  ADD    IP,    IP,   R0          ; load address of code
  ADD    LR,    LR,   R0          ; relocated return address
RelocateOnly
  LDR    R1,    [IP, #&28]        ; header + &28 = code base set by Link
  SUBS   R1,    IP,   R1          ; relocation offset
  MOVEQ  PC,    LR                ; relocate by 0 so nothing to do
  STR    IP,    [IP,  #&28]       ; new image base = actual load address
  ADR    R2,    End               ; start of reloc list
```



```
RelocLoop
  LDR     R0,    R2],  #4         ; offset of word to relocate
  CMNS    R0,    #1               ; terminator?
  MOVEQS  PC,    LR               ; yes => return
  LDR     R3,    [IP,  R0]        ; word to relocate
  ADD     R3,    R3,   R1         ; relocate it
  STR     R3,    [IP, R0]         ; store it back
  B       RelocLoop               ; and do the next one
  End                             ; The list of offsets of locations to
relocate
                                  ; starts here; terminated by -1.
```

ASD

Acknowledgement: This design is based on work originally done for Acorn Computers by Topexpress Ltd.

This section describes the format of symbolic debugging data generated by ARM compilers and assemblers running under RISC OS and used by the desktop debugger DDT.

For each separate compilation unit (called a *section*) the compiler produces debugging data an a special AREA of the object code (see the section entitled AOF on page 6-351 for an explanation of AREAs and their attributes). Debugging data are position independent, containing only relative references to other debugging data within the same section and relocatable references to other compiler-generated AREAs.

Debugging data AREAs are combined by the linker into a single contiguous section of a program image (see the section entitled AIF on page 6-368 for a description of Application Image Format). Because the debugging section is position-independent, the debugger can move it to a safe location before the image starts executing. If the image is not executed under debugger control the debugging data is simply overwritten.

The format of debugging data allows for a variable amount of detail. This potentially allows the user to trade off among memory used, disc space used, execution time, and debugging detail.

Assembly-language level debugging is also supported, though in this case the debugging tables are generated by the linker, not by language processors. These low-level debugging tables appear in an extra section item, as if generated by an independent compilation. Low-level and high-level debugging are orthogonal facilities, though DDT allows the user to move smoothly between levels if both sets of debugging data are present in an image.

Order of Debugging Data

A debug data AREA consists of a series of *items*. The arrangement of these items mimics the structure of the high-level language program itself.

For each debug AREA, the first item is a section item, giving global information about the compilation, including a code identifying the language and flags indicating the amount of detail included in the debugging tables.

Each data, function, procedure, etc., definition in the source program has a corresponding debug data item and these items appear in an order corresponding to the order of definitions in the source. This means that any nested structure in

the source program is preserved in the debugging data and the debugger can use this structure to make deductions about the scope of various source-level objects. Of course, for procedure definitions, two debug items are needed: a **procedure** item to mark the definition itself and an **endproc** item to mark the end of the procedure's body and the end of any nested definitions. If procedure definitions are nested then the procedure - endproc brackets are also nested. Variable and type definitions made at the outermost level, of course, appear outside of all procedure/endproc items.

Information about the relationship between the executable code and source files is collected together and appears as a **fileinfo** item, which is always the final item in a debugging AREA. Because of the C language's #include facility, the executable code produced from an outer-level source file may be separated into disjoint pieces interspersed with that produced from the included files. Therefore, source files are considered to be collections of 'fragments', each corresponding to a contiguous area of executable code and the fileinfo item is a list with an entry for each file, each in turn containing a list with an entry for each fragment. The fileinfo field in the section item addresses the fileinfo item itself. In each procedure item there is a 'file entry' field which refers to the file-list entry for the source file containing the procedure's start; there is a separate one in the endproc item because it may possibly not be in the same source file.

Representation of Data Types

Several of the debugging data items (eg procedure and variable) have a **type** word field to identify their data type. This field contains, in the most significant 3 bytes, a code to identify a base type and, in the least significant byte, a pointer count: 0 to denote the type itself; 1 to denote a pointer to the type; 2 to denote a pointer to a pointer to...; etc.

For simple types the code is a positive integer as follows:

void	0	(all codes are decimal)
signed integers		
single byte	10	
half-word	11	
word	12	
unsigned integers		
single byte	20	
half-word	21	
word	22	

floating point

float	30
double	31
long double	32

complex

single complex	41
double complex	42

functions

function	100

For compound types (arrays, structures, etc.) there is a special kind of debug data item (**array**, **struct**, etc.) to give details of the type such as array bounds and field types. The type code for such types is negative being the negation of the (byte) offset of the special item from the start of the debugging AREA.

If a type has been given a name in a source program, it will give rise to a **type** debugging data item which contains the name and a type word as defined above. If necessary, there will also be a debugging data item such as an array or struct to define the type itself. In that case, the type word will refer to this item.

Enumerated types in C and scalars in Pascal are treated simply as integer sub-ranges of an appropriate size, the name information is not available in the this version of the debugging format. Set types in Pascal are not treated in detail: the only information recorder for them is the total size occupied by the object in bytes.

Fortran character types are supported by a special kind of debugging data item the format of which is yet to be defined.

Representation of Source File Positions

Several of the debugging data items have a **sourcepos** field to identify a position in the source file. This field contains a line number and character position within the line packed into a single word. The most significant 10 bits encode the character offset (0-based) from the start of the line and the least- significant 22 bits give the line number.

Debugging Data Items in Detail

The first word of each debugging data item contains the byte length of the item (encoded in the most significant 16 bits) and a code identifying the kind of item (in the least significant 16 bits). The following codes are defined:-

1	section
2	procedure
3	endproc
4	variable
5	type
6	struct
7	array
8	subrange
9	set
10	fileinfo

The meaning of the second and subsequent words of each item is defined below.

Where items include a string field, the string is packed into successive bytes beginning with a length byte, and padded at the end to a word boundary (the padding value is immaterial, but NUL or ' ' is preferred). The length of a string is in the range [0 - 255] bytes.

Where an item contains a field giving an offset in the debugging data area (usually to address another item), this means a byte offset from the start of the debugging data for the whole section (in other words, from the start of the section item).

Section

A section item is the first item of each section of the debugging data.

language:8	one byte code identifying the source language
debuglines:1	$1 \Rightarrow$ tables contain line numbers
debugvars:1	$1 \Rightarrow$ tables contain data about local variables
spare:14	
debugversion:8	one byte version number of the debugging data
codeaddr	pointer to start of executable code in this section
dataaddr	pointer to start of static data for this section
codesize	byte size of executable code in this section
datasize	byte size of the static data in this section
fileinfo	offset in the debugging data of the file information for this section (or 0 if no fileinfo is present)
debugsize	total byte length of debugging data for this section
name or nsyms	string or integer

The name field contains the program name for Pascal and Fortran programs. For C programs it contains a name derived by the compiler from the main file name (notionally a module name). Its syntax is similar to that for a variable name in the source language. For a low-level debugging section (language = 0) the field is treated as a 4 byte integer giving the number of symbols following.

The following language byte codes are defined:-

0	Low-level debugging data (notionally, assembler)
1	C
2	Pascal
3	Fortran77
other	reserved to Acorn.

The fileinfo field is 0 if no source file information is present.

The debugversion field was defined to be 1; the new debugversion for the extended debugging data format (encompassing low-level debugging data) is 2. For low-level debugging data, other fields have the following values:-

language	0
codeaddr	Image$$RO$$Base
dataaddr	Image$$RW$$Base
codesize	Image$$RO$$Limit - Image$$RO$$Base
datasize	Image$$RW$$Limit - Image$$RW$$Base
fileinfo	0
nsyms	number of symbols within the following debugging data
debugsize	total size of the low-level debugging data including the size of the section item

The section item is immediately followed by nsyms symbols, each having the following format:-

stridx:24	byte offset in string table of symbol name
flags:8	(see below)
value	the value of the symbol

The flags field has the following values:-

0/1	the symbol is a local/global symbol
+	(there may be many local symbols with the same name)
0/2/4/6	symbol names an absolute/code/data/zero-init value

Note that the linker reduces all symbol values to absolute values. The flags field records the history, or origin, of the symbol in the image.

The string table is in standard AOF format. It consists of a length word followed by the strings themselves, each terminated by a NUL (0). The length word includes the length of the length word, so no offset into the string table is less than 4. The end of the string table is padded to the next word boundary.

Procedure

A procedure item appears once for each procedure or function definition in the source program. Any definitions with the procedure have their related debugging data items between the procedure item and the matching endproc item. The format of procedure items is as follows:-

type	the return type if this is a function, else 0
args	the number of arguments
sourcepos	a word encoding the source position of the start of the procedure
startaddr	pointer to the first instruction of the procedure
bodyaddr	pointer to the first instruction of the procedure body (see below)
endproc	offset of the related endproc item
fileentry	offset of the file list entry for the source file
name	string

The bodyaddr field points to the first instruction after the procedure entry sequence, that is the first address at which a high-level breakpoint could sensibly be set. The startaddr field points to the beginning of the entry sequence, that is the address at which control actually arrives when the procedure is called.

A label in a source program is represented by a special procedure item with no matching endproc (the endproc field is 0 to denote this). Pascal and Fortran numerical labels are converted by the compiler into strings prefixed by '$n'.

For Fortran77, multiple entry points to the same procedure each give rise to a separate procedure item but they all have the same endproc offset referring to a single endproc item.

Endproc

This item marks the end of the debugging data items belonging to a particular procedure. It also contains information relating to the procedure's return. Its format is as follows:-

sourcepos	a word encoding the position in the source file of the end of the procedure
endaddr	a pointer to the code byte AFTER the compiled code for the procedure
filentry	offset of the file list entry for the procedure's end
nreturns	number of procedure return points (may be 0)
retaddrs...	pointers to the procedure-return code

If the procedure body is an infinite loop, there will be no return point so nreturns will be 0. Otherwise the retaddrs should each point to a suitable location at which a breakpoint may be set 'at the exit of the procedure'. When execution reaches this point, the current stack frame should still be in this procedure.

Variable

This item contains debugging data relating to a source program variable or a formal argument to a procedure (the first variable items in a procedure always describe its arguments). Its format is as follows:-

type	a type word
sourcepos	a word encoding the source position of the variable
class	a word encoding the variable's storage class
location	see explanation below
name	string

The following codes define the storage classes of variables:-

1	external variables (or Fortran common)
2	static variables private to one section
3	automatic variables
4	register variables
5	Pascal `var` arguments
6	Fortran arguments
7	Fortran character arguments

The meaning of the location field of a variable item depends on the storage class: it contains an absolute address for static and external variables (relocated by the linker); a stack offset (ie an offset from the frame- pointer) for automatic and var-type arguments; an offset into the argument list for Fortran arguments; and a register number for register variables (the 8 floating point registers are numbered 16 - 23).

No account is taken of variables which ought to be addressed by +ve offsets from the stack-pointer rather than -ve offsets from the frame-pointer.

The sourcepos field is used by the debugger to distinguish between different definitions having the same name (eg identically named variables in disjoint source-level naming scopes such as nested block in C).

Type

This item is used to describe a named type in the source language (eg a typedef in C). The format is as follows:-

type	a type word (described earlier)
name	string

Struct

This item is used to describe a structured data type (eg a struct in C or a record in Pascal). Its format is as follows:-

fields	the number of fields in the structure
size	total byte size of the structure
fieldtable...	a table of fields entries in the following format:-
offset	byte offset of this field within the structure
type	a type word (interpretation as described earlier)
name	string

Union types are described by struct items in which all fields have 0 offsets.

C bit fields are not treated in full detail: a bit field is simply represented by an integer starting on the appropriate word boundary (so that the word contains the whole field).

Array

This item is used to describe a one-dimensional array. Multi-dimensional arrays are described as arrays of arrays. Which dimension comes first is dependent on the source language (different for C and Fortran). The format is as follows:-

size	total byte size of each element
arrayflags	(see below)
basetype	a type word
lowerbound	constant value or stack offset of variable
upperbound	constant value or stack offset of variable

If the size field is zero, debugger operations affecting the whole array, rather than individual elements of it, are forbidden.

The following bit numbers in the arrayflags field are defined:-

0	lower bound is undefined
1	lower bound is a constant
2	upper bound is undefined
3	upper bound is a constant

If a bound is defined and not constant then it is an integer variable on the stack and the boundvalue field contains the stack offset of the variable (from the frame-pointer).

Subrange

This item is used to describe subrange typed in Pascal. It also serves to describe enumerated types in C and scalars in Pascal (in which case the base type is understood to be an unsigned integer of appropriate size). Its format is as follows:-

size	half-word: 1, 2, or 4 to indicate byte size of object
typecode	half-word: simple type code
lwb	lower bound of subrange
upb	upper bound of subrange

Set

This item is used to describe a Pascal set type. Currently, the description is only partial. The format is:-

size	byte size of the object

Fileinfo

This item appears once per section after all other debugging data items. The half of the header word which would usually give the item length is not required and should be set to 0.

Each source file is described by a sequence of 'fragments', each of which describes a contiguous region of the file within which the addresses of compiled code increase monatonically with source-file position. The order in which fragments appear in the sequence is not necessarily related to the source file positions to which they refer.

Note that for compilations that make no use of the #include facility, the list of fragments will have only one entry and all line-number information will be contiguous.

The item is a list of entries each with the following format:-

length	length of this entry in bytes (0 marks the final entry)
date	date and time when the file was last modified
filename	string (or null if the name is not known)
n	number of fragments following
fragments...	n fragments with the following structure...

fragmentsize	length of this entry in bytes
firstline	linenumber
lastline	linenumber
codeaddr	pointer to the start of the fragment's executable code
codesize	byte size of the code in the fragment
lineinfo...	a variable number of line number data

There is one lineinfo half-word for each statement of the source file fragment which gives rise to executable code. Exactly what constitutes an executable statement may be defined by the language implementation; the definition may for instance include some declarations. The half-word can be regarded as 2 bytes: the first contains the number of bytes of code generated from the statement and cannot be zero; the second contains the number of source lines occupied by the statement (ie the difference between the line number of the start of the statement and the line number of the next statement). This may be zero if there are multiple statements on the same source line.

If the whole half-word is zero, this indicates that one of the quantities is too large to fit into a byte and that the following 2 half-words contain (in order) the number of lines followed by the number of bytes of code generated from the statement.

82 Appendix E: File formats

Introduction

The file formats described in this appendix are those generated by RISC OS itself and various applications. Each is shown as a chart giving the size and description of each element. The elements are sequential and the sizes are in bytes.

This appendix contains information about the following file formats:

- Sprite files
- Template files
- Draw files
- Font files, including IntMetrics and font files
- Music files

Sprite files

A sprite file is saved in the same format as a sprite area is in memory, except that the first word of the sprite area is not saved.

For a full description of sprite area formats, refer to the section entitled *Format of a sprite area* on page 2-258.

Template files

The following section describes the Wimp template file format:

Header

The file starts with a header:

Size	Description
4	file offset of font data (–1 if none)
4	reserved (must be zero)
4	reserved (must be zero)
4	reserved (must be zero)

Index entries

The header is followed by a series of index entries to data later in the file:

Size	Description
4	file offset of data for this entry
4	size of data for this entry
4	entry type (1 = window)
12	identifier (terminated by ASCII 13)

Terminator

The index entries are terminated by a null word:

Size	Description
4	0

Data

Each set of entries referred to earlier in the index contains the following:

Size	Description
88	window definition (as in Wimp_CreateWindow – see page 4-159)
$ni \times 32$	icon definitions
?	indirected icon data

Any pointers to indirected icon data are the file offsets. Any references to anti-aliased fonts use internal handles.

Font data

The file ends with an optional set of font data (the presence of which is indicated by the first word of the header):

Size	Description
4	x-point-size × 16
4	y-point-size × 16
40	font name (terminated by ASCII 13)

The first font entry is that referred to by internal handle 1, the second font entry is that referred to by internal handle 2, etc.

Draw files

The Draw file format provides an object-oriented description of a graphic image. It represents an object in its editable form, unlike a page-description language such as PostScript which simply describes an image.

Programmers wishing to define their own object types should contact Acorn; see *Appendix H: Registering names* on page 6-473.

Coordinates

All coordinates within a Draw file are signed 32-bit integers that give absolute positions on a large image plane. The units are 1/(180 × 256) inches, or 1/640 of a printer's point. When plotting on a standard RISC OS screen, an assumption is made that one OS-unit on the screen is 1/180 of an inch. This gives an image reaching over half a mile in each direction from the origin. The actual image size (eg the page format) is not defined by the file, though the maximum extent of the objects defined is quite easy to calculate. Positive-x is to the right, Positive-y is up. The printed page conventionally has the origin at its bottom left hand corner. When rendering the image on a raster device, the origin is at the bottom left hand corner of a device pixel.

Colours

Colours are specified in Draw files as absolute RGB values in a 32-bit word. The format is:

Byte	Description
0	reserved (must be zero)
1	unsigned red value
2	unsigned green value
3	unsigned blue value

For colour values, 0 means none of that colour and 255 means fully saturated in that colour.

You must always write byte 0 (the reserved one) as 0, but don't assume that it always will be 0 when reading.

The bytes in a word of an Draw file are in little-endian order, eg the least significant byte appears first in the file.

The special value &FFFFFFFF is used in the filling of areas and outlines to mean 'transparent'.

File headers

The file consists of a header, followed by a sequence of objects.

The file header is of the following form.

Size	Description	
4	'Draw'	
4	major format version stamp – currently 201 (decimal)	
4	minor format version stamp – currently 0	
12	identity of the program that produced this file – typically 8 ASCII characters, padded with spaces	
4	x-low	bounding box
4	y-low	bottom-left (x-low, y-low) is inclusive
4	x-high	top-right (x-high, y-high) is exclusive
4	y-high	

When rendering a Draw file, check the major version number. If this is greater than the latest version you recognise then refuse to render the file (eg generate an error message for the user), as an incompatible change in the format has occurred.

The entire file is rendered by rendering the objects one by one, as they appear in the file.

The bounding box indicates the intended image size for this drawing.

A Draw file containing a file header but no objects is legal; however, the bounding box is undefined. In particular the 'x-low' value may be greater than the 'x-high' value (and similarly for the y values).

Objects

Each object consists of an object header, followed by a variable amount of data depending on the object type.

Object header

The object header is of the following form:

Size	Description	
4	object type field	
4	object size: number of bytes in the object – always a multiple of 4	
4	x-low	object bounding box
4	y-low	bottom-left (x-low, y-low) is inclusive
4	x-high	top-right (x-high, y-high) is exclusive
4	y-high	

The bounding box describes the maximum extent of the rendition of the object: the object cannot affect the appearance of the display outside this rectangle. The upper coordinates are an outer bound, in that the device pixel at (x-low, y-low) may be affected by the object, but the one at (x-high, y-high) may not be. The rendition procedure may use clipping on these rectangles to abandon obviously invisible objects.

Objects with no direct effect on the rendition of the file have no bounding box (hence the header is only two words long). Such objects will be identified explicitly in the object descriptions that follow. If an unidentified object type field is encountered when rendering a file, ignore the object and continue.

The rest of the data for an object depends on the object type.

Font table object

Object type number 0

A font table object has no bounding box in its object header, which is followed by a sequence of font number definitions:

Size	Description
1	font number (non-zero)
n	n character textual font name, null terminated
0 - 3	up to 3 zero characters, to pad to a word boundary

This object type is somewhat special in that only one instance of it ever appears in a Draw file. It has no direct effect on the appearance of the image, but maps font numbers (used in text objects) to textual names of fonts. It must precede all text objects. Comparison of font names is case-insensitive.

Text object

Object type number 1

Size	Description
4	text colour
4	text background colour hint
4	text style
4	x unsigned nominal size of the font (in 1/640 point)
4	y unsigned nominal size of the font (in 1/640 point)
8	x, y coordinates of the start of the text base line
n	*n* characters in the string, null terminated
0 - 3	up to 3 zero characters, to pad to a word boundary

The character string consists of printing ANSI characters with codes within 32 - 126 or 128 - 255. This need not be checked during rendering, but other codes may produce undefined or system-dependent results.

The text style word consists of the following:

Bit(s)	Description
0 - 7	one byte font number
8 - 31	reserved (must be zero)

Italic, bold variants etc are assumed to be distinct fonts.

The font number is related to the textual name of a font by a preceding font table object within the file (see above). The exception to this is font number 0, which is a system font that is sure to be present. When rendering a Draw file, if a font is not recognised, the system font should be used instead. The system font is monospaced, with the gap between letters equal to the x nominal size of the font.

The background colour hint can be used by font rendition code when performing anti-aliasing. It is referred to as a hint because it has no effect on the rendition of the object on a 'perfect' printer; nevertheless for screen rendition it can improve the appearance of text on coloured backgrounds. The font rendition code can assume that the text appears on a background that matches the background colour hint.

Path object

Object type number 2

Size	Description
4	fill colour (−1 ⇒ do not fill)
4	outline colour (−1 ⇒ no outline)
4	outline width (unsigned)
4	path style description
?	optional dash pattern definition
?	sequence of path components

An outline width of 0 means draw the thinnest possible outline that the device can represent. A path component consists of:

Size	Description
4	1-word *tag identifier*: bits 0 - 7 = tag identifier byte: 0 ⇒ end of path: no arguments 2 ⇒ move to absolute position: followed by one x, y pair 5 ⇒ close current sub-path: no arguments 8 ⇒ draw to absolute position: followed by one x, y pair 6 ⇒ Bezier curve through two control points, to absolute position: followed by three x, y pairs bits 8 - 31 reserved (must be zero)
$n \times 8$	sequence of *n* 2-word (x, y) coordinate pairs (where *n* is zero, one or three, as determined by the value of the *tag identifier*)

The tag values match the arguments required by the Draw module. This block of memory can be passed directly to the Draw module for rendition; see the chapter entitled *Draw module* on page 5-111 for precise rules concerning the appearance of paths. See also manuals on PostScript. (Reference: *PostScript Language Reference Manual*. Adobe Systems Incorporated (1990) 2nd ed. Addison-Wesley, Reading, Mass, USA).

The possible set of legal path components in a path object is described as follows. A path consists of a sequence of (at least one) subpaths, followed by an 'end of path' path component. A subpath consists of a 'move to' path component, followed by a sequence of (at least one) 'draw to' and 'Bezier to' path components, followed (optionally) by a 'close sub-path' path component.

The path style description word is as follows:

Bit(s)	Description
0 - 1	join style: 0 = mitred joins 1 = round joins 2 = bevelled joins
2 - 3	end cap style: 0 = butt caps 1 = round caps 2 = projecting square caps 3 = triangular caps
4 - 5	start cap style (same possible values as end cap style)
6	winding rule: 0 = non-zero 1 = even-odd
7	dash pattern: 0 = dash pattern missing 1 = dash pattern present
8 - 15	reserved (must be zero)
16 - 23	triangle cap width: a value within 0 - 255, measured in sixteenths of the line width
24 - 31	triangle cap length: a value within 0 - 255, measured in sixteenths of the line width

The mitre cut-off value is the PostScript default (eg 10). If the dash pattern is present then it is in the following format:

Size	Description
4	offset distance into the dash pattern to start
4	number of elements in the dash pattern

followed by, for each element of the dash pattern:

Size	Description
4	length of the dash pattern element

The dash pattern is reused cyclically along the length of the path, with the first element being filled, the next a gap, and so on.

Sprite object

Object type number 5

This is followed by a sprite. See the section entitled *Format of a sprite* on page 2-258 for details.

This contains a pixelmap image. The image is scaled to entirely fill the bounding box.

If the sprite has a palette then this gives absolute values for the various possible pixels. If the sprite has no palette then colours are defined locally. Within RISC OS the available 'Wimp colours' are used – for further details see the chapter entitled *Sprites* on page 2-247 and the chapter entitled *The Window Manager* on page 4-83.

Group object

Object type number 6

Size	Description
12	group object name, padded with spaces

This is followed by a sequence of other objects.

The objects contained within the group will have rectangles contained entirely within the rectangle of the group. Nested grouped objects are allowed.

The object name has no effect on the rendition of the object. It should consist entirely of printing characters. It may have meaning to specific editors or programs. It should be preserved when copying objects. If no name is intended, twelve space characters should be used.

Tagged object

Object type number 7

Size	Description
4	tag identifier

This is followed by an object and optional word-aligned data.

To render a Tagged object, simply render the enclosed object. The identifier and additional data have no effect on the rendition of the object. This allows specific programs to attach meaning to certain objects, while keeping the image renderable.

Programmers wishing to define their own object tags should contact Acorn; see *Appendix H: Registering names* on page 6-473.

Text area object

Object type number 9

Size	Description
?	1 or more text column objects (object type 10, no data – see below)
4	zero, to mark the end of the text columns
4	reserved (must be zero)
4	reserved (must be zero)
4	initial text foreground colour
4	initial text background colour hint
?	the body of the text column (ASCII characters, terminated by a null character)
0 - 3	up to 3 zero characters, to pad to a word boundary

A text area contains a number of text columns. The text area has a body of text associated with it, which is partitioned between the columns. If there is just one text column object then its bounding box must be exactly coincident with that of the text area.

The body of the text is paginated in the columns. Effects such as font settings and colour changes are controlled by escape sequences within the body of the text. All escape sequences start with a backslash character (\); the escape code is case sensitive, though any arguments it has are not.

Arguments of variable length are terminated by a '/' or <newline>. Arguments of fixed length are terminated by an optional '/'.

Values with range limits mean that if a value falls outside the range, then the value is truncated to this limit.

Escape sequence **Description**

- \! <version><newline or />
  Must appear at the start of the text, and only there. <version> must be 1.
- \A<code><optional />
  Set alignment. <code> is one of L (left = default), R (right), C (centre), D (double). A change in alignment forces a line break.
- \B<R><spaces><G><spaces><B><newline or />
  Set text background colour hint to the given RGB intensity (or the best available approximation). Each value is limited to 0 - 255.

- \C<R><spaces><G><spaces><B><newline or />
  Set text foreground colour to the given RGB intensity (or the best available approximation). Each value is limited to 0 - 255.
- \D<number><newline or />
  Indicates that the text area is to contain <number> columns. Must appear before any printing text.
- \F<digit*><name><spaces><size>[<spaces><width>]<newline or />
  Defines a font reference number. <name> is the name of the font, and <size> its height. <width> may be omitted, in which case the font width and height are the same. Font reference numbers may be reassigned. <digit*> is one or two digits. <size> and <width> are in points.
- \<digit*><optional />
  Selects a font, using the font reference number
- \L<leading><newline or />
  Define the leading in points from the end of the (output) line in which the \L appears – ie the vertical separation between the bases of characters on separate lines. Default, 10 points.
- \M<leftmargin><spaces><rightmargin><newline or />
  Defines margins that will be left on either size of the text, from the start of the output line in which the sequence appears. The margins are given in points, and are limited to values > 0. If the sum of the margins is greater than the width of the column, the effects are undefined. Both values default to 1 point.
- \P<leading><newline or />
  Define the paragraph leading in points, ie the vertical separation between the end of one paragraph and the beginning of a new paragraph. Default, 10 points.
- \U<position><spaces><thickness><newline or />
  Switch on underlining, at <position> units relative to the character base, and of <thickness> units, where a unit is 1/256 of the current font size. <position> is limited to –128...+127, and <thickness> to 0...255. To turn the underlining off, either give a thickness of 0, or use the command '\U.'
- \V[–]<digit><optional />
  Vertical move by the specified number of points.

- \- Soft hyphen: if a line cannot be split at a space, a hyphen may be inserted at this point instead; otherwise, it has no printing effect.
- \<newline> Force line break.
- \\ appears as \ on the screen
- \;<text><newline> Comment: ignored.

Other escape sequences are flagged as errors during verification.

Lines within a paragraph are split either at a space, or at a soft hyphen, or (if a single word is longer than a line) at any character.

A few other characters have a special interpretation:

- Control characters are ignored, except for tab, which is replaced by a space.
- Newlines (that are not part of an escape sequence) are interpreted as follows:

  Occurring before any printing text: a paragraph leading is inserted for each newline.

  In the body of the text: a single newline is replaced by a space, except when it is already followed or preceded by a space or tab. A sequence of n newlines inserts a space of (n–1) times the paragraph leading, except that paragraph leading at the top of a new text column is ignored.

Lines which protrude beyond the limits of the box vertically, eg because the leading is too small, are not displayed; however, any font changes, colour changes, etc. in the text are applied. Characters should not protrude horizontally beyond the limits of the text column, eg due to italic overhang for this font being greater than the margin setting.

Restrictions

If a chunk of text contains more than 16 colour change sequences, only the last 16 will be rendered correctly. This is a consequence of the size of the colour cache used within the font manager. A chunk in this case means a block of text up to anything that forces a line break, eg the end of a paragraph or a change on the alignment.

Text column object

Object type number 10

No further data, ie just an object header.

A text column object may only occur within a text area object. Its use is described in the section on text area objects.

Options object

Object type number 11

The object header for an options object has space allocated for a bounding box, but since one would be meaningless, the space is unused. You must treat the 4 words normally used for the bounding box as reserved, and set them to zero.

Size	Description
4	(paper size + 1) × &100 (ie &500 for A4)
4	paper limits options: bit 0 set ⇒ paper limits shown bits 1 - 3 reserved (must be zero) bit 4 set ⇒ landscape orientation (else portrait) bits 5 - 7 reserved (must be zero) bit 8 set ⇒ printer limits are default bits 9 - 31 reserved (must be zero)
8	grid spacing (floating point)
4	grid division
4	grid type (zero ⇒ rectangular, non-zero ⇒ isometric)
4	grid auto-adjustment (zero ⇒ off, non-zero ⇒ on)
4	grid shown (zero ⇒ no, non-zero ⇒ yes)
4	grid locking (zero ⇒ off, non-zero ⇒ on)
4	grid units (zero ⇒ inches, non-zero ⇒ centimetres)
4	zoom multiplier (1 - 8)
4	zoom divider (1 - 8)
4	zoom locking (zero ⇒ none, non-zero ⇒ locked to powers of two)
4	toolbox presence (zero ⇒ no, non-zero ⇒ yes)
4	initial entry mode: one of bit 0 set ⇒ line bit 1 set ⇒ closed line bit 2 set ⇒ curve bit 3 set ⇒ closed curve bit 4 set ⇒ rectangle bit 5 set ⇒ ellipse bit 6 set ⇒ text line bit 7 set ⇒ select
4	undo buffer size, in bytes

When Draw reads a draw file, only the first options object is taken into account – any others are discarded. When it saves a diagram to file, the options in force for that diagram are saved with it.

The Draw application supplied with RISC OS 2.0 does not use this object type.

Transformed text object

Object type number 12

Size	Description
24	transformation matrix
4	font flags: bit 0 set ⇒ text should be kerned bit 1 set ⇒ text written from right to left bits 2 - 31 reserved (must be zero)
4	text colour
4	text background colour hint
4	text style
4	x unsigned nominal size of the font (in 1/640 point)
4	y unsigned nominal size of the font (in 1/640 point)
8	x, y coordinates of the start of the text base line
n	*n* characters in the string, null terminated
0 - 3	up to 3 zero characters, to pad to a word boundary

The transformation matrix is as described in Font_Paint (see page 5-24), in the same format used elsewhere in the Draw module.

The remaining fields are exactly as specified for Text objects (see page 6-394).

Transformed sprite object

Object type number 13

Size	Description
24	Transformation matrix

This is followed by a sprite. See the section entitled *Format of a sprite* on page 2-258 for details.

This contains a pixelmap image. The image is transformed from its own coordinates (ie the bottom-left at (0, 0) and the top-right at (w × x_eig, h × y_eig), where (w, h) are the width and height of the sprite in pixels, and (x_eig, y_eig) are the eigen factors for the mode in which it was defined) by the transformation held in the matrix.

If the sprite has a palette then this gives absolute values for the various possible pixels. If the sprite has no palette then colours are defined locally. Within RISC OS the available 'Wimp colours' are used – for further details see the chapter entitled *Sprites* on page 2-247 and the chapter entitled *The Window Manager* on page 4-83.

Font files

In all the formats described below, 2-byte quantities are little-endian: that is, the least significant byte comes first, followed by the most-significant. The values are unsigned unless otherwise stated.

Fonts are described in:

- IntMetrics and IntMet*n* files
- x90y45 files (old style 4-bpp bitmaps)
- New font file formats.

IntMetrics / IntMet*n* files

Header

Size	Description
40	name of font, padded with Return characters
4	16
4	16
1	*nlo* = low byte of number of defined characters
1	*version number* of file format: 0 *flags* and *nhi* must be zero 1 **not supported** 2 *flags* supported; *nchars* can be > 255
1	*flags*: bit 0 set ⇒ there is no bbox data (use Outlines) bit 1 set ⇒ there is no x-offset data bit 2 set ⇒ there is no y-offset data bit 3 set ⇒ there is no more data after the metrics bit 4 reserved (must be zero) bit 5 set ⇒ character map size precedes map bit 6 set ⇒ kern characters are 16-bit, else 8-bit bit 7 reserved (must be zero)
1	*nhi* = high byte of number of defined characters $n = nhi \times 256 + nlo$

If *flags* bit 5 is set:

Size	Description
2	*m* = character map size 0 ⇒ no map

Character mapping

Size	Description
m	character mapping (ie indices into following tables) For example, if the 40th byte in this mapping has the value 4, then the fourth entry in each of the following arrays refers to character 40. A zero entry means that character is not defined in this font. If *flags* bit 5 is clear, 256 characters are mapped (ie *m* = 256).

If there is no map (see above), the character code is used to index into the tables.

Note that since the mapping table is 8-bit, there cannot be one if $n > 256$.

Table of bounding boxes

If *flags* bit 0 is clear:

Size		Description
2*n*	x0	bounding box for each character (16-bit signed)
2*n*	y0	bottom-left (x0, y0) is inclusive
2*n*	x1	top-right (x1, y1) is exclusive
2*n*	y1	coordinates are in 1/1000th em

Coordinates are relative to the 'origin point'.

Tables of character widths

If *flags* bit 1 is clear:

Size	Description
2*n*	x-offset after printing each character, in 1/1000th em (16-bit signed)

If *flags* bit 2 is clear:

Size	Description
2*n*	y-offset after printing each character, in 1/1000th em (16-bit signed)

To calculate the offset to here, let:

nlo = byte at offset 48 in file
nhi = byte at offset 51 in file
flags = byte at offset 49 in file
$n = nhi \times 256 + nlo$

Then:

offset = 52
if (*flags* bit 5 clear) then offset += 256
else offset += 2 + byte(52) + 256 × byte(53)
if (*flags* bit 0 clear) then offset += 8*n*
if (*flags* bit 1 clear) then offset += 2*n*
if (*flags* bit 2 clear) then offset += 2*n*

Offsets to extra data areas

If *flags* bit 3 is set:

Size	Description
2	offset to 'miscellaneous' data area
2	offset to kern pair data area
2	offset to reserved data area #1
2	offset to reserved data area #2

The entries must be consecutive in the file, so the end of one area coincides with the beginning of the next. The areas are not necessarily word-aligned, and the space at the end of each area is reserved (ie there must not be any 'dead' space at the end of an area).

Miscellaneous data area

Size	Description
2	x0 — maximum bounding box for font (16-bit signed)
2	y0 — bottom-left (x0, y0) is inclusive
2	x1 — top-right (x1, y1) is exclusive
2	y1 — all coordinates are in 1/1000ths em
2	default x-offset per char (if *flags* bit 1 is set), in 1/1000th em (16-bit signed)
2	default y-offset per char (if *flags* bit 2 is set), in 1/1000th em (16-bit signed)
2	italic h-offset per em (–1000 × TAN (italic angle)) (16-bit signed)
1	underline position, in 1/256th em (signed)
1	underline thickness, in 1/256th em (unsigned)
2	CapHeight in 1/1000th em (16-bit signed)
2	XHeight in 1/1000th em (16-bit signed)
2	Descender in 1/1000th em (16-bit signed)
2	Ascender in 1/1000th em (16-bit signed)
4	reserved (must be zero)

Kern pair data

If *flags* bit 6 is clear, character codes are 8-bit; if *flags* bit 6 is set, character codes are 16-bit (lo, hi).

Size	Description		
1 or 2	left-hand character code		repeat
1 or 2	right-hand character code	repeat	
2	x-kern amount (if *flags* bit 1 is clear) in 1/1000ths em (16-bit signed)		
2	y-kern amount (if *flags* bit 2 is clear) in 1/1000ths em (16-bit signed)		
1 or 2	0 ⇒ end of list for this letter		
1 or 2	0 ⇒ end of kern pair data		

Reserved data area #1 and #2

These must be null.

x90y45 font files

If the length of a x90y45 file is less than 256 bytes, then the contents are the name of the f9999x9999 file to use as master bit maps.

Index entries

Each font file starts with a series of 4-word (ie 16 byte) index entries, corresponding to the sizes defined:

Size	Description
1	point size, **not** multiplied by 16
1	bits per pixel (4)
1	pixels per inch in the x-direction
1	pixels per inch in the y-direction
4	reserved (must be zero)
4	offset of pixel data in file
4	size of pixel data

The list is terminated by:

1	0

Pixel data

Pixel data is limited to 64KBytes per block. Each block starts word-aligned relative to the start of the file:

Size	Description	
4	x-size, in 1/16ths point × x pixels per inch	
4	y-size, in 1/16ths point × y pixels per inch	
4	pixels per inch in the x-direction	
4	pixels per inch in the y-direction	
1	x0	maximum bounding box for font
1	y0	bottom-left (x0, y0) is inclusive
1	x1	top-right (x1, y1) is exclusive
1	y1	all coordinates are in pixels
512	2-byte offsets from table start of character data. A zero value means the character is not defined.	

Character data

Size	Description	
1	x0	bounding box for character
1	y0	bottom-left (x0, y0) is inclusive
1	x1 – x0 = X	top-right (x1, y1) is exclusive
1	y1 – y0 = Y	all coordinates are in pixels
X × Y / 2	4-bits per pixel (bpp), consecutive rows bottom to top: not aligned until the end	
0 - 3.5	alignment	

New font file formats

The new font file formats includes definitions for the following types of font files:

- f9999x9999 (new style 4-bpp anti-aliased fonts)
- b9999x9999 (1-bpp bitmaps)
- Outlines (outline font format, for all sizes)

'9999' = pixel size (ie point size × 16 × dpi / 72) zero-suppressed decimal number.

If the length of an outlines file is less than 256 bytes, then the contents are the name of another font whose glyphs are to be used instead (with this font's metrics).

File header

The file header is of the following form:

Size	Description
4	'FONT' – identification word
1	*bpp* (bits per pixel): 0 ⇒ outlines 1 = 1 bpp 4 = 4 bpp
1	*version number* of file format (changes are cumulative): 4 no 'don't draw skeleton lines unless smaller than this' byte present 5 byte at [table+512] = maximum pixel size for skeleton lines (see below) 6 byte at [chunk + indexsize] = dependency mask (see below) 7 flag word precedes index in chunk (offsets are relative to index, not chunk) 8 file offset array is in a different place
2	If *bpp* = 0: design size of font If *bpp* > 0: flags: bit 0 set ⇒ horizontal subpixel placement bit 1 set ⇒ vertical subpixel placement bits 2-5 reserved (must be zero) bit 6 set ⇒ flag word precedes index in chunk (must be set if *version number* ≥ 7, else clear). bit 7 reserved (must be zero) Outline files derive the value of bit 6 from *version number*.
2	x0 — maximum bounding box for font (16-bit signed)
2	y0 — bottom-left (x0, y0) is inclusive
2	x1 – x0 — top-right (x1, y1) is exclusive
2	y1 – y0 — all coordinates are in pixels or design units

If *version number* < 8, the number of chunks *nchunks* = 8, and these bytes end the header:

Size	Description
4	file offset of 0…31 chunk (word-aligned)
4	file offset of 32…63 chunk (word-aligned)
20	file offsets of further chunks, in order (word-aligned)
4	file offset of 224…255 chunk (word-aligned)
4	file offset of end (ie size of file)
	If offset(*n*+1)=offset(*n*), then chunk *n* is null.

If version number ≥ 8, these bytes end the header:

Size	Description
4	file offset of area containing file offsets of chunks
4	*nchunks* = number of defined chunks
4	*ns* = number of scaffold index entries (including entry[0] = size)
4	*scaffold flags*: bit 0 set ⇒ all scaffold base chars are 16-bit bit 1 set ⇒ these outlines should not be anti-aliased (eg System.Fixed) bits 2 - 31 reserved (must be zero)
4 × 5	all reserved (must be zero)

Table start

Size	Description
2	*n* = size of table/scaffold data

Table data

Bitmaps

If *bpp* > 0, the file defines a bitmap, and only the following 8 bytes of table data are used. For such a file, *n*= 10 – other values are reserved.

Size	Description
2	x-size (1/16th point)
2	x-resolution (dpi)
2	y-size (1/16th point)
2	y-resolution (dpi)

Outlines

If *bpp* = 0, the file defines outlines, and the following table data is used.

Size	Description
ns × 2 – 2	offsets to scaffold data (16-bit): If *scaffold flags* bit 0 is clear: bits 0 - 14 = offset of scaffold data from table start bit 15 set ⇒ base character code is 2 bytes, else 1 byte If *scaffold flags* bit 0 is set: bits 0 - 15 = offset of scaffold data from table start base character code is always 2 bytes 0 ⇒ no scaffold data for char
1	skeleton threshold pixel size (if *version number* ≥ 5) When rastering the outlines, skeleton lines will only be drawn if either the x- or the y- pixel size is less than this value (except if value = 0, which means 'always draw skeleton lines').
?	… sets of scaffold data follow, each set of which can include many scaffold lines (see descriptions below)

Scaffold data

Size	Description
1	character code of 'base' scaffold entry (0 ⇒ none)
1	bit *n* set ⇒ x-scaffold line *n* is defined in base character
1	bit *n* set ⇒ y-scaffold line *n* is defined in base character
1	bit *n* set ⇒ x-scaffold line *n* is defined locally
1	bit *n* set ⇒ y-scaffold line *n* is defined locally
	… local scaffold lines follow (see description below)

Scaffold lines

Size	Description
2	bits 0 - 11 = coordinate in 1/1000ths em (signed) bits 12 - 14 = scaffold link index (0 ⇒ none) bit 15 set ⇒ 'linear' scaffold line
1	width (254 ⇒ L-tangent, 255 ⇒ R-tangent)

Table end

Size	Description
?	description of contents of file: *Font name*, 0, 'Outlines', 0, '999x999 point at 999x999 dpi', 0
	… word-aligned chunk data follows (see description below)

If *version number* ≥ 8:

Size	Description
4	file offset of chunk 0 (word-aligned)
4	file offset of chunk 1 (word-aligned)
4 × (*nchunks*–3)	file offset of further chunks in order (word-aligned)
4	file offset of chunk (*nchunks* – 1) (word-aligned)
4	file offset of end (ie size of file)

Chunk data

If *version number* ≥ 7:

Size	Description
4	flag word: bit 0 set ⇒ horizontal subpixel placement bit 1 set ⇒ vertical subpixel placement bits 2 - 6 reserved (must be zero) bit 7 set ⇒ dependency byte(s) present (see below) bits 8 - 30 reserved (must be zero) bit 31reserved (must be one)

For all versions:

Size	Description
nchunks × 32	offset within chunk to character 0 ⇒ character is not defined Size is × 4 if vertical placement is used, and × 4 if horizontal placement is used. Character index is more tightly bound than vertical placement, which is more tightly bound than horizontal placement.
?	dependency byte (if outline file, and version ≥ 6) One bit required for each chunk in file. Bit *n* set ⇒ chunk *n* must be loaded in order to rasterise this chunk. This is required for composite characters which include characters from other chunks (see below).
	…character data follows, word-aligned at end of chunk (see description below)

Note: All character definitions must follow the index in the order in which they are specified in the index. This is to allow the font editor to easily determine the size of each character.

Character data

Size	Description
1	*character flags*: bit 0 set ⇒ coordinates are 12-bit, else 8-bit bit 1 set ⇒ data is 1-bpp, else 4-bpp bit 2 set ⇒ initial pixel is black, else white bit 3 set ⇒ data is outline, else bitmap If *character flags* bit 3 is clear: bits 4 - 7 = 'f' value for char (0 ⇒ not encoded) If *character flags* bit 3 is set: bit 4 set ⇒ composite character bit 5 set ⇒ with an accent as well bit 6 set ⇒ character codes within this character are 16-bit, else 8-bit bit 7 reserved (must be zero)

if *character flags* bits 3 and 4 are set:

Size	Description
1 or 2	character code of base character

if *character flags* bit 5 is set:

Size	Description
1 or 2	character code of accent
2 or 3	x, y offset of accent character

if *character flags* bits 3 or 4 are clear:

Size	Description	
1 or 1.5	x0	bounding box for character (8- or 12-bit signed)
1 or 1.5	y0	bottom-left (x0, y0) is inclusive
1 or 1.5	x1 – x0	top-right (x1, y1) is exclusive
1 or 1.5	y1 – y0	all coordinates are in pixels or design units
?	data: (depends on type of file) 1-bpp uncrunched: rows from bottom to top 4-bpp uncrunched: rows from bottom to top 1-bpp crunched: list of (packed) run-lengths outlines: list of move/line/curve segments	

Word-aligned at the end of the character data.

Outline character format

Here the 'pixel bounding box' is actually the bounding box of the outline in terms of the design size of the font (in the file header). The data following the bounding box consists of a series of move/line/curve segments followed by a terminator and an optional extra set of line segments followed by another terminator. When constructing the bitmap from the outlines, the font manager will fill the first set of line segments to half-way through the boundary using an even-odd fill, and will thin-stroke the second set of line segments (if present). For further details see the chapter entitled *Draw module* on page 5-111.

Each line segment consists of:

Size	Description
1	bits 0 - 1 = segment type:
	0 terminator (see description below)
	1 move to x, y
	2 line to x, y
	3 curve to x1, y1, x2, y2, x3, y3
	bits 2 - 4 = x-scaffold link
	bits 5 - 7 = y-scaffold link
?	coordinates in design units

Terminator:

Size	Description
1	bit 2 set ⇒ stroke paths follow (same format, but paths are not closed)
	bit 3 set ⇒ composite character inclusions follow:

Composite character inclusions:

1	character code of character to include (0 ⇒ finished)
2/3	x, y offset of this inclusion (design units)

The coordinates are either 8- or 12-bit sign-extended, depending on bit 0 of the *character flags* (see above), including the composite character inclusions.

The scaffold links associated with each line segment relate to the last point specified in the definition of that move/line/curve, and the control points of a Bezier curve have the same links as their nearest endpoint.

Note that if a character includes another, the appropriate bit in the parent character's chunk dependency flags must be set. This byte tells the Font Manager which extra chunk(s) must be loaded in order to rasterise the parent character's chunk.

1-bpp uncompacted format

1 bit per pixel, bit set ⇒ paint in foreground colour, in rows from bottom-left to top-right, not aligned until word-aligned at the end of the character.

1-bpp compacted format

The whole character is initially treated as a stream of bits, as for the uncompacted form. The bit stream is then scanned row by row: consecutive duplicate rows are replaced by a 'repeat count', and alternate runs of black and white pixels are noted. The repeat counts and run counts are then themselves encoded in a set of 4-bit entries.

Bit 2 of the *character flags* determines whether the initial pixel is black or white (black = foreground), and bits 4 - 7 are the value of '*f*' (see below). The character is then represented as a series of packed numbers, which represent the length of the next run of pixels. These runs can span more than one row, and after each run the pixel colour is changed over. Special values are used to denote row repeats.

File	Meaning
n nibbles, value 0	run length = *next_n+1_nibbles* + (13–f) × 16 + f+1 – 16
1 nibble, value 1…*f*	run length = *this_nibble*
1 nibble, value *f*+1…13	run length = *next_nibble* + (*this_nibble*–f–1) × 16 + f+1
1 nibble, value 14	row repeat count = *next_packed_number*
1 nibble, value 15	row repeat count = 1

where:

- *this_nibble* is the actual value (1…*f*, or *f*+1…13) of the nibble
- *next_nibble* is the actual value (0…15) of the nibble following *this_nibble*
- *next_n+1_nibbles* is the actual value ($0 \ldots 2^{4(n+1)} - 1$) of the next *n*+1 nibbles after the *n* zero nibbles
- *next_packed_number* is the value of the packed number following the nibble of value 14.

The optimal value of *f* lies between 1 and 12, and must be computed individually for each character, by scanning the data and calculating the length of the output for each possible value. The value yielding the shortest result is then used, unless that is larger than the bitmap itself, in which case the bitmap is used.

Repeat counts operate on the current row, as understood by the unpacking algorithm, ie at the end of the row the repeat count is used to duplicate the row as many times as necessary. This effectively means that the repeat count applies to the row containing the first pixel of the next run to start up.

Note that rows consisting of entirely white or entirely black pixels cannot always be represented by using repeat counts, since the run may span more than one row, so a long run count is used instead.

Encoding files

An encoding file is a text file which contains a set of identifiers which indicate which characters appear in which positions in a font. Each identifier is preceded by a '/', and the characters are numbered from 0, increasing by 1 with each identifier found.

Comments are introduced by '%', and continue until the next control character.

The following special comment lines are understood by the font manager:

```
%%RISCOS_BasedOn base_encoding
%%RISCOS_Alphabet alphabet
```

where *base_encoding* and *alphabet* denote positive decimal integers.

Both lines are optional, and they indicate respectively the number of the base encoding and the alphabet number of this encoding.

If the %%RISCOS_BasedOn line is not present, then the Font Manager assumes that the target encoding describes the actual positions of the glyphs in an existing file, the data for which is in:

```
font_directory.IntMetricsalphabet
font_directory.Outlinesalphabet
```

where *alphabet* is null if the %%RISCOS_Alphabet line is omitted.

(In fact the leafnames are shortened to fit in 10 characters, by removing characters from just before the *alphabet* suffix).

In this case the IntMetrics and Outlines files are used directly, since there is a one-to-one correspondence between the positions of the characters in the datafiles and the positions required in the font.

If the %%RISCOS_BasedOn line is present, then the Font Manager accesses the following datafiles:

```
font_directory.IntMetricsbase_encoding
font_directory.Outlinesbase_encoding
```

and assumes that the positions of the glyphs in the datafiles are as given by the contents of the base encoding file.

The base encoding is called '/Base*n*', and lives in the Encodings directory under Font$Path, along with all the other encodings. Because it is preceded by a '/', the Font Manager does not return it in the list of encodings returned by Font_ListFonts.

Note that only one encoding file with a given name can apply to all the fonts known to the system. Because of this, a given encoding can only be either a direct encoding, where the alphabet number is used to reference the datafiles, or an indirect encoding, where the base encoding number specifies the datafile names.

Here is the start of a sample base encoding ('/Base0'):

```
% /Base0 encoding

%%RISCOS_Alphabet 0

/.notdef /.NotDef /.NotDef /.NotDef
/zero /one /two /three /four /five /six /seven /eight
```

Here is the start of a sample encoding file ('Latin1'):

```
% Latin 1 encoding

%%RISCOS_BasedOn 0
%%RISCOS_Alphabet 101

/.notdef /.notdef /.notdef /.notdef /.notdef /.notdef /.notdef /.notdef
/.notdef /.notdef /.notdef /.notdef /.notdef /.notdef /.notdef /.notdef
/.notdef /.notdef /.notdef /.notdef /.notdef /.notdef /.notdef /.notdef
/.notdef /.notdef /.notdef /.notdef /.notdef /.notdef /.notdef /.notdef
/space /exclam /quotedbl /numbersign
/dollar /percent /ampersand /quotesingle
```

(Note that the sample /Base0 file is not the same as the released one).

These illustrate several points:

- The %% lines must appear before the first identifier.
- Character 0 in any encoding must be called '.notdef', and represent a null character.
- Other null characters in the base encoding must be called '.NotDef', to distinguish them from character 0.
- Non-base encoding files wanting to refer to the null character should use '.notdef' in all cases.
- The other character names should follow the Adobe PostScript names wherever possible. (See *PostScript Language Reference Manual*. Adobe Systems Incorporated (1990) 2nd ed. Addison-Wesley, Reading, Mass, USA.) This is to enable the encoding to refer to Adobe character names when included as part of a print job by the PostScript printer driver.
- The number of characters described by the base encoding can be anything from 0 to 768, and should refer to distinct characters (apart from the '.NotDef's). Other encodings, however, must contain exactly 256 characters, which need not be distinct.

Music files

Header

Size	Description
8	'Maestro' followed by linefeed (&0A)
1	2 (type 2 music file)

This is followed zero or more of the following blocks in any order. It is terminated by the end of the file. Note that types 7 to 9 are not implemented in Maestro, but are described for any extensions or other music programs that may be written.

Music data

Size	Description
1	1 indicates Music data follows
5	*n* = number of bytes in the 'Gates' array (stored as a BASIC integer – ie &40 followed by four bytes of data, most significant first).
5 × 8	*q*1…*q*8 = number of bytes in queue of notes and rests for each of the 8 channels 1…8 (stored as BASIC integers – ie &40 followed by four bytes of data, most significant first).
n	gate data (see *Gates* on page 6-422)
	For c = 1 to 8 (ie for each channel in turn)
Σ*q*1…*q*8	data for all notes or rests in channel *c* (see *Notes and rests* on page 6-424)
	Next c

Stave data

Size	Description
1	2 indicates Stave data follows
1	number of music staves – 1 (0 - 3)
1	number of percussion staves (0 - 1)

Which channels are used by which staves depends on the number of music staves and the number of percussion staves as follows:

Music staves	Percussion staves	Stave 1	Stave 2	Stave 3	Stave 4	Percussion
1	0	1 - 8				
1	1	1 - 7				8
2	0	1 - 4	5 - 8			
2	1	1 - 4	5 - 7			8
3	0	1	2 - 5	6 - 8		
3	1	1	2 - 5	6, 7		8
4	0	1, 2	3, 4	5, 6	7, 8	
4	1	1, 2	3, 4	5, 6	7	8

Instrument data

Instrument names are not recorded; only channel numbers.

Size	Description
1	3 indicates Instrument data follows

This is followed by 8 blocks of 2 bytes each:

Size	Description
1	channel number (always consecutive 1 - 8)
1	*voice number*: 0 ⇒ no voice attached

Volume data

Size	Description
1	4 indicates Volume data follows
1 × 8	volume on each channel (0 - 7 = ppp - fff); one byte for each channel

Stereo position data

Size	Description
1	5 indicates Stereo data follows
1 × 8	stereo position of channel (0 - 6 = full left - full right); one byte for each channel

Tempo data

Size	Description
1	6 indicates Tempo data follows
1	0 - 14, which corresponds to one of: 40, 50, 60, 65, 70, 80, 90, 100, 115, 130, 145, 160, 175, 190, and 210beats per minute

To convert to values to program into SWI Sound_QTempo, use the formula:

Sound_QTempo value = beats per minute × 128 × 4096 / 6000

Title string

Size	Description
1	7 indicates title string follows
n	null terminated string of *n* characters total length

Instrument names

Size	Description
1	8 indicates Instrument names follow
Σn1...n8	8 null terminated strings for each *voice number* used in ascending order in command 3 above.

MIDI channels

Size	Description
1	9 indicates MIDI channel numbers follow
1 × 8	MIDI channel number on this stave (0 ⇒ not transmitted over MIDI, else 1 - 16); one byte for each channel

Gates

A Gate is a point in the music where something is interpreted: eg a note, time-signature, key-signature, bar-line or clef can each occupy a gate. The gate data is one byte for a note or rest, or 2 bytes for an attribute such as a time-signature, key-signature, bar-line, clef, etc.

Note or rest

A note or rest is represented by a single non-zero byte.

Bit(s)	Description
0 - 7	Gate mask: bit *n* set ⇒ gate 1 note or rest from queue *n*.

Attribute

An attribute is represented by a null byte (so that it can be distinguished from a note or rest), followed by a byte describing the attribute.

Byte	Description
0	0
1	one of the following forms:

Time-signature

Bit(s)	Description
0	1
1 - 4	number of beats per bar – 1 (0 - 15)
5 - 7	beat type (0 = breve, to 7 = hemidemisemiquaver)

Key-signature

Bit(s)	Description
0 - 1	10 binary (ie bit 1 set)
2	type of accidental (0 = sharp, 1 = flat)
3 - 5	number of accidentals in key signature (0 - 7)
6 - 7	reserved (must be zero)

Clef

Bit(s)	Description
0 - 2	100 binary (ie bit 2 set)
3 - 4	0 = treble, 1 = alto, 2 = tenor, 3 = bass
5	reserved (must be zero)
6 - 7	stave – 1 (0 - 3)

Slur

Bit(s)	Description
0 - 3	1000 binary (ie bit 3 set)
4	1 = on, 0 = off
5	reserved (must be zero)
6 - 7	stave – 1 (0 - 3)

Octave shift

Bit(s)	Description
0 - 4	10000 binary (ie bit 4 set)
5	0 = up, 1 = down
6 - 7	stave – 1 (0 - 3)

Bar

Bit(s)	Description
0 - 5	100000 binary (ie bit 5 set)
6 - 7	reserved (must be zero)

Reserved for future expansion

Bit(s)	Description
0 - 6	1000000 binary (ie bit 6 set)
0 - 7	10000000 binary (ie bit 7 set)

Notes and rests

Notes and rests are each stored in a 2 byte block that has some common elements.

Notes

Bit(s)	Description
0	stem orientation (0 = up, 1 = down)
1	1 ⇒ join beams (barbs) to next note
2	1 ⇒ tie with next note
3 - 7	stave line position (0 - 31, 16 = centre line)
8 - 10	accidental: 0 = no accidental 1 = natural 2 = sharp 3 = flat 4 = double-sharp 5 = double-flat 6 = natural sharp 7 = natural flat
11 - 12	number of dots (0 - 3)
13 - 15	type (0 = breve, to 7 = hemidemisemiquaver)

Rests

Bits	Description
0 - 10	reserved (set to zero)
11 - 12	number of dots (0 - 3)
13 - 15	type (0 = breve, to 7 = hemidemisemiquaver)

If a rest coincides with a note, its position is determined by the following note on the same channel.

83 Appendix F: System variables

This details standard variables used in RISC OS, and gives important guidelines on the names you should use for any system variables you create for your applications to use.

Application variables

The following section gives standard names used for variables that are bound to a particular application. An application should not need to set all these variables, but where one of the variables below matches your needs, you should use it and follow the given guidelines. Where you need a system variable and can't find a relevant one below, you should use your own, naming it *App*$...

In the descriptions below you should replace *App* with your application's name. You must first register this name with Acorn, to avoid any possibility of your system variables clashing with those used by other programmers' applications; see *Appendix H: Registering names* on page 6-473.

App$Dir

An *App*$Dir variable gives the full pathname of the directory that holds the application *App*. This is typically set in the application's !Run file by the line:

```
Set App$Dir <Obey$Dir>
```

App$Path

An *App*$Path variable gives the full pathname of the directory that holds the application *App*. An *App*$Path variable differs from an *App*$Dir variable in two important respects:

- The pathname includes a trailing '.'
- The variable may hold a set of pathnames, separated by commas.

It's common to use an *App*$Dir variable rather than an *App*$Path variable, but there may be times when you need the latter.

An App$Path variable might, for example, be set in the application's !Run file by the line:

```
Set App$Path <Obey$Dir>.,%.App.
```

if the application held further resources in the subdirectory *App* of the library.

App$Options

An App$Options variable holds the start-up options of the application *App*:

- An option that can be either on or off should consist of a single character, followed by the character '+' or '-' (eg M+ or S-).
- Other options should consist of a single character, followed by a number (eg P4 or F54).
- Options should be separated by spaces; so a complete string might be F54 M+ P4 S-.

This variable is typically used to save the state of an application to a desktop boot file, upon receipt of a desktop save message. A typical line output to the boot file might be:

```
Set App$Options F54 M+ P4 S-
```

You should only save those options that differ from the default, and hence not output a line at all if the application is in its default state. You should however be prepared to read options that set the default values, in case users explicitly add such options.

App$PrintFile

An App$PrintFile variable holds the name of the file or system device to which the application *App* prints. Typically this will be printer:, and would be set in your application's !Run file as follows:

```
Set App$PrintFile printer:
```

App$Resources

An App$Resources variable gives the full pathname of the directory that holds the application *App*'s resources. This might be set in the application's !Run file by the line:

```
Set App$Resources <Obey$Dir>.Resources
```


App$Running

An App$Running variable shows that the application *App* is running. It should have the value 'Yes' if the application is running. This might be used in the application's !Run file as follows:

```
If "App$Running" <> "" then Error App is already running
Set App$Running Yes
```

When the application stops running, you should use *Unset to delete the variable.

Changing and adding commands

Alias$Command

An Alias$*Command* variable is used to define a new command named *Command*. For example:

```
Set Alias$Mode echo |<22>|<%0>
```

By using the name of an existing command, you can change how it works.

Using file types

File$Type_XXX

A File$Type_XXX variable holds the textual name for a file having the hexadecimal file type XXX. It is typically set in the !Boot file of an application that provides and edits that file type. For example:

```
Set File$Type_XXX TypeName
```

The reason the !Boot file is used rather than the !Run file is so that the file type can be converted to text from the moment its 'parent' application is first seen, rather than only from when it is run.

Alias$@LoadType_XXX, Alias$@PrintType_XXX and Alias$@RunType_XXX

These variables set the command used to respectively load, print and run a file of hexadecimal type XXX. They are typically set in the !Boot file of an application that provides and edits that file type. For example:

```
Set Alias$@PrintType_XXX /<Obey$Dir> -Print 
Set Alias$@RunType_XXX /<Obey$Dir> 
```

Note that the above lines **both have a trailing space** (invisible in print!).

The reason the !Boot file is used rather than the !Run file is so that files of the given type can be loaded, printed and run from the moment their 'parent' application is first seen, rather than only from when it is run.

For more information see the section entitled *Load-time and run-time system variables* on page 3-14.

Setting the command line prompt

CLI$Prompt

The CLI$Prompt variable sets the command line interpreter prompt. By default this is '*'. One common way to change this is so that the system time is displayed as a prompt. For example:

```
SetMacro CLI$Prompt <Sys$Time> *
```

This is set as a macro so that the system time is evaluated each time the prompt is displayed.

Configuring RISC OS commands

Copy$Options, Count$Options and Wipe$Options

These variables set the behaviour of the *Copy, *Count and *Wipe commands. For a full description, see page 3-147, page 3-150 and page 3-185 respectively.

System path variables

File$Path and Run$Path

These variables control where files are searched for during, respectively, read operations or execute operations. They are both path variables, which means that – in common with other path variables – they consist of a comma separated list of full pathnames, each of which has a trailing '.'.

If you wish to add a pathname to one of these variables, you must ensure that you append it once, and once only. For example, to add the 'bin' subdirectory of an application to Run$Path, you could use the following lines in the application's !Boot file:

```
If "<App$Path>" = "" then Set Run$Path <Run$Path>,<Obey$Dir>.bin.
Set App$Path <Obey$Dir>.
```

For more information see the section entitled *File$Path and Run$Path* on page 3-16.

Obey files

Obey$Dir

The Obey$Dir variable is set to the directory from which an Obey file is being run, and may be used by commands within that Obey file. For examples, see various other sections of this chapter. For more detailed information, see the section entitled *Obey$Dir* on page 6-286.

Time and date

Sys$Time, Sys$Date and Sys$Year

These variables are code variables that are evaluated at the time of their use to give, respectively, the current system time, date and year.

For an example of the use of Sys$Time, see the section entitled *CLI$Prompt* on page 6-428.

Sys$DateFormat

The Sys$DateFormat variable sets the format in which the date is presented by the SWI OS_ConvertStandardDateAndTime (see page 1-424). For details of the format used by this variable, see the section entitled *Format field names* on page 1-393.

Return codes

Sys$ReturnCode, Sys$RCLimit

The Sys$ReturnCode variable contains the last return value given by the SWI OS_Exit, and the Sys$RCLimit variable sets the maximum return value that will not generate an error. For more details, see page 1-293.

!System and !Scrap

System$Dir and System$Path

These variables give the full pathname of the System application. They have the same value, save that System$Path has a trailing '.', whereas System$Dir does not. You must not change their values.

(There are two versions of this pathname for reasons of backward compatibility.)

Wimp$Scrap

The Wimp$Scrap variable gives the full pathname of the Wimp scrap file used by the file transfer protocol. You must not use this variable for any other purpose, nor change its value.

Wimp$ScrapDir

The Wimp$ScrapDir variable gives the full pathname of a scrap directory within the Scrap application, which you may use to store temporary files. You must not use this variable for any other purpose, nor change its value.

The desktop

Wimp$State

The Wimp$State variable shows the current state of the Wimp. If the desktop is running, it has the value 'desktop'; otherwise it has the value 'commands'.

84 Appendix G: The Acorn Terminal Interface Protocol

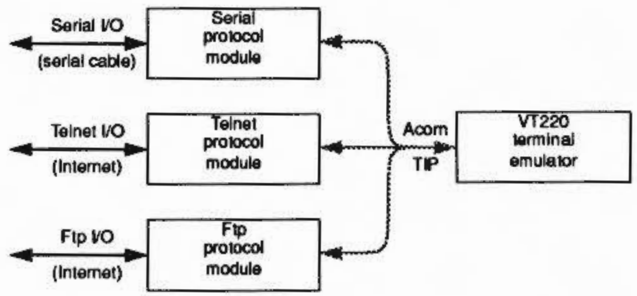
Introduction

This appendix describes version 1.00 of the *Acorn Terminal Interface Protocol* (or *Acorn* TIP) used to communicate between a terminal emulator and a protocol module. By using this protocol you can integrate your own terminal emulators and protocol modules with those provided by the TCP/IP Protocol Suite.

Although this chapter only talks about the Acorn TIP in the context of terminal emulators and protocol modules, there's no reason why you shouldn't use it for other applications that involve input and output.

Protocol modules

A *protocol module* converts one of the many different protocols computers use for input and output to the Acorn TIP. For example in the case of the VT220 application and the protocol modules supplied as part of the TCP/IP Protocol Suite, we have:



- Data passing between a terminal emulator and a protocol module uses the Acorn TIP, and passes over a *logical link*. These are grey in the drawing above.

- Data passing between a protocol module and a remote machine or process uses whatever protocol the module is designed to support, and passes over a *connection*. These are black in the drawing above.

Using the Acorn TIP

If you decide to write other protocol modules and/or terminal emulators, you should use the Acorn TIP. Since this provides a standard interface between protocol modules and terminal emulators, users will be able to use your modules and emulators with the TCP/IP ones, and with ones that other programmers write too. If your software's compatible, we think it's more likely users will buy it.

Writing a protocol module

If you're writing a protocol module, you must first familiarise yourself with how a RISC OS relocatable module works. You'll find full details of this in the chapter entitled *Modules* on page 1-191. Your protocol module must conform to the standards laid out in that chapter.

Service calls

You must support the service calls detailed in this chapter.

SWIs

You must also support various SWIs from the set detailed in this chapter. These must be at the defined offsets from your module's SWI base number, which is allocated by Acorn. To support many of these SWIs you will need to send suitable commands over the physical connection to the remote host.

- You must support:

Offset	SWI name
0	Protocol_OpenLogicalLink
1	Protocol_CloseLogicalLink
2	Protocol_GetProtocolMenu
3	Protocol_OpenConnection
4	Protocol_CloseConnection
7	Protocol_MenuItemSelected
8	Protocol_UnknownEvent
9	Protocol_GetLinkState
10	Protocol_Break

- If your protocol module supports the sending of data over a connection to a remote machine (or process) you must also support:

Offset	SWI Name
5	Protocol_TransmitData

If you have chosen to support file transfer SWIs you must furthermore support:

Offset	SWI Name
11	Protocol_SendFile
12	Protocol_SendFileData
13	Protocol_AbortTansfer

- If your protocol module supports the receipt of data over a connection from a remote machine (or process) you must also support:

Offset	SWI Name
6	Protocol_DataRequest

If you have chosen to support file transfer SWIs you must furthermore support:

Offset	SWI Name
13	Protocol_AbortTransfer
14	Protocol_GetFileInfo
15	Protocol_GetFileData
17	Protocol_GetFile

- You may also choose to support:

Offset	SWI Name
18	Protocol_DirOp

Data structures

Your protocol module must keep two different types of data structure constantly updated, as terminal emulators may directly access these any time they need to. These are:

- A single *protocol information block* which contains the following information:

Offset	Information
0	pointer to protocol name string
4	pointer to protocol version string
8	pointer to protocol copyright string
12	maximum number of connections allowed by module
16	current number of open connections

The three strings are all null-terminated, and have a maximum length of 30 characters. For more details see *Protocol_OpenLogicalLink* (*Offset* 0) on page 6-442.

- A *poll word* for each logical link that shows the status of that link by the state of various bit flags:

Bit	Meaning when set
0	data is pending
1	file is pending
2	paused operation is to continue

For more details see *Protocol_OpenConnection* (*Offset* 3) on page 6-446.

Multiple links and connections

All protocol modules **must** (if physically possible) support multiple logical links, and multiple connections.

Writing a terminal emulator

If you're writing a terminal emulator there are various functions that it's likely you'll want it to support. This section tells you which SWIs you'll need to use for many such functions, and outlines how to use them. The later section that details each SWI will give you the detailed information you need.

Finding available and compatible protocols

To find what protocols are available and compatible with the needs of your emulator, you must repeatedly issue Service_FindProtocols until it is not claimed. Then you must issue Service_FindProtocolsEnd.

Choosing a protocol and opening a link

For your user to choose a protocol, you'll probably want to give them a menu of the ones you found to be available. Once they've made the choice, you can then issue Service_ProtocolNameToNumber to find the base SWI number of their chosen protocol module. You can then use this to call the SWI Protocol_OpenLogicalLink (offset 0 from the base number you just found).

You can also use the facilities outlined in the section entitled *Protocol modules and the Wimp* on page 6-436 to provide menus so that your user can set up the way the protocol and connection will work.

Opening a connection

To open a connection, call Protocol_OpenConnection (offset 3). Sometimes the protocol module won't immediately be able to open the connection; you'll need to use Protocol_GetLinkState (offset 9) to find out whether the connection eventually makes or fails.

Closing a connection and a link

To close a connection, call Protocol_CloseConnection (offset 4). To close a logical link, call Protocol_CloseLogicalLink (offset 1); this also closes any associated connections.

Examining the poll word

When you open a connection, you set the address of a poll word. The protocol module sets bits in this word when it needs attention. It's vital that your emulator regularly examines this word so that the protocol module gets adequate service. We suggest you do so each time you get a null event from Wimp_Poll.

Sending data

To send data, call Protocol_TransmitData (offset 5).

Receiving data

When the protocol module receives data over a connection, it will notify your emulator by setting a bit in the poll word. To get the data forwarded to your emulator, call Protocol_DataRequest (offset 6).

Sending files

To send a file, call Protocol_SendFile (offset 11) to give details of the file to the protocol module. When the protocol module shows it is ready for you to send the file (by using the poll word), send the file in one or more data packets by repeatedly calling Protocol_SendFileData (offset 12). Finally, call Protocol_SendFileData (offset 12) a last time to mark the end of the file transfer.

You can use this call to send multiple files.

Wherever possible you should make sure that the data packets are small enough that they can be quickly sent, so your emulator doesn't hog the computer for long periods.

Receiving files

When the protocol module receives a file over a connection, it will notify your emulator by setting a bit in the poll word. To get the file forwarded to your emulator, call Protocol_GetFileInfo (offset 14) to get details of the file. When the protocol module shows it is ready to forward the file (again by using the poll word), call Protocol_GetFileData (offset 15) until you've received all the data packets making up the file.

Explicitly getting a file

To explicitly get a file, call Protocol_GetFile (offset 17). You'll actually receive it just as we outlined above.

Aborting file operations

To abort any file operation, call Protocol_AbortTransfer (offset 13).

Directory operations

There are no SWIs specified in the Acorn TIP to send, receive or get entire directories in one call. Instead we provide a single SWI call – Protocol_DirOp (offset 18) – with which you can create a directory, move into a directory, and move one level up a directory tree. You can combine this SWI with the ones outlined above to move around a remote file system, creating directories, and sending and getting files at will (subject, of course, to your having access rights).

Protocol modules and the Wimp

The Acorn TIP provides several calls which help interaction between the Wimp and protocol menus. These are necessary because the 'pick and mix' nature of protocol modules and terminal emulators means you'll have to combine menus from each; and because protocol modules are not foreground tasks, and so don't receive notice of menu selections and Wimp events.

To get a protocol's menu tree, call Protocol_GetProtocolMenu (offset 2); you can then combine it with your emulator's menu tree. If a user clicks on the protocol module's part of the menu tree, call Protocol_MenuItemSelected (offset 7) to pass this on. To pass on a Wimp event to a protocol module, call Protocol_UnknownEvent (offset 8); you should do this for every event your emulator can't deal with, as the protocol module may be able to.

Generating a break

Finally, you can generate a Break over the connection by calling Protocol_Break (offset 10).

Documentation of Service Calls and SWIs

The rest of this chapter details in turn each Service Call and SWI used to communicate between a protocol module and a terminal emulator. It looks at each in three stages:

1. What your terminal emulator should do before calling the Service Call or SWI.
2. What a protocol module should do when it receives the Service Call or SWI.

3. What your terminal emulator should do when the call returns to it.

We've followed the same viewpoint throughout as we have above: we assume that you're writing a terminal emulator to work with someone else's protocol module. So we talk about **your** terminal emulator, but **the** protocol module. If, in fact, you're writing a protocol module, you should find it easy enough to make the shift of viewpoint you'll need to.

Service_FindProtocols (Service Call &41580)

Finds all available compatible protocols

On entry

R1 = &41580 (reason code)
R2 = lowest TIP version supported × 100 (first public version was 1.00)
R3 = last TIP version known × 100 (current version is 1.00)
R4 = emulator flags

On exit

R1 = 0 to claim, else registers preserved to pass on
R2 = pointer to protocol name string (null terminated)
R3 = base SWI number of protocol module
R4 = pointer to protocol information block
R5 = protocol flags

Use

Use this service call in your **terminal emulator** to find all available compatible protocol modules. (For full details of OS_ServiceCall see page 1-243.) You should:

1 Repeatedly issue this service call until it is not claimed – without polling the Wimp in the meantime.

2 Issue Service_FindProtocolsEnd (see page 6-440).

The emulator flags have the following meanings:

Bits	Value	Meaning
0	0	emulator doesn't support file transfer calls
	1	emulator supports file transfer calls
1-2	00	direction of link immaterial
	01	one-way link wanted – protocol to emulator
	10	one-way link wanted – emulator to protocol
	11	two-way link needed
3	0	bits 1-2 are minimum requirement
	1	bits 1-2 are exact requirement

All other bits are reserved and must be zero.

The **protocol module** checks to see if:

- it uses a version of the Acorn TIP in the range supported by the terminal emulator
- it supports links in the direction required by the terminal emulator.

If one of the above isn't true, the protocol module must not claim the call – that is, it must return with registers preserved.

If both the above are true it must claim the call – that is, it must return with the values shown above in the section entitled *On exit*. It must then set an internal flag so it doesn't claim this call again until it receives a Service_FindProtocolsEnd.

The protocol information block it returns contains the following information:

Offset	Information
0	pointer to protocol name string
4	pointer to protocol version string
8	pointer to protocol copyright string
12	maximum number of connections allowed by module
16	current number of open connections

The three strings are all null-terminated, and have a maximum length of 30 characters. The protocol module must always keep this block updated so terminal emulators can directly access it.

The protocol flags it returns have the following meanings:

Bits	Value	Meaning
0	0	can open new link
	1	can't open new link, or not useful (see below)
1	0	protocol doesn't support file transfer SWIs
	1	protocol supports file transfer SWIs
2	0	protocol doesn't support Protocol_DirOp
	1	protocol supports Protocol_DirOp

If the protocol is mainly for file transfer (such as Ftp) and the terminal emulator doesn't support file transfer calls (bit 0 of R3 was clear on entry) the protocol module should set bit 0 to show it's 'not useful'.

All other bits are reserved and must be zero.

Related Service Calls

Service_FindProtocolsEnd (Service Call &41581),
Service_ProtocolNameToNumber (Service Call &41582)

Service_FindProtocolsEnd (Service Call &41581)

Indicates that protocol modules must again respond to Service_FindProtocols

On entry

R1 = &41581 (reason code)

On exit

R1 = 0 to claim, else preserved to pass on

Use

Use this service call in your **terminal emulator** to indicate the end of your search for available protocols.

Protocol modules must change their internal flag so they respond again to Service_FindProtocols calls – from whatever terminal emulator the calls originate. They **must not** claim this call.

Related Service Calls

Service_FindProtocols (Service Call &41580),
Service_ProtocolNameToNumber (Service Call &41582)

Service_ProtocolNameToNumber (Service Call &41582)

Requests the conversion of a protocol name to a base SWI number

On entry

R1 = &41581
R2 = pointer to protocol name (null-terminated)

On exit

R1 = 0 to claim, else registers preserved to pass on
R2 = base SWI number for protocol

Use

Use this service call in your **terminal emulator** to request the conversion of a protocol name to a base SWI number.

If a **protocol module** recognises the protocol name it must claim the call and return the base SWI number of the protocol. Otherwise it must pass the call on.

Related Service Calls

Service_FindProtocols (Service Call &41580),
Service_FindProtocolsEnd (Service Call &4151)

Protocol_OpenLogicalLink (Offset 0)

Opens a logical link to a protocol module

On entry

R0 = terminal emulator's link handle
R1 = pointer to terminal identifier string (null terminated)

On exit

R0 = protocol module's link handle
R1 = protocol module's Wimp_Poll mask
R2 = pointer to protocol information block
R3 = protocol information flags

Use

Use this call in your **terminal emulator** to open a logical link to a protocol module. The handle you pass on entry will be returned to you by future SWI calls you make to the protocol module – we suggest you use a pointer to your data structures that are specific to this link.

You may use the terminal identifier string for such things as setting the 'type' of your terminal emulator on the remote machine.

The **protocol module** returns its own handle for the link – again this is typically a pointer to its own data that is specific to the link. The Wimp_Poll mask it returns specifies those Wimp events that it doesn't need.

The protocol information block contains the following information:

Offset	Information
0	pointer to protocol name string
4	pointer to protocol version string
8	pointer to protocol copyright string
12	maximum number of connections allowed by module
16	current number of open connections

The three strings are all null-terminated, and have a maximum length of 30 characters. The protocol module must always keep this block updated so terminal emulators can directly access it.

The protocol information flags have the following meanings:

Bit	Meaning when set
0	protocol needs more information to open a connection
1	protocol supports file transfer SWIs
2	protocol supports Protocol_DirOp

All other bits are reserved and must be zero.

When this call returns to your **terminal emulator** you should examine bit 0 of the protocol information flags. If it is clear then you should immediately call Protocol_OpenConnection; if it is set you will have to wait until the user shows they are ready to supply the information the protocol module needs (by, for instance, moving the pointer over the arrow that shows an 'open connection' menu item to have a submenu).

Also, you should AND the protocol module's Wimp_Poll mask with your terminal emulator's own one. Use the resultant mask whenever you call Wimp_Poll.

Related SWIs

Protocol_CloseLogicalLink (offset 1), Protocol_OpenConnection (offset 3), Protocol_CloseConnection (offset 4), Protocol_GetLinkState (offset 9)

Protocol_CloseLogicalLink (Offset 1)

Closes a logical link to a protocol module

On entry

R0 = protocol module's link handle

On exit

R0 preserved

Use

Use this call in your **terminal emulator** to close a logical link to a protocol module.

The **protocol module** closes any connections that are associated with the logical link.

Related SWIs

Protocol_OpenLogicalLink (offset 0), Protocol_OpenConnection (offset 3), Protocol_CloseConnection (offset 4), Protocol_GetLinkState (offset 9)

Protocol_GetProtocolMenu (Offset 2)

Gets a protocol's menu tree

On entry

R0 = protocol module's link handle

On exit

R0 = terminal emulator's link handle
R1 = pointer to protocol and link specific Wimp menu block (as used by Wimp_CreateMenu)

Use

Use this call in your **terminal emulator** to get a protocol's menu tree. You must use this call each time you want to open the protocol's menu, as it may change depending on the state of the logical link. For example items may become unavailable and so be greyed out, or the user may change the contents of a writable entry.

The **protocol module** returns a pointer to a menu block that is the same as that used by Wimp_CreateMenu. (See page 4-222 for details of this call.) This menu block must accurately reflect the current state of the logical link between the terminal emulator and the protocol module.

Related SWIs

Protocol_MenuItemSelected (offset 7), Protocol_UnknownEvent (offset 8)

Protocol_OpenConnection (Offset 3)

Opens a connection from a protocol module

On entry

R0 = protocol module's link handle
R1 = pointer to poll word for this connection
R3 = pointer to protocol specific string (null-terminated), or 0
R4 = x coordinate of top-left corner of dialogue box
R5 = y coordinate of top-left corner of dialogue box

On exit

R0 = terminal emulator's link handle
R1 = pointer to connection name (null-terminated)
R2 = pointer to protocol specific information, or 0
R3 = protocol status flags

Use

Use this call in your **terminal emulator** to open a connection from a protocol module. At the same time you pass the protocol module the address of a poll word in your workspace, which your terminal emulator must regularly check to review the state of the logical link to the protocol module. We suggest you do so each time you get a null event from Wimp_Poll.

When a bit is set in the poll word, something needs attention. The table below shows the meaning of each bit, and the **initial** SWI call you have to make to handle the situation. See the relevant pages for details of what to do, and of any further calls you may need to make.

Bit	Meaning when set	Call needed
0	data is pending	Protocol_DataRequest
1	file is pending	Protocol_GetFileInfo
2	paused operation is to continue	Protocol_GetFileData or Protocol_SendFileData or Protocol_DirOp

The poll word must be in RMA space, so the protocol module can update it whether or not your terminal emulator is the foreground task.

The values you need to pass in R3, R4 and R5 depend on circumstances:

- If the protocol module needs no further information to open the connection these values are ignored.
- If the user has shown they are ready to supply the information the protocol module needs (typically by moving the pointer over the arrow that shows an 'open connection' menu item to have a submenu), you must set R3 to zero, and R4 and R5 to the coordinates where you want the protocol module to open a dialogue box. You can get these coordinates by making your terminal emulator's menu issue Message_MenuWarning when the submenu is to be activated (see Wimp_CreateMenu on page 4-222 and Wimp_SendMessage on page 4-261).
- If the user has already supplied you with the information that the protocol module needs (say in a script) you should pass that in R3. The values of R4 and R5 are ignored.

The **protocol module** opens the connection after first (if necessary) using a dialogue box to get any information it needs.

The documentation of a protocol module **must** state the format of information it expects to find in R3 (if it needs any). Wherever possible, this format should consist of the same fields that the protocol module provides in its dialogue box, in the same order, and comma-separated.

The protocol module returns a connection name suitable for the terminal emulator to use as a window title (if the connection is open or pending). The protocol specific information it returns may be used for error messages. The protocol status flags it returns have the following meanings:

Bits	Value	Meaning
0-1	00	no connection opened
	01	connection pending
	10	connection open
	11	connection failed
2	0	no data pending
	1	data pending

All other bits are reserved and must be zero. The protocol module should select 'connection failed' in preference to 'no connection opened'.

When this call returns to your **terminal emulator** you must examine the state of these flags:

- If the connection failed (bits 0 and 1 are set) and no data is pending (bit 2 is clear) you must attempt to close the connection by calling Protocol_CloseConnection.

- If the connection is pending you must wait until bit 0 of the logical link's poll word is set. Then you should call Protocol_GetLinkState to find if the connection was opened, or if it failed.
- Bit 2 ('data pending') has exactly the same meaning as bit 0 of a logical link's poll word, and is provided to reduce the amount of polling that needs to be done. If it is set you should initiate the data transfer by calling Protocol_DataRequest.

Related SWIs

Protocol_OpenLogicalLink (offset 0), Protocol_CloseLogicalLink (offset 1), Protocol_CloseConnection (offset 4), Protocol_GetLinkState (offset 9)

Protocol_CloseConnection (Offset 4)

Closes a link's connection from a protocol module

On entry

R0 = protocol module's link handle

On exit

R0 = pointer to protocol specific information, or 0

Use

Use this call in your **terminal emulator** to close a link's connection from a protocol module.

The **protocol module** closes the connection associated with the given link.

Related SWIs

Protocol_OpenLogicalLink (offset 0), Protocol_CloseLogicalLink (offset 1), Protocol_OpenConnection (offset 3), Protocol_GetLinkState (offset 9)

Protocol_TransmitData (Offset 5)

Transmits data over a connection via a protocol module

On entry

R0 = protocol module's link handle
R1 = pointer to receive buffer
R2 = length of receive buffer (in bytes)
R3 = pointer to transmit buffer
R4 = length of transmit buffer (in bytes)
R5 = emulator transmit flags

On exit

R0 = terminal emulator's link handle
R2 = bytes of data placed in receive buffer
R3 = protocol status flags
R4 = pointer to protocol specific information

Use

Use this call in your **terminal emulator** to transmit data over a connection via a protocol module. You'll also receive any pending data that the protocol module has been holding for you.

The emulator transmit flags have the following meanings:

Bit	Value	Meaning
3	0	transmitted data is in bytes
	1	transmitted data is in words

All other bits are reserved and must be zero. If the transmitted data is in words, each word contains one character.

The **protocol module** transmits the data over the connection. Also, if it has any pending data for the terminal emulator it forwards as much as it is able to place in the emulator's receive buffer.

The protocol specific information it returns may be used for error messages.

The protocol status flags it returns have the following meanings:

Bits	Value	Meaning
0-1	00	no connection opened
	01	connection pending
	10	connection open
	11	connection failed
2	0	no data pending
	1	more data pending
3	0	data is in bytes
	1	data is in words

All other bits are reserved and must be zero.

When this call returns to your **terminal emulator** you must check R2 to see if you have received any data, and process it if necessary. You must also examine the protocol status flags in R3:

- If the connection failed (bits 0 and 1 are set) and no data is pending (bit 2 is clear) you must attempt to close the connection by calling Protocol_CloseConnection.
- If the connection is pending you have made an error in your programming by trying to use the connection before it has been properly opened.
- Bit 2 ('more data pending') has exactly the same meaning as bit 0 of a logical link's poll word, and is provided to reduce the amount of polling that needs to be done. If it is set you should initiate the data transfer by calling Protocol_DataRequest.
- If the data you've received is in words, each word contains one character.

Related SWIs

Protocol_SendFile (offset 11), Protocol_SendFileData (offset 12)

Protocol_DataRequest (Offset 6)

Requests that a protocol module forwards any pending data

On entry

R0 = protocol module's link handle
R1 = pointer to receive buffer
R2 = length of receive buffer (in bytes)

On exit

R0 = terminal emulator's link handle
R1 preserved
R2 = bytes of data placed in receive buffer
R3 = protocol status flags
R4 = pointer to protocol specific information

Use

Use this call in your **terminal emulator** to request that a protocol module forwards any pending data. You should do so in either of these cases:

- if bit 0 ('data pending') of the link's poll word is set
- if the 'data pending' bit (commonly bit 2) of the protocol status flags (commonly in R3) is set on return from a Protocol… SWI call.

The **protocol module** forwards as much of the pending data as it is able to place in the emulator's receive buffer.

The protocol specific information it returns may be used for error messages. The protocol status flags it returns have the following meanings:

Bits	Value	Meaning
0-1	00	no connection opened
	01	connection pending
	10	connection open
	11	connection failed
2	0	no data pending
	1	more data pending
3	0	data is in bytes
	1	data is in words

All other bits are reserved and must be zero.

When this call returns to your **terminal emulator** you must examine the state of these flags:

- If the connection failed (bits 0 and 1 are set) and no data is pending (bit 2 is clear) you must attempt to close the connection by calling Protocol_CloseConnection.
- If the connection is pending you have made an error in your programming by trying to use the connection before it has been properly opened.
- Bit 2 ('data pending') has exactly the same meaning as bit 0 of a logical link's poll word, and is provided to reduce the amount of polling that needs to be done. If it is set you should continue the data transfer by calling Protocol_DataRequest.
- If the data is in words, each word contains one character.

Related SWIs

Protocol_GetFileInfo (offset 14), Protocol_GetFileData (offset 15), Protocol_GetFile (offset 17)

Protocol_MenuItemSelected (Offset 7)

Requests that a protocol module services a menu selection

On entry

R0 = protocol module's link handle
R1 = pointer to menu selection block
R2 = x coordinate of mouse
R3 = y coordinate of mouse
R4 = emulator menu flags

On exit

R0 - R4 preserved

Use

Use this call in your **terminal emulator** to request that a protocol module services a selection made within its own menu. You should call this if you:

- get notice of a mouse click within the protocol's menu, via a Menu_Selection reason code from Wimp_Poll
- get notice of the pointer moving over a right arrow to activate one of the protocol's submenus, via a MenuWarning message

(See the descriptions of Wimp_Poll on page 4-183 and Wimp_SendMessage on page 4-261 for more details.)

The menu selection block contains:

R1	item in protocol menu that was selected (starting with 1)
R1+1	item in first protocol submenu that was selected
R1+2	item in second protocol submenu that was selected
...	
terminated by 0 byte	

Note: There are several important differences between this menu selection block and that returned by Wimp_Poll with a Menu_Selection reason code:

Wimp menu selection block	**Protocol menu selection block**
Menu items start from 0	Menu items start from 1
Each number is a word	Each number is a byte
List is terminated by –1	List is terminated by 0
R1 gives item in main menu menu	R1 gives item at root of protocol

The emulator menu flags show why you have made this call:

Bit	**Value**	**Meaning**
0	0	called because of a mouse click
	1	called because of a MenuWarning message

All other bits are reserved and must be zero.

The **protocol module** services the menu selection, either doing what the user clicked over, or displaying the necessary submenu.

Related SWIs

Protocol_GetProtocolMenu (offset 2), Protocol_UnknownEvent (offset 8)

Protocol_UnknownEvent (Offset 8)

Passes on Wimp events to a protocol module

On entry

R0 = pointer to Wimp event block (as returned by Wimp_Poll)

On exit

R0 preserved

Use

Use this call in your **terminal emulator** to pass on Wimp events you can't deal with to the protocol module you're using. You should also pass on idle events if the protocol module's Wimp_Poll mask (see Protocol_OpenLogicalLink) doesn't mask them out – even if your terminal emulator uses them.

The **protocol module** processes the Wimp event if it is one in which it is interested.

Related SWIs

Protocol_GetProtocolMenu (offset 2), Protocol_MenuItemSelected (offset 7)

Protocol_GetLinkState (Offset 9)

Gets the state of a logical link

On entry

R0 = protocol module's link handle

On exit

R0 = terminal emulator's link handle
R1 = pointer to connection name (null-terminated)
R2 = pointer to protocol specific information, or 0
R3 = protocol status flags

Use

Use this call in your **terminal emulator** to get the state of a logical link.

One time you should do so is if an attempt you've made to open a connection has resulted in a pending connection. You should then wait for bit 0 of the logical link's poll word ('data pending') to be set before making this call to find if the connection was opened, or if it failed.

The **protocol module** returns a connection name suitable for the terminal emulator to use as a window title (if the connection is open or pending). The protocol specific information it returns may be used for error messages. The protocol status flags it returns have the following meanings:

Bits	Value	Meaning
0-1	00	no connection opened
	01	connection pending
	10	connection open
	11	connection failed
2	0	no data pending
	1	data pending

All other bits are reserved and must be zero.

When this call returns to your **terminal emulator** you must examine the state of these flags:

- If the connection failed (bits 0 and 1 are set) and no data is pending (bit 2 is clear) you must attempt to close the connection by calling Protocol_CloseConnection.

- If the connection is pending you must wait until bit 0 of the logical link's poll word is set. Then you should call either Protocol_DataRequest or Protocol_GetLinkState to find if the connection was opened, or if it failed.
- Bit 2 ('data pending') has exactly the same meaning as bit 0 of a logical link's poll word, and is provided to reduce the amount of polling that needs to be done. If it is set you should initiate the data transfer by calling Protocol_DataRequest.

Related SWIs

Protocol_OpenLogicalLink (offset 0), Protocol_CloseLogicalLink (offset 1), Protocol_OpenConnection (offset 3), Protocol_CloseConnection (offset 4)

Protocol_Break (Offset 10)

Forces a protocol module to generate a Break

On entry

R0 = protocol module's link handle

On exit

R0 = terminal emulator's link handle
R3 = protocol status flags

Use

Use this call in your **terminal emulator** to force a protocol module to generate a Break.

The **protocol module** generates a Break. The precise interpretation of this varies from module to module.

The documentation of a protocol module **must** state how it interprets this call.

The protocol status flags it returns have the following meanings:

Bits	Value	Meaning
0-1	00	no connection opened
	01	connection pending
	10	connection open
	11	connection failed
2	0	no data pending
	1	data pending

All other bits are reserved and must be zero.

When this call returns to your **terminal emulator** you must examine the state of these flags:

- If the connection failed (bits 0 and 1 are set) and no data is pending (bit 2 is clear) you must attempt to close the connection by calling Protocol_CloseConnection.
- If the connection is pending you have made an error in your programming by trying to use the connection before it has been properly opened.

- Bit 2 ('data pending') has exactly the same meaning as bit 0 of a logical link's poll word, and is provided to reduce the amount of polling that needs to be done. If it is set you should initiate the data transfer by calling Protocol_DataRequest.

Related SWIs

None

Protocol_SendFile (Offset 11)

Initiates sending a file over a protocol module's connection

On entry

R0 = protocol module's link handle
R1 = RISC OS file type
R2 = pointer to file name (null terminated)
R3 = estimated size of file (in bytes)
R4 = emulator send flags

On exit

R0 = terminal emulator's link handle
R1 = protocol status flags

Use

Use this call in your **terminal emulator** to initiate sending a file over a protocol module's connection.

The emulator send flags have the following meanings:

Bit	Meaning when set
0	transfer cannot be safely paused (ie is a RAM transfer)
1	transfer is part of a multiple file transfer

All other bits are reserved and must be zero.

The **protocol module** must ready itself to accept the file over the terminal emulator's logical link, and to send it over the connection that is associated with the link. When it is ready it must show this by setting bit 2 of the link's poll word.

If bit 1 of the emulator send flags is set (a multiple file transfer) and the protocol module uses dialogue box(es) to show the state of the transfer, it must use the same box(es) for each file in turn, rather than using a new one for each file.

The protocol status flags it returns have the following meanings:

Bits	Value	Meaning
0-1	00	no connection opened
	01	connection pending
	10	connection open
	11	connection failed

All other bits are reserved and must be zero.

When this call returns to your **terminal emulator** you must examine the state of these flags:

- If the connection failed (bits 0 and 1 are set) and no data is pending (bit 2 of the link's poll word is clear) you must attempt to close the connection by calling Protocol_CloseConnection.
- If the connection is pending you have made an error in your programming by trying to use the connection before it has been properly opened.

When you start a file transfer with this call the link is in a paused state. You should wait for bit 2 of the link's poll word to be set before you try to resume the transfer by calling Protocol_SendFileData (see the next page).

Related SWIs

Protocol_TransmitData (offset 5), Protocol_SendFileData (offset 12), Protocol_AbortTransfer (offset 13), Protocol_DirOp (offset 18)

Protocol_SendFileData (Offset 12)

Sends the data in a file over a protocol module's connection

On entry

R0 = protocol module's link handle
R1 = pointer to transmit buffer
R2 = length of transmit buffer (in bytes)
R3 = emulator send data flags

On exit

R0 = terminal emulator's link handle
R1 = protocol status flags

Use

Use this call in your **terminal emulator** to send the data in a file over a protocol module's connection. You can (if necessary) split the file into separate data packets and repeatedly use this call to transmit each packet.

The emulator send data flags have the following meanings:

Bit	Meaning when set
0	last data packet of a file (ie EOF)
1	no data is included – end of file transfer

All other bits are reserved and must be zero.

You must not set both these bits at once, so a file transfer must end with two calls of this SWI: the first with bit 0 set (EOF), the second with bit 1 set (end of file transfer).

The **protocol module** sends the file over the connection that is associated with the link. If it has to pause the transfer it must show when it is ready to resume by setting bit 2 of the link's poll word.

The protocol status flags it returns have the following meanings:

Bits	Value	Meaning
0-1	00	no connection opened
	01	connection pending
	10	connection open
	11	connection failed
2-3	00	transfer not started
	01	transfer paused
	10	transfer completed
	11	transfer failed or aborted

All other bits are reserved and must be zero.

When this call returns to your **terminal emulator** you must examine the state of these flags:

- If the connection failed (bits 0 and 1 are set) and the transfer is not paused (bits 2-3 do not have the value 01) you must attempt to close the connection by calling Protocol_CloseConnection.
- If the connection is pending you have made an error in your programming by trying to use the connection before it has been properly opened.
- If the transfer is paused (bits 2-3 have the value 01) you must wait for bit 2 of the link's poll word to be set before making this call again to continue the transfer.

Related SWIs

Protocol_TransmitData (offset 5), Protocol_SendFile (offset 11), Protocol_AbortTransfer (offset 13), Protocol_DirOp (offset 18)

Protocol_AbortTransfer (Offset 13)

Aborts a file transfer

On entry

R0 = protocol module's link handle

On exit

R0 preserved

Use

Use this call in your **terminal emulator** to abort a file transfer.

The **protocol module** aborts the transfer and makes sure that the connection associated with the link is ready for other use.

Related SWIs

Protocol_SendFile (offset 11), Protocol_SendFileData (offset 12), Protocol_GetFileInfo (offset 14), Protocol_GetFileData (offset 15), Protocol_GetFile (offset 17)

Protocol_GetFileInfo (Offset 14)

Requests that a protocol module initiates forwarding a pending file

On entry

R0 = protocol module's link handle

On exit

R0 = terminal emulator's link handle
R1 = RISC OS file type
R2 = pointer to file name (null terminated)
R3 = 0, or estimated size of file if available (in bytes)

Use

Use this call in your **terminal emulator** to request that a protocol module initiates forwarding a pending file. You should do so:

- if bit 1 ('file pending') of the link's poll word is set.
  This will usually be as a result of your calling Protocol_GetFile to request that the file be sent.

The **protocol module** returns details of the file to the terminal emulator.

When this call returns to your **terminal emulator** you must use these details to get ready to receive the file, before calling Protocol_GetFileData to actually get the data.

Related SWIs

Protocol_DataRequest (offset 6), Protocol_AbortTransfer (offset 13), Protocol_GetFileData (offset 15), Protocol_GetFile (offset 17), Protocol_DirOp (offset 18)

Protocol_GetFileData (Offset 15)

Requests that a protocol module forwards the data in a file

On entry

R0 = protocol module's link handle
R1 = pointer to receive buffer
R2 = length of receive buffer (in bytes)

On exit

R0 = terminal emulator's link handle
R1 preserved
R2 = bytes of data placed in receive buffer
R3 = protocol status flags

Use

Use this call in your **terminal emulator** to request that a protocol module forwards the data in a file.

The **protocol module** must forward the file data to the terminal emulator. It can (if necessary) split the file into separate data packets, pausing the transfer after each packet. If so, it must show when it is ready to forward the next packet by setting bit 2 of the link's poll word.

The protocol status flags it returns have the following meanings:

Bits	Value	Meaning
0-1	00	no connection opened
	01	connection pending
	10	connection open
	11	connection failed
2-3	00	transfer not started
	01	transfer paused
	10	transfer completed
	11	transfer failed or aborted

All other bits are reserved and must be zero.

When this call returns to your **terminal emulator** you must examine the state of these flags:

- If the connection failed (bits 0 and 1 are set) and the transfer is not paused (bits 2-3 do not have the value 01) you must attempt to close the connection by calling Protocol_CloseConnection.
- If the connection is pending you have made an error in your programming by trying to use the connection before it has been properly opened.
- If the transfer is paused (bits 2-3 have the value 01) you must wait for bit 2 of the link's poll word to be set before making this call again to continue the transfer.

Related SWIs

Protocol_DataRequest (offset 6), Protocol_AbortTransfer (offset 13), Protocol_GetFileInfo (offset 14), Protocol_GetFile (offset 17), Protocol_DirOp (offset 18)

Protocol_MenuHelp (Offset 16)

This call is reserved for future expansion.

On entry

R0 = protocol module's link handle
R1 = pointer to menu selection array, relative to protocol-specific menu tree

On exit

R0, R1 preserved

Use

Use this call in your **terminal emulator** to request that a protocol module sends its interactive help message for the menu entry. The menu selection array you send must be terminated by a null.

The **protocol module** must send the appropriate help message.

Related SWIs

Protocol_GetProtocolMenu (offset 2), Protocol_MenuItemSelected (offset 7)

Protocol_GetFile (Offset 17)

Requests that a protocol module gets a file over a connection

On entry

R0 = protocol module's link handle
R1 = pointer to file name (null terminated)

On exit

R0, R1 preserved

Use

Use this call in your **terminal emulator** to request that a protocol module gets a file over a connection.

The **protocol module** gets the necessary information to respond to a Protocol_GetFileInfo call, and the first packet of the file to respond to a Protocol_GetFileData call, before showing that it ready by setting bit 1 ('file pending') of the link's poll word.

Related SWIs

Protocol_DataRequest (offset 6), Protocol_AbortTransfer (offset 13), Protocol_GetFileInfo (offset 14), Protocol_GetFileData (offset 15), Protocol_DirOp (offset 18)

Protocol_DirOp (Offset 18)

Performs various directory operations over a connection

On entry

R0 = protocol module's link handle
R1 = reason code
R2 = pointer to directory name – reason codes 1 & 2 only (null terminated)

On exit

R0 = terminal emulator's link handle
R1, R2 preserved
R3 = protocol status flags

Use

Use this call in your **terminal emulator** to perform various directory operations over a connection. The type of operation is set by a reason code in R1:

Reason code	Type of operation
0	null – see below
1	create directory
2	move into directory
3	move up one level in directory tree

The **protocol module** performs the specified operation. The protocol status flags it returns have the following meanings:

Bits	Value	Meaning
0-1	00	no connection opened
	01	connection pending
	10	connection open
	11	connection failed
2-3	00	invalid context
	01	operation in progress – paused
	10	operation completed
	11	operation failed or aborted

All other bits are reserved and must be zero.

When this call returns to your **terminal emulator** you must examine the state of these flags:

- If the connection failed (bits 0 and 1 are set) and there is no operation in progress (bits 2-3 do not have the value 01) you must attempt to close the connection by calling Protocol_CloseConnection.
- If the connection is pending you have made an error in your programming by trying to use the connection before it has been properly opened.
- If the operation is still in progress (bits 2-3 have the value 01) you must wait for bit 2 of the link's poll word to be set. You can then make this call again with a null reason code to read the flags for the completed operation.

Related SWIs

Protocol_SendFile (offset 11), Protocol_SendFileData (offset 12), Protocol_AbortTransfer (offset 13), Protocol_GetFileInfo (offset 14), Protocol_GetFileData (offset 15), Protocol_GetFile (offset 17)

85 Appendix H: Registering names

Introduction

Various names and numbers that appear in RISC OS must be registered with Acorn to ensure that they don't clash with those used by other programmers. This appendix tells you what those names and numbers are, and how to register them with Acorn.

Generally, you can propose the name(s) that you would like to use, and will be allocated them if they are previously unused. However, numbers are normally allocated consecutively, so you are unlikely to have any choice as to which ones you are allocated.

Acorn keeps a single central set of header files that record all such names and numbers. Your request will be checked against the relevant file. Finally, your allocation will be recorded in the file, and you will be informed of it.

Things requiring registration

Filetypes

If you need to use a new filetype, you must register it with Acorn.

You should give a proposed textual equivalent for the filetype (as used by the 'Full info' Filer displays), and a more complete description of the filetype's functionality and/or conformance to any standards. Acorn will then inform you whether your name is unique, and – if it is unique – which filetype number you have been allocated.

For a list of currently defined filetypes, see *Table C: File types* on page 6-487.

Associated sprites

Registering filetypes is necessary to prevent any clashes in the Wimp's sprite pool between different 'file_XXX' and 'small_XXX' sprites (where XXX is a hexadecimal filetype) used by the Filer to display the filetype. Once you have registered a filetype, you may consider such sprites as also registered.

Associated system variables

Registering filetypes is also necessary to prevent any clashes between FileSType_XXX, Alias$@LoadType_XXX, Alias$@PrintType_XXX and Alias$@RunType_XXX system variables (where XXX is a hexadecimal filetype). Once you have registered a filetype, you may consider such variables as also registered.

SWI chunk numbers and names

If you need to supply your own SWIs, you must ask Acorn for an allocation of a SWI chunk number, the use of the SWIs within which you can then determine yourself.

You should give a proposed name for the SWI chunk. Acorn will then inform you whether your name is unique, and – if it is unique – which SWI chunk number you have been allocated.

SWIs are named as *ChunkName_FunctionName* (so in Wimp_Initialise, Wimp is the chunk name, and Initialise is the function name). The chunk name is normally the name of the application or module providing the SWI, which will itself need registration – see below.

For more information on SWI numbers and names, see the chapter entitled *An introduction to* SWIs on page 1-21.

Wimp message numbers

If you need to use a new Wimp message, you must ask Acorn for an allocation of a range of Wimp message numbers, the use of which you can then determine yourself.

For more information on Wimp messages, see *Wimp_SendMessage* (SWI &400E7) on page 4-261.

Error numbers

If you need to generate your own errors, you must ask Acorn for an allocation of a range of error numbers, the use of which you can then determine yourself.

For more information on error numbers, see the section entitled *Error numbers* on page 1-38.

Filing system numbers and names

If you create your own filing system, you must register it with Acorn.

You should give a proposed name for the filing system, and a more complete description of its functionality and/or conformance to any standards. Acorn will then inform you whether your name is unique, and – if it is unique – which filing system number you have been allocated.

For a list of currently defined filing system numbers, see the section entitled *Filing system information word* on page 4-2.

Expansion cards: manufacturer codes and product type codes

If you create an expansion card, you must ask Acorn for an allocation of a manufacturer code and a product type code.

You should give a brief description of its functionality and/or conformance to any standards. Acorn will then inform you which codes you have been allocated.

For more information on these codes, see the section entitled *Extended Expansion Card Identity* on page 6-91.

CMOS RAM bytes

There are 4 bytes of CMOS RAM reserved for each expansion card slot, which your expansion cards may freely use; see the section entitled *Non-volatile memory* (CMOS RAM) on page 1-346. For all other purposes you should remember state in some other manner (for example using an *App*$Options system variable in a desktop boot file, or using a Choices file within your application). It is only in very exceptional circumstances that Acorn may allocate CMOS RAM bytes to other parties.

Country and alphabet numbers and names

If you need to use a new country or alphabet, you must register it with Acorn.

You should give a proposed name for the country or alphabet, and (for alphabets) a more complete description of its functionality and/or conformance to any standards. Acorn will then inform you whether your name is unique, and – if it is unique – which country or alphabet number you have been allocated.

For a list of currently defined country and alphabet numbers, see the section entitled *Names and numbers* on page 5-254.

DrawFile object types and tagged object types

If you need to use a new object type or tagged object type in a Draw file, you must register it with Acorn.

For an object type you should give full details of its file format. For a tagged object type you should give a brief description of the purpose of the tag. Acorn will then inform you which type numbers you have been allocated.

For a list of currently defined object IDs and tagged object IDs, see the section entitled *Draw files* on page 6-391.

Module names

If you create a new module, you must register it with Acorn, since only one module of a given name can be loaded at once.

You should give a proposed name for the module and a brief description of its functionality. Acorn will then inform you whether your name is unique, and hence if you may use it.

Associated system variables

Registering module names is also necessary to prevent any clashes between system variables used by modules, such as *Module*$Options. Once you have registered the module name '*Module*', you may consider all variables beginning with '*Module*$' as also registered.

To ensure there are no clashes with '*App*$' or '*Resource*$' system variables, Acorn will also check that your module name does not match any **other** programmers' registered application or shared resource names. However, you may register identical module, application and /or shared resource names; it is then your responsibility to prevent any clashes between your **own** system variables.

Application names

If you create a new application, you must register it with Acorn.

You should give a proposed name for the application and a brief description of its functionality. Acorn will then inform you whether your name is unique, and hence if you may use it.

Associated sprites

Registering application names is necessary to prevent any clashes in the Wimp's sprite pool between different application's '!*app*' and 'sm!*app*' sprites, used by the Filer to display the application directory's icon. Once you have registered an application name, you may consider such sprites as also registered.

Associated system variables

Registering application names is also necessary to prevent any clashes between system variables used by applications, such as *App*$Dir or *App*$Options. Once you have registered the application name '*App*', you may consider all variables beginning with '*App*$' as also registered.

To ensure there are no clashes with '*Module*$' or '*Resource*$' system variables, Acorn will also check that your application name does not match any **other** programmers' registered module or shared resource names. However, you may register identical module, application and /or shared resource names; it is then your responsibility to prevent any clashes between your **own** system variables.

Shared resources

If you create a new shared resource directory, you must register it with Acorn.

You should give a proposed name for the shared resource and a brief description of its functionality. Acorn will then inform you whether your name is unique, and hence if you may use it.

Associated sprites

Registering shared resource names is necessary to prevent any clashes in the Wimp's sprite pool between different shared resource's '!*resource*' and 'sm!*resource*' sprites (used by the Filer to display the shared resource directory's icon). Once you have registered an shared resource name, you may consider such sprites as also registered.

Associated system variables

Registering shared resource names is also necessary to prevent any clashes between system variables used by shared resources, such as *Resource*$Dir. Once you have registered the shared resource name '*Resource*', you may consider all variables beginning with '*Resource*$' as also registered.

To ensure there are no clashes with '*Module*$' or '*App*$' system variables, Acorn will also check that your shared resource name does not match any **other** programmers' registered module or application names. However, you may register identical module, application and /or shared resource names; it is then your responsibility to prevent any clashes between your **own** system variables.

* Commands

If you create a new * Command, you must register it with Acorn.

You should give a proposed name for the command, and a brief description of its functionality. Acorn will then inform you whether your name is unique, and hence if you may use it.

Sprite names

If you add a sprite to the Wimp sprite pool – for example using *IconSprites – you must register it with Acorn.

You should give a proposed name for the sprite. Acorn will then inform you whether your name is unique, and hence if you may use it.

Provided you have registered a filetype, application or shared resource, you need not register the associated sprites that the Filer uses to display them. See page 6-473, page 6-476 and page 6-477 respectively.

You should not register the names of sprites that are held in your applications' own sprite areas. Desktop applications must not use the system sprite pool.

Font names

If you create a new font, you must register it with Acorn.

You should give a proposed name for the font. Acorn will then inform you whether your name is unique, and hence if you may use it.

Device numbers

If you need to add a new device, you must ask Acorn for an allocation of a major and a minor device number.

You should give a brief description of the device's functionality. Acorn will then inform you which device numbers you have been allocated.

Printer driver numbers

If you create a new printer driver module, you must ask Acorn for an allocation of a printer driver number.

You should give a brief description of the printer driver's functionality. Acorn will then inform you which printer driver number you have been allocated.

To go elsewhere (Xref them)

Shared resources

The recommended approach is to create an application directory whose !Boot file sets up an environment variable which other applications which know about it use to access the shared resources (within the shared resource directory).

!System is an example of such a shared resource, which provides shared resources for the RISC OS welcome disc applications. Note that other applications may rely on using !System resources, **but** further resources **must not** be put into !System. These should instead go into their own shared resource directories, with names obtained by applying to Acorn.

This approach ensures that users can view shared resources as fixed objects that must be present for other applications to work, and not have to worry about what is inside them.

Where upgrades of a particular shared resource are concerned, the old copy should be archived and deleted from view, to avoid the possibility of accidental access to the old information. Note that if this does occur, the resulting error messages should make it clear to the user what he should do next.

Fonts

All Acorn font names should conform to:

fontname.[*weight*.[*style*]]

The weight element can only be omitted if there is no style element either, eg for a Symbol font.

Font names for all fonts mapping onto LaserWriter fonts (ie having the same metrics and general appearance) have been preallocated, to allow Acorn to produce a version of !PrinterPS that already knows the correct font name mappings.

These names are:

Churchill.Medium.Italic	ZapfChancery-MediumItalic
Clare.Medium	AvantGarde-Book
Clare.Medium.Oblique	AvantGarde-BookOblique
Clare.Demi	AvantGarde-Demi
Clare.Demi.Oblique	AvantGarde-DemiOblique
Corpus.Medium	Courier
Corpus.Medium.Oblique	Courier-Oblique
Corpus.Bold	Courier-Bold

Corpus.Bold.Oblique	Courier-BoldOblique
Homerton.Medium	Helvetica
Homerton.Medium.Oblique	Helvetica-Oblique
Homerton.Bold	Helvetica-Bold
Homerton.Bold.Oblique	Helvetica-BoldOblique
NewHall.Medium	NewCenturySchlbk-Roman
NewHall.Medium.Italic	NewCenturySchlbk-Italic
NewHall.Bold	NewCenturySchlbk-Bold
NewHall.Bold.Italic	NewCenturySchlbk-BoldItalic
Pembroke.Medium	Palatino-Roman
Pembroke.Medium.Italic	Palatino-Italic
Pembroke.Bold	Palatino-Bold
Pembroke.Bold.Italic	Palatino-BoldItalic
Robinson.Light	Bookman-Light
Robinson.Light.Italic	Bookman-LightItalic
Robinson.Demi	Bookman-Demi
Robinson.Demi.Italic	Bookman-DemiItalic
Selwyn	ZapfDingbats
Sidney	Symbol
Trinity.Medium	Times-Roman
Trinity.Medium.Italic	Times-Italic
Trinity.Bold	Times-Bold
Trinity.Bold.Italic	Times-BoldItalic

We have a program called !FontConv that can convert AFM (Adobe Format Metrics) files into IntMetrics files, to ensure that the correct metrics are used.

Printer drivers

Each 'PDriver' module used by the !PrinterXX applications has a unique 'printer number' assigned to it, to allow programs that know about particular printer types to take special action under some circumstances.

This only applies to people writing their own printer driver modules

Acorn can make the current printer driver source code available to you if required.

List of VDU codes

A list of the VDU codes is given in the table below. Some VDU codes require extra bytes to be sent as parameters; for example, VDU 22 (select screen mode) needs one extra byte to specify the mode. The number of extra bytes needed is also given in the table:

VDU code	Ctrl plus	Extra bytes	Meaning
0	@	0	Does nothing
1	A	1	Sendss next character to printer only
2	B	0	Enables printer
3	C	0	Disables printer
4	D	0	Writes text at text cursor
5	E	0	Writes text at graphics cursor
6	F	0	Enables VDU driver
7	G	0	Generates bell sound
8	H	0	Moves cursor back one character
9	I	0	Moves cursor on one space
10	J	0	Moves cursor down one line
11	K	0	Moves cursor up one line
12	L	0	Clears text window
13	M	0	Moves cursor to start of current line
14	N	0	Turns on page mode
15	O	0	Turns off page mode
16	P	0	Clears graphics window
17	Q	1	Defines text colour
18	R	2	Defines graphics colour
19	S	5	Defines logical colour
20	T	0	Restores default logical colours
21	U	0	Disables VDU drivers
22	V	1	Selects screen mode
23	W	9	Multi-purpose command
24	X	8	Defines graphics window
25	Y	5	PLOT command
26	Z	0	Restores default windows
27	[	0	Does nothing
28	\	4	Defines text window

VDU code	Ctrl plus	Extra bytes	Meaning
29	]	4	Defines graphics origin
30	^	0	Homes text cursor
31	_	2	Moves text cursor

87 Table B: Modes

The modes available in RISC OS depend on the configured monitor type (see *Configure MonitorType on page 2-232) and the model of computer. Below is a table of all modes provided by RISC OS, which shows:

- the mode number
- the text resolution in columns × rows
- the graphics resolution in pixels, which corresponds to the clarity of the mode's display
- the resolution in OS units, which corresponds to the area of workspace shown by the mode
- the number of logical colours available
- the memory used per screen to the nearest 0.1Kbyte
- the vertical refresh rate to the nearest Hz (invalid for monitor type 5), which indicates the degree of flickering that you may perceive
- the bandwidth used to display the screen to the nearest 0.1Mbyte/second, which corresponds to the load the mode places on the computer
- the monitor types that support that mode:

Type	Monitor	
0	50Hz TV standard colour or monochrome monitor	
1	Multiscan monitor	
2	Hi-resolution 64Hz monochrome monitor	
3	VGA-type monitor	
4	Super-VGA-type monitor	(not available in RISC OS 2)
5	LCD (liquid crystal display)	(not available in RISC OS 2)

- the notes on the following page that are relevant to the mode.

Mode	Text resolution	Pixel resolution	OS units resolution	Logical colours	Mem used	Refresh rate	Band-width	Monitor types	Notes
0	80 × 32	640 × 256	1280 × 1024	2	20K	50Hz	1M/s	0,1,3,4,5	③
1	40 × 32	320 × 256	1280 × 1024	4	20K	50Hz	1M/s	0,1,3,4,5	③
2	20 × 32	160 × 256	1280 × 1024	16	40K	50Hz	2M/s	0,1,3,4,5	③
3	80 × 25	Text only	Text only	2	40K	50Hz	2M/s	0,1,3,4,5	③⑤⑦
4	40 × 32	320 × 256	1280 × 1024	2	20K	50Hz	1M/s	0,1,3,4,5	③
5	20 × 32	160 × 256	1280 × 1024	4	20K	50Hz	1M/s	0,1,3,4,5	③
6	40 × 25	Text only	Text only	2	20K	50Hz	1M/s	0,1,3,4,5	③⑤⑦
7	40 × 25	Teletext	Teletext	16	80K	50Hz	4M/s	0,1,3,4,5	③⑤
8	80 × 32	640 × 256	1280 × 1024	4	40K	50Hz	2M/s	0,1,3,4,5	③
9	40 × 32	320 × 256	1280 × 1024	16	40K	50Hz	2M/s	0,1,3,4,5	③
10	20 × 32	160 × 256	1280 × 1024	256	80K	50Hz	4M/s	0,1,3,4,5	③
11	80 × 25	640 × 250	1280 × 1000	4	39.1K	50Hz	2M/s	0,1,3,4,5	③⑧
12	80 × 32	640 × 256	1280 × 1024	16	80K	50Hz	4M/s	0,1,3,4,5	③
13	40 × 32	320 × 256	1280 × 1024	256	80K	50Hz	4M/s	0,1,3,4,5	③
14	80 × 25	640 × 250	1280 × 1000	16	78.2K	50Hz	3.9M/s	0,1,3,4,5	③⑧
15	80 × 32	640 × 256	1280 × 1024	256	160K	50Hz	8M/s	0,1,3,4,5	③
16	132 × 32	1056 × 256	2112 × 1024	16	132K	50Hz	6.6M/s	0,1	⑥
17	132 × 25	1056 × 250	2112 × 1000	16	129K	50Hz	6.5M/s	0,1	⑥⑧
18	80 × 64	640 × 512	1280 × 1024	2	40K	50Hz	2M/s	1	
19	80 × 64	640 × 512	1280 × 1024	4	80K	50Hz	4M/s	1	
20	80 × 64	640 × 512	1280 × 1024	16	160K	50Hz	8M/s	1	
21	80 × 64	640 × 512	1280 × 1024	256	320K	50Hz	16M/s	1	
23	144 × 56	1152 × 896	2304 × 1792	2	126K	64Hz	8.1M/s	2	
24	132 × 32	1056 × 256	2112 × 1024	256	264K	50Hz	13.2M/s	0,1	⑥
25	80 × 60	640 × 480	1280 × 960	2	37.5K	60Hz	2.3M/s	1,3,4,5	
26	80 × 60	640 × 480	1280 × 960	4	75K	60Hz	4.5M/s	1,3,4,5	
27	80 × 60	640 × 480	1280 × 960	16	150K	60Hz	9M/s	1,3,4,5	
28	80 × 60	640 × 480	1280 × 960	256	300K	60Hz	18M/s	1,3,4,5	
29	100 × 75	800 × 600	1600 × 1200	2	58.6K	56Hz	3.3M/s	1,4	①②
30	100 × 75	800 × 600	1600 × 1200	4	117.2K	56Hz	6.6M/s	1,4	①②
31	100 × 75	800 × 600	1600 × 1200	16	234.4K	56Hz	13.2M/s	1,4	①②
33	96 × 36	768 × 288	1536 × 1152	2	27K	50Hz	1.4M/s	0,1	①
34	96 × 36	768 × 288	1536 × 1152	4	54K	50Hz	2.7M/s	0,1	①
35	96 × 36	768 × 288	1536 × 1152	16	108K	50Hz	5.4M/s	0,1	①
36	96 × 36	768 × 288	1536 × 1152	256	216K	50Hz	10.8M/s	0,1	①
37	112 × 44	896 × 352	1792 × 1408	2	38.5K	60Hz	2.3M/s	1	①
38	112 × 44	896 × 352	1792 × 1408	4	77K	60Hz	4.6M/s	1	①
39	112 × 44	896 × 352	1792 × 1408	16	154K	60Hz	9.2M/s	1	①
40	112 × 44	896 × 352	1792 × 1408	256	308K	60Hz	18.5M/s	1	①
41	80 × 44	640 × 352	1280 × 1408	2	27.5K	60Hz	1.7M/s	1,3,4,5	①③④
42	80 × 44	640 × 352	1280 × 1408	4	55K	60Hz	3.3M/s	1,3,4,5	①③④
43	80 × 44	640 × 352	1280 × 1408	16	110K	60Hz	6.6M/s	1,3,4,5	①③④
44	80 × 25	640 × 200	1280 × 800	2	15.7K	60Hz	0.9M/s	1,3,4,5	①③
45	80 × 25	640 × 200	1280 × 800	4	31.3K	60Hz	1.9M/s	1,3,4,5	①③
46	80 × 25	640 × 200	1280 × 800	16	62.5K	60Hz	3.8M/s	1,3,4,5	①③

Notes on display modes

1 These modes are not available in RISC OS 2.00, nor (except for mode 31) are they available in RISC OS 2.01.

2 These modes are not available on early models of RISC OS computers (ie the Archimedes 300 and 400 series, and the A3000), because they are unable to clock VIDC at the necessary rate.

3 These modes are handled differently with a VGA or Super-VGA-type monitor. **If you are using such a monitor**:

- RISC OS 2.00 does not implement these modes.
- The picture is displayed on a screen having 352 raster lines. Where a mode has fewer than 352 vertical pixels, it is centred on the screen with blank rasters at the top and bottom. Because of their appearance these modes are known as *letterbox modes*.
- The refresh rate is 70Hz.
- The bandwidths shown in the table for these modes are lower than these monitor types consume, because no allowance has been made for the blank rasters.
- Early models of RISC OS computers (ie the Archimedes 300 and 400 series, and the A3000) scan these modes some 4.7% slow. Again this is because they are unable to clock VIDC at the necessary rate. Most VGA and Super-VGA-type monitors can still successfully lock onto this signal, but some may not. Furthermore, these models do not provide a *Sync Polarity* signal. This makes the effect of *letterbox modes* (see above) more severe.

4 Early models of RISC OS computers (ie the Archimedes 300 and 400 series, and the A3000) also scan these modes some 4.7% slow with multiscan monitors. Again this is because they are unable to clock VIDC at the necessary rate.

5 These modes do not display graphics, for compatibility with BBC/Master series computers.

6 In these modes circles, arcs, sectors and segments do not look circular. This is because the aspect ratio of the pixels is not in a 1:2, 1:1 or 2:1 ratio.

7 This is a *gap mode*, where the colour of the gaps is not necessarily the same as the text background.

8 These modes are not a multiple of eight pixels high. By default, in these modes the bottom of the screen corresponds to the bottom line of ECF patterns, but the top line will not correspond to the top line of ECF patterns.

Modes 22 and 32 have not been defined.

If an attempt is made to select a mode which is not appropriate to the current monitor type (or OS version), a suitable mode for that monitor is used. For example, an attempt to select mode 23 on a type 0 monitor will result in mode 0 being used.

In 256 colour modes, there are some restrictions on the control of the colours. Only 64 base colours may be selected; 4 levels of tinting turn the base colours into 256 shades. Also, the selection from the colour palette of 4096 shades is only possible in groups of 16.

88 Table C: File types

List of file types

File types are three-digit hexadecimal numbers. They are divided into three ranges:

E00 - FFF	reserved for use by Acorn
800 - DFF	may be allocated to software houses (A00 to AFF are used for Acornsoft files, 800 to 80C for BBC uniform files)
000 - 7FF	free for users

For each type, there may be a default action on loading and running the file. These actions may change, depending on whether the desktop is in use, and which applications have been seen. The system variables Alias$@LoadType_XXX and Alias$@RunType_XXX give the actions (XXX = file type).

Some types have a textual equivalent set at start-up, which may be used in most commands (but not in the above system variables) instead of the hexadecimal code. These are indicated in the table below by a double dagger '‡', or by a single dagger '†' if not available in RISC OS 2. For example, file type &FFF is set at start-up to have the textual equivalent *Text*. Other textual equivalents may be set as an application starts – for example, Acorn Desktop Publisher sets up file type &AF9 to be *DtpDoc*, and file type &AFA to be *DtpStyle*. These textual equivalents are set using the system variables File$Type_XXX, where XXX is the hexadecimal file type.

The following types are currently used or reserved by Acorn. Most file types used by other software houses are not shown. This list may be extended from time to time:

Acorn file types

Type	Description	Textual equivalent	
FFF	Plain ASCII text	Text	‡
FFE	Command (Exec) file	Command	‡
FFD	Data	Data	‡
FFC	Position independent code	Utility	‡
FFB	Tokenised BASIC program	BASIC	‡
FFA	Relocatable module	Module	‡
FF9	Sprite or saved screen	Sprite	‡
FF8	Absolute application loaded at &8000	Absolute	‡
FF7	BBC font file (sequence of VDU operations)	BBC font	‡
FF6	Fancy font (4 bpp bitmap only)	Font	‡

FF5	PostScript	PoScript	‡
FF4	Dot Matrix data file	Printout	†
FF3	LaserJet data file	LaserJet	
FF2	Configuration (CMOS RAM)	Config	†
FF1	Raw unprocessed data (eg terminal streams)	RawData	
FF0	Tagged Image File Format	TIFF	
FEF	Diary data	Diary	
FEE	NotePad data	NotePad	
FED	Palette data	Palette	‡
FEC	Template file	Template	‡
FEB	Obey	Obey	‡
FEA	Desktop	Desktop	†
FE9	ViewWord	ViewWord	
FE8	ViewPS	ViewPS	
FE7	ViewSheet	ViewSht	
FE6	UNIX executable	UNIX Ex	
FE5	EPROM image	EPROM	
FE4	DOS file	DOS	†
FE3	Atari file	Atari	
FE2	Commodore Amiga file	Amiga	
FE1	Make data	Make	
FE0	Desktop accessory	Accessry	
FDF	TCP/IP suite: VT220 script	VTScript	
FDE	TCP/IP suite: VT220 setup	VTSetup	
FDD	Master utilities	MasterUtl	
FDC	TCP/IP suite: unresolvable UNIX soft link	SoftLink	
FDB	Text using CR and LF for line ends	TextCRLF	
FDA	PC Emulator: DOS batch file	MSDOSbat	
FD9	PC Emulator: DOS executable file	MSDOSexe	
FD8	PC Emulator: DOS command file	MSDOScom	
FD7	Obey file in a task window	TaskObey	†
FD6	Exec file in a task window	TaskExec	†
FD5	DOS Pict	Pict	
FD4	International MIDI Assoc. MIDIfiles standard	MIDI	
FD3	Acorn DDE: debuggable image	DebImage	
FD2	SrcFiler: diff file	SrcDiff	
FD1	BASIC stored as text	BASICTxt	
FD0	PC Emulator: configuration	PCEmConf	
FCF	Font cache	FontCache	†
FCE	FileCore floppy disc image	FileCoreFloppyDisc	
FCD	FileCore hard disc image	FileCoreHardDisc	
FCC	Device object within DeviceFS	Device	†
FCA	Single compressed file	Squash	

FC9	Sun raster file	SunRastr	
FC8	DOS MultiFS disc image	DOSDisc	
F0E	BBC Econet utilities	EconetUtl	
F09	BBC Winchester utilities	WiniUtil	

Industry standard file types

Type	Description	Textual equivalent
DFE	Comma separated variables	CSV
DEA	Data exchange format (AutoCAD etc)	DXF
DB4	SuperCalc III file	SuperCalc
DB3	DBase III file	DBaseIII
DB2	DBase II	DBaseII
DB1	DBase index file	DBaseIndex
DB0	Lotus 123 file	Lotus123
CE5	$\TeX$ file	TeX
CAF	IGES file	IGIS
CAE	Hewlett-Packard graphics language	HPGLPlot
C85	JPEG (Joint Photographic Experts Group) file	JPEG

BBC ROM file type

Type	Description	Textual equivalent	
BBC	BBC ROM file (ROMFS)	BBC ROM	‡

Acornsoft file types

Type	Description	Textual equivalent	
AFF	Draw file	DrawFile	†
AFE	Mouse event record	Mouse	
AFD	GCAL source file	Gcal	
AFC	GCODE intermediate file	GcalOut	
AFB	PhonePad file	PhonePad	
AFA	DTP style file	DtpStyle	
AF9	DTP documents	DtpDoc	
AF8	First Word Plus file	1stWord+	
AF7	Help file	HelpInfo	
AF6	ASim trace file	SimTrace	
AF5	Query form	Query	
AF4	EMail cabinet	EMail	
AF3	Disc image	Duplicate	
AF2	Nova file	Nova	
AF1	Maestro file	Music	

AF0	ArcWriter file	ARCWriter	
AE9	Alarm file	Alarms	†
ADB	Outline font	New Font	

BBC Uniform file types

Type	Description	Textual equivalent
80C	Stationery pad	StationaryPad
80B	Videotex file	VideoTex
80A	Database form file	DataBaseForm
809	Database file	DataBase
808	UniForm PostScript file	UniformPostScript
807	Graphs and charts file	GraphsAndCharts
806	Graphics file	Graphics
805	Drawing file	Drawing
804	Picture file	Picture
803	Spreadsheet file	Spreadsheet
802	UniForm Text only file	UniformText
801	Wordprocessor file	Wordprocessor
800	General BBC UniForm file	Uniform

89 Table D: Character sets

Introduction

A list of the eight alphabet sets available on your Acorn computer are included in this table. Most are based on the International Standards Organisation ISO 8859 document.

The description of the *Country command on page 5-274 explained the relationship between ***country***, ***alphabet*** and ***keyboard***. There are some useful keyboard shortcuts which you can use to switch between alphabets while you are working. You can use these wherever you can use the keyboard: for example, in the Command Line, in Edit, or when entering a filename to save a file. The first two keystroke combinations allow you to switch easily between alphabets.

Alt Ctrl F1	Selects the keyboard layout appropriate to the country UK.
Alt Ctrl F2	Selects the keyboard layout appropriate to the country for which the computer is configured (if available).

Alt <ASCII code typed on numeric keypad>
Enters the character corresponding to the decimal ASCII number typed.

The following sequence also switches the keyboard layout:

1. Press and hold Alt and Ctrl together; press F12.
2. Release Ctrl.
3. Still holding Alt, type on the numeric keypad the international telephone dialling code for the country you want (eg 049 for Germany, 039 for Italy, 033 for France).
4. Release Alt.

Latin1 alphabet (ISO 8859/1)

This is the default alphabet used by Acorn computers.

3			#	3	C	S	c	s			£	³	Ã
4			$	4	D	T	d	t			¤	´	Ä
5			%	5	E	U	e	u			¥	µ	Å
6			&	6	F	V	f	v			¦	¶	Æ
7			'	7	G	W	g	w			§	·	Ç
8			(	8	H	X	h	x			¨	¸	È
9			)	9	I	Y	i	y			©	¹	É
A			*	:	J	Z	j	z			ª	º	Ê
B			+	;	K	[	k	{			«	»	Ë
C			,	<	L	\	l	|			¬	¼	Ì
D			-	=	M	]	m	}			-	½	Í
E			.	>	N	^	n	~			®	¾	Î
F			/	?	O	_	o				¯	¿	Ï

Latin2 alphabet (ISO 8859/2)

3			#	3	C	S	c	s			Ł	ł	A
4			$	4	D	T	d	t			¤	´	Ä
5			%	5	E	U	e	u			Ľ	ľ	Ĺ
6			&	6	F	V	f	v			Ś	ś	Ć
7			'	7	G	W	g	w			§	ˇ	Ç
8			(	8	H	X	h	x			¨	¸	Č
9			)	9	I	Y	i	y			Š	š	É
A			*	:	J	Z	j	z			Ş	ş	Ę
B			+	;	K	[	k	{			Ť	ť	Ë
C			,	<	L	\	l	|			Ź	ź	Ě
D			-	=	M	]	m	}			-	˝	Í
E			.	>	N	^	n	~			Ž	ž	Î
F			/	?	O	_	o				Ż	ż	Ď

Latin3 alphabet (ISO 8859/3)

3			#	3	C	S	c	s			£	³	
4			$	4	D	T	d	t			¤	´	Ä
5			%	5	E	U	e	u				µ	Ċ
6			&	6	F	V	f	v			Ĥ	ĥ	Ĉ
7			'	7	G	W	g	w			§	·	Ç
8			(	8	H	X	h	x			¨	¸	È
9			)	9	I	Y	i	y			İ	ı	É
A			*	:	J	Z	j	z			Ş	ş	Ê
B			+	;	K	[	k	{			Ğ	ğ	Ë
C			,	<	L	\	l	|			Ĵ	ĵ	Ì
D			-	=	M	]	m	}			-	½	Í
E			.	>	N	^	n	~					Î
F			/	?	O	_	o				Ż	ż	Ï

Latin4 alphabet (ISO 8859/4)

3			#	3	C	S	c	s			Ŗ	ŗ	Ã
4			$	4	D	T	d	t			¤	´	Ä
5			%	5	E	U	e	u			Ĩ	ĩ	Å
6			&	6	F	V	f	v			Ļ	ļ	Æ
7			'	7	G	W	g	w			§	ˇ	Į
8			(	8	H	X	h	x			¨	¸	Č
9			)	9	I	Y	i	y			Š	š	É
A			*	:	J	Z	j	z			Ē	ē	Ę
B			+	;	K	[	k	{			Ģ	ģ	Ë
C			,	<	L	\	l	|			Ŧ	ŧ	Ė
D			-	=	M	]	m	}			-	Ŋ	Í
E			.	>	N	^	n	~			Ž	ž	Î
F			/	?	O	_	o				¯	ŋ	Ī

Greek alphabet (ISO 8859/7)

3			#	3	C	S	c	s			£	³	Γ
4			$	4	D	T	d	t				΄	Δ
5			%	5	E	U	e	u				΅	Ε
6			&	6	F	V	f	v			¦	Ά	Ζ
7			'	7	G	W	g	w			§	·	Η
8			(	8	H	X	h	x			¨	Έ	Θ
9			)	9	I	Y	i	y			©	Ή	Ι
A			*	:	J	Z	j	z				Ί	Κ
B			+	;	K	[	k	{			«	»	Λ
C			,	<	L	\	l	|			¬	Ό	Μ
D			-	=	M	]	m	}			-	½	Ν
E			.	>	N	^	n	~				Ύ	Ξ
F			/	?	O	_	o				—	Ώ	Ο

Bfont characters

This character set is
sake of compatibilit

	0	1	2	3	4	5	6	7	8	9	A	B	C
0	Nothing	Clear graphics		0	@	P	£	p	Ä	ä	°	╭	Ø
1	Next to printer	Define text colour	!	1	A	Q	a	q	Å	å	│	╮	Α
2	Start printer	Define graphics colour	"	2	B	R	b	r	Æ	æ	─	╰	Β
3	Stop printer	Define logical colours	#	3	C	S	c	s	Ç	ç	┌	╯	Γ
4	Separate cursors	Default logical colours	$	4	D	T	d	t	É	é	─	¿	Δ
5	Join cursors	Disable VDU	%	5	E	U	e	u	Ö	ö	┐	¡	Ε
6	Enable VDU	Select mode	&	6	F	V	f	v	Ü	ü	─	Ñ	Ζ
7	Bell	Reprogram characters	'	7	G	W	g	w	©	ì	┬	ñ	Η
8	Back	Define graphics area	(	8	H	X	h	x	←	î	╵	†	Θ
9	Forward	Plot	)	9	I	Y	i	y	→	ò	│	‡	Ι
A	Down	Default text / graphics areas	*	:	J	Z	j	z	↓	ô	└	'	Κ
B	Up	Nothing	+	;	K	[	k	{	↑	ù	├	`	Λ
C	Clear screen	Define text area	,	<	L	\	l	¦	à	û	┘	¶	Μ
D	Start of line	Define graphics origin	-	=	M	]	m	}	è	ÿ	┤	·	Ν
E	Paged mode	Move text cursor to (0,0)	.	>	N	^	n	~	ë	¤	┴	√	Ξ
F	Scroll mode	Move text cursor	/	?	O	_	o	Back space and delete	ê	§	┼	▒	Ο

Teletext characters

Teletext characters

Teletext alphanumeric

	0	1	2	3	4	5	6	7
0	Nothing	Nothing		0	@	P	£	p
1	Next to printer	Nothing	!	1	A	Q	a	q
2	Start printer	Nothing	"	2	B	R	b	r
3	Stop printer	Nothing	#	3	C	S	c	s
4	Nothing	Nothing	$	4	D	T	d	t
5	Nothing	Disable VDU	%	5	E	U	e	u
6	Enable VDU	Select mode	&	6	F	V	f	v
7	Bell	Reprogram characters	'	7	G	W	g	w
8	Back	Nothing	(	8	H	X	h	x
9	Forward	Nothing	)	9	I	Y	i	y
A	Down	Nothing	*	:	J	Z	j	z
B	Up	Nothing	+	;	K	←	k	¼
C	Clear Screen	Nothing	,	<	L	½	l	‖
D	Start of line	Nothing	-	=	M	→	m	¾
E	Paged mode	Move cursor to (0,0)	.	>	N	↑	n	÷
F	Scroll mode	Move cursor	/	?	O	—	o	Back space and delete

	8	9	A	B	C	D	E	F
0	Nothing	Nothing		0	@	P	—	p
1	Alpha red	Graphic red	!	1	A	Q	a	q
2	Alpha green	Graphic green	"	2	B	R	b	r
3	Alpha yellow	Graphic yellow	£	3	C	S	c	s
4	Alpha blue	Graphic blue	$	4	D	T	d	t
5	Alpha magenta	Graphic magenta	%	5	E	U	e	u
6	Alpha cyan	Graphic cyan	&	6	F	V	f	v
7	Alpha white *	Graphic white	'	7	G	W	g	w
8	Flash	Conceal display	(	8	H	X	h	x
9	Steady *	Contiguous graphics *	)	9	I	Y	i	y
A	Nothing	Separated graphics	*	:	J	Z	j	z
B	Nothing	Nothing	+	;	K	←	k	¼
C	Normal height *	Black * background	,	<	L	½	l	‖
D	Double height	New background	-	=	M	→	m	¾
E	Nothing	Hold graphics	.	>	N	↑	n	÷
F	Nothing	Release graphics *	/	?	O	#	o	■

* every line starts with these options

Teletext graphics

	0	1	2	3	4	5	6	7
0	Nothing	Nothing			@	P		
1	Next to printer	Nothing			A	Q		
2	Start printer	Nothing			B	R		
3	Stop printer	Nothing	#		C	S		
4	Nothing	Nothing			D	T		
5	Nothing	Disable VDU			E	U		
6	Enable VDU	Select mode			F	V		
7	Bell	Reprogram characters			G	W		
8	Back	Nothing			H	X		
9	Forward	Nothing			I	Y		
A	Down	Nothing			J	Z		
B	Up	Nothing			K	←		
C	Clear screen	Nothing			L	½		
D	Start of line	Nothing			M	→		
E	Paged mode	Move cursor to (0,0)			N	↑		
F	Scroll mode	Move cursor			O			Back space and delete

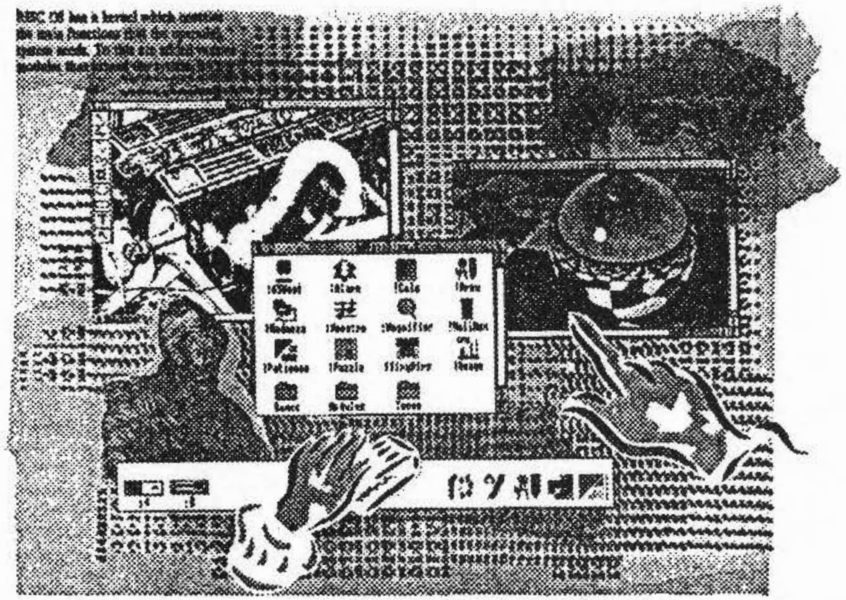
	8	9	A	B	C	D	E	F
0	Nothing	Nothing			@	P		
1	Alpha red	Graphic red			A	Q		
2	Alpha green	Graphic green			B	R		
3	Alpha yellow	Graphic yellow			C	S		
4	Alpha blue	Graphic blue			D	T		
5	Alpha magenta	Graphic magenta			E	U		
6	Alpha cyan	Graphic cyan			F	V		
7	Alpha white *	Graphic white			G	W		
8	Flash	Conceal display			H	X		
9	Steady *	Contiguous graphics *			I	Y		
A	Nothing	Separated graphics			J	Z		
B	Nothing	Nothing			K	←		
C	Normal height *	Black * background			L	½		
D	Double height	New background			M	→		
E	Nothing	Hold graphics			N	↑		
F	Nothing	Release graphics *			O	#		

* every line starts with these options

RISC OS

PROGRAMMER'S REFERENCE MANUAL

Indices



Acorn

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