The Advanced User Guide

for the Acorn Electron

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ACORNSOFT

Published by Adder Publishing, Cambridge

The “Acorn Electron Advanced User Guide” is published by Adder Publishing for Acornsoft Limited.

Acornsoft Limited, Betjeman House, 104 Hills Road, Cambridge, CR2 1LQ, England. Telephone (0223) 316039
ISBN 0907876 17 X

Adder Publishing, PO Box 148, Cambridge, CB1 2EQ
ISBN 0 947929 03 7

First published September 1984

The Authors would like to thank Nigel Dickens, Tim Dobson, Steve Furber, Tim Gleeson, David Johnson-Davies, Dr John Horton, Zahid Najam, Mark Plumbley, John Thackeray, Ken Vail, Geoff Vincent, Adrian Warner, Leycester Whewell, Albert Williams and everyone else who helped in the production of this book.

The Authors gratefully acknowledge Acorn Computers Limited for their kind permission to reproduce the complete Electron circuit diagram. The Authors would like to point out that Acorn Computers reserve the right to make improvements in the specification of its products. Therefore the circuit diagram and other contents of this book may not be in complete agreement with the product supplied.

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This book was prepared using the Acornsoft VIEW wordprocessor on the BBC
Microcomputer and then computer typeset by Parker Typesetting Service, Leicester.
Printed in Great Britain by The Burlington Press Ltd. Foxton, Cambridge.
Book production by Adder Publishing.

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Introduction

The *Advanced User Guide for the Electron* has been designed to be an invaluable reference guide for users of the Electron computer. The original *Electron User Guide* provides a description of BASIC on the Electron and reaches the point at which programming in Assembly Language is introduced, along with a very brief introduction to the available system calls. The Advanced User Guide takes over at this point by providing a thorough, well indexed and cross referenced description of all the available facilities and how to use them. This will allow the serious programmer to make the most of his/her machine, whilst keeping within the Acorn Guidelines to ensure compatibility with other machines in the Acorn BBC Micro series.

It is inevitable that a machine like the Electron should be partially overpowered by it's *big brother* the BBC Micro. However, many of the facilities which are provided on the larger machine can also be added on to an Electron. A whole new series of operating system calls have been provided to take account of this, and are described within these pages.

What may not at first sight be so apparent is that in many ways the Electron has more expansion potential than a BBC Micro! This is because *all* of the 6502 bus lines are available to expansion modules via the expansion connector. A full description of this connector, including interfacing details for paged ROMs and other devices have therefore been included.

The authors have tried to provide a book which will be found by the side of all enthusiastic Electron programmers. All material is in an easily accessible referenced format. Where appropriate, examples are presented and discussed. In particular, there is a large section concerned with the use of paged ROMs. It is intended that this should help programmers to build up the necessary skills for producing their own exciting software in ROMs.

All of the information contained in this book has been checked on an Electron fitted with Electron OS1.00 and BASIC 2. Where appropriate, an Electron Plus 1 expansion module was also used.

1 The Acorn Design Philosphy

A glance through the back pages of any microcomputer magazine will reveal a large number of machines ‘For Sale’. This is a reflection of the speed at which the industry moves; the all-new whizz-bang machine can become yesterday’s micro in as little as a year. The manufacturer has to tread a careful path; on the one hand he is committed to improving his products, but on the other he must not render his existing range obsolete.

The Acorn design philosophy has been to produce a system right from the start which would allow for growth in both the software and hardware. All users should be aware of this if they wish their own software and hardware to be compatible with the complete range of available systems, from a humble Electron right up to a machine with Econet, second processor, hard disks etc. Ensuring compatibility is not hard, it simply requires a little self-discipline in your approach.

The *rules* as such are simple. If your software needs to access anything outside its own domain (that is the memory and other resources it has been provided with) then use the officially supported operating system routines. The second is to make no assumptions about the environment your program will run under. This includes the amount of memory available, the processor and any other software / hardware components which might be there. Run-time enquiries have been built into the system to allow you to discover these facilities.

Programs which run in RAM, say a simple Basic program, may discover that there is not enough memory available for them. A test for this should be made at the start of the program, since they should not be allowed to crash and should never use any memory outside their allocation. Programs placed in ROM should not make assumptions about their eventual run-time environment either. They may find themselves copied over the Tube and running in RAM on another processor!
One of the most common situations on the BBC microcomputer

where incompatability arises, is where software is designed for use on non-Econet machines and then used on such machines. This ultimately denies the software producer a sale and denies the Econet machine owner use of a particular program. This is a situation which can be avoided by intelligent software design and reasonable product testing. The Electron contains fewer pitfalls in this respect, but where software is destined for a wider distribution, the programmer should think about different machine configurations and potential problems.

2 OPERATING SYSTEM CALLS

The list below contains all the Acorn supported operating system routines and their vectors which exist in the Electron OS 1.0. See the *User Guide* for a general description of these calls.

2.1 OSWRCH Write character routine

Call address &FFEE Indirected through &20E

This routine outputs the character in the accumulator to the currently selected output stream(s).

On exit:

A, X and Y are preserved.
C, N, V and Z are undefined.

The interrupt status is preserved (though interrupts may be enabled during a call).

2.2 Non-vectored OSWRCH

Call address &FFCB

This call is normally made by OSWRCH. This call has no vector and so cannot be intercepted. Its use is not recommended for this reason.

2.3 OSRDCH Read character routine

Call address &FFEO Indirected through &210

This routine reads a character from the currently selected input stream and returns it in the accumulator.

On exit:
C=0 indicates that a valid character has been read. C= 1 indicates that a character has not been read due to an error.

If an error should occur acknowledgement of the error condition should be made using OSBYTE &7E.

X and Y are preserved.
N, V and Z are undefined.

The interrupt status is preserved (though interrupts may be enabled during a call).

2.4 Non-vectored OSRDCH

Call address &FFC8

This call is normally made by OSRDCH, it is not available for interception and its use is not recommended by Acorn.

2.5 OSNEWL Write a newline routine

Call address &FFE7 Not indirected

This routine writes a line feed (&A/10*)* and a carriage return (&D/13) to the current output stream(s) using OSWRCH.

On exit:

A=&0D (13)
X and Y are preserved.
C, N, V and Z are undefined.

Interrupt status is preserved (though it may be enabled during a call).

2.6 OSASCI Write character routine, OSNEWL called if A=&0D (13).

Call address &FFE3 Not indirected

This is a write character routine performing the same action as OSWRCH but which outputs a line feed and a carriage return in response to a carriage return character.

On exit:

A, X and Y are preseved.
C, N, V and Z are undefined.

Interrupt status is preserved (though interrupts may be enabled during a call).

2.7 GSINIT General *string* input initialise routine.

Call address &FFC2

The original intention was that this routine together with GSREAD would provide a standard string input facility for the use of filing system paged ROMs. It is now felt that this routine is unsuitable for that purpose and accordingly its use is not recommended.

This routine initialises a string for input prior to reading using GSREAD.

Entry parameters:

String address stored in &F2 and &F3 plus offset in Y
C=0, if first space, CR or second" terminates input
C= 1, if first space does not terminate input

On exit:

Y contains the offset of the first non-blank character from the address contained in &F2 and &F3.

A contains the first non-blank character of string

Z flag is set if the string is a null string

2.8 GSREAD Read character from string input routine.

Call address &FFC5

This routine is used to read characters from an input string after a GSINIT call. Control codes and non-ASCII values may be introduced into the input string by using an escape character, '|'. The escape character followed by a letter gives a character value equal to the ASCII value minus 64 (&40). The escape character followed by a '1' character gives a value of 128 plus the value of the next character in the string. An escape character followed by itself gives the escape character.

Entry parameters:

&F2, &F3 and Y set by GSLNLT

C=0 String terminated by first space, carriage return or second quotation mark.

C= 1 String terminated by carriage return or second quotation mark.

On exit:

A contains the character read from the string.
Y contains the index for the next character to be read.
C= 1 if the end of string is reached.
X is preserved.

2.9 OSRDRM Read byte from paged ROM routine.

Call address &FFB9

Entry parameters:

ROM number stored in Y.

Address stored in &F6 and &F7.

This call returns a byte read from a paged ROM.

On exit:

A contains the value of the byte read.

This routine was included for the implementation of ROM filing system software in paged ROM and is not recommended for general use.

2.10 OSEVEN Generate an event routine.

Call address &FFBF

The user event may be generated using this routine. Software replacing OS routines should generate the appropriate events by making this call.

Entry parameter:

The event number should be placed in Y.

On exit:

C=0 if and only if the event was enabled.

2.11 OSCLI Pass string to the CLI.

Call address &FFF7 Indirected through &208

This routine is implemented on the BBC micro, the Electron and the Tube operating system.

This call provides the machine code user with a convenient method of performing any of the *commands that the system provides from Basic. The command required is placed in a string as normal text and this call is made.

If the string passed to the CLI is not terminated by a carriage return within 255 bytes this routine has undefined effects.

The following commands are recognised:

*****	*String escape character* rest of command ignored
***.**	treated as a *CAT command
*/	treated as a *RUN command
*BASIC	select BASIC as current language
*CAT	issue catalogue request to filing system
*CODE	passed to user vector (see chapter 6)
*EXEC	select text file as input stream

*FX	issue OSBYTE call (no registers returned)
*HELP	issue paged ROM service call 9, see chapter 10
*KEY	take rest of line as text for soft key
*LINE	passed to user vector (see chapter 6)
*LOAD	issue load request to filing system
*MOTOR	open/close cassette motor relay
*OPT	issue option request to filing system
*ROM	select *ROM filing system
*RUN	issue load and execute request to filing system
*SAVE	issue save request to filing system
*SPOOL	include text file in output stream
*TAPE	select tape filing system
*TV	ignored by the Electron

These commands may be abreviated by taking the first few letters and terminating with a '.' character. Parameters may be passed in the text following the command.

Other *unrecognised commands* are first offered to paged ROMs (see section 10.1) and are then offered to the currently selected filing system via the filing system control vector (see chapter *5).*

Entry parameters:

X and Y contain the address of a line of text (X=low-byte, Y=high-byte) terminated by a CR character.

On exit:

A, X, Y, C, N, V and Z are undefined. Interrupt status is preserved but interrupts may be enabled during a call.

3 OSBYTE CALLS

OSBYTE calls are a powerful and flexible way of invoking many of the available operating system facilities.

OSBYTE calls are specified by the contents of the accumulator (A register) in the *6502*. This means that up to *256* different calls can be made.

The command line interpreter (see section 2.11) performs OSBYTE calls in response to *FX commands. This enables the user to make OSBYTE calls from the keyboard or within BASIC programs. It should be noted however that no results are returned by a *FX call and so it is inappropriate to use certain OSBYTEs in this way.

OSBYTE Miscellaneous OS functions specified by the contents of the accumulator.

Call address &FFF4 Indirected through &20A

On entry:

A selects an OSBYTE routine.
X contains an OSBYTE parameter.
Y contains an OSBYTE parameter.

All calls are made to the OSBYTE subroutine at address &FFF4. This is then indirected through the vector at &20A (which means that user programs can intercept the OSBYTE calls before they get to the operating system if so desired). The selected function is determined by the accumulator contents. Two parameters can be passed to and from OSBYTE routines by putting the values to be passed in the X and Y registers respectively.

Example

Using OSBYTE 4 to disable cursor editing.

From BASIC this would be typed as:

```
*FX 4,1
```

From assembly language it could be performed as:

```
LDA     #4      \Load accumulator with 4
LDX     #1      \Select cursor disabled option
JSR     &FFF4   \Make OSBYTE call
```

If an OSBYTE is not recognised by the Electron, it will be *offered* to any fitted paged ROMs (see chapters 8 to 11). The OSBYTE will then usually be claimed by the relevant expansion module's ROM. When OSBYTE is called directly, if none of the paged ROMs claim it then the call returns with the overflow flag set. If the OSBYTE itself was initiated by a *FX command then the *FX handler will generate the 'Bad command' error.

When OSBYTE calls are used in a second processor only a limited amount of information is returned. For low numbered OSBYTE calls (0 to 127) only the X register is returned and for high numbered OSBYTE calls only the X and Y registers, and the carry flag are returned.

All the OSBYTE calls recognised by the operating system are described on the following pages. The description for each call includes details of the entry parameters required and the state of the registers on exit. All OSBYTE calls may be made using the *FX command, but it is not always appropriate to do so (i.e. those calls returning values in the X and Y registers). Where it is appropriate to use a *FX command this has been indicated. Preceding the full OSBYTE descriptions is a complete summary of the OSBYTE calls in a list.

OSBYTE/*FX Call Summary

dec.	hex.	function
0	0	Print operating system version.
1	1	Set the User flag.
2	2	Select input stream.
3	3	Select output stream.
4	4	Enable/disable cursor editing.
5	*5*	Select printer destination.
6	6	Set character ignored by printer.
7	7	Set RS423 baud rate for receiving data.
8	8	Set RS423 baud rate for data transmission.
9	9	Set flashing colour mark state duration.
10	A	Set flashing colour space state duration.
11	B	Set keyboard auto-repeat delay interval.
12	C	Set keyboard auto-repeat rate.
13	D	Disable events.
14	E	Enable events.
15	F	Flush selected buffer class.
16	10	Select ADC channels to be sampled.
17	11	Force an ADC conversion.
18	12	Reset soft keys.
19	13	Wait for vertical sync.
20	14	Explode soft character RAM allocation.
21	15	Flush specific buffer.
22	16	Increment paged ROM polling semaphore
23	17	Decrement paged ROM polling semaphore
24	18	Change sound system.

OSBYTE/*FX calls 25 (&19) to 114 (&72) are not used by OS 1.00.

115	73	Blank/restore palette.
116	74	Reset internal sound system.
117	75	Read VDU status.
118	76	Read keyboard status.
119	77	Close any SPOOL or EXEC files.
120	78	Write to two-key-roll-over locations.

121	79	Perform keyboard scan.
122	7A	Perform keyboard scan from 16 (&10).
123	7B	Inform OS, printer driver going dormant.
124	7C	Clear ESCAPE condition.
125	7D	Set ESCAPE condition.
126	7E	Acknowledge detection of ESCAPE condition.
127	7F	Check for EOF on an open file.
128	80	Read ADC channel or get buffer status.
129	81	Read key with time limit or key depression.
130	82	Read machine high order address.
131	83	Read top of OS RAM address (OSHWM).
132	84	Read bottom of display RAM address (HIMEM).
133	85	Read bottom of display address for a given MODE.
134	86	Read text cursor position (POS and VPOS).
135	87	Read character at cursor position.
136	88	Perform *CODE.
137	89	Perform *MOTOR.
138	8A	Insert value into buffer.
139	8B	Perform *OPT.
140	8C	Perform *TAPE.
141	8D	Perform *ROM.
142	8E	Enter language ROM.
143	8F	Issue paged ROM service request.
144	90	Perform *TV (not implemented).
145	91	Get character from buffer.
146	92	Read from FRED. 1 MHz bus.
147	93	Write to FRED, 1 MHz bus.
148	94	Read from JIM, 1 MHz bus.
149	95	Write to JIM, 1 MHz bus.
150	96	Read from SHEILA, 1 MHz bus.
151	97	Write to SHEILA, 1 MHz bus.
152	98	Examine buffer status.
153	99	Insert character into input buffer.
154	9A	Reset video flash cycle.
155	9B	Reserved.
156	9C	Read/write 6850 control register and copy.
157	9D	‘Fast Tube B PUT.’
158	9E	Read from speech processor.
159	9F	Write to speech processor.
160	A0	Read VDU variable value.

OSBYTE/*FX calls 161 (&A1) to 165 (&A5) are not used by OS 1.00 and are reserved for future expansion.

166	A6	Read start address of OS variables (low byte).
167	A7	Read start address of OS variables (high byte).
168	A8	Read address of ROM pointer table (low byte).
169	A9	Read address of ROM pointer table (high byte).
170	AA	Read address of ROM information table (low byte).
171	AB	Read address of ROM information table (high byte).
172	AC	Read address of key translation table (low byte).
173	AD	Read address of key translation table (high byte).
174	AE	Read start address of OS VDU variables (low byte).
175	AF	Read start address of OS VDU variables (high byte).
176	BO	Read/write filing system timeout counter.
177	Bi	Read/write input source.
178	B2	Undefined
179	B3	Read/write primary OSHWM.
180	B4	Read/write current OSHWM.
181	B5	Read/write RS423 mode.
182	B6	Read character definition explosion state.
183	B7	Read/write cassette/ROM filing system switch.
184	B8	Undefined.
185	B9	Read/write timer paged ROM service call semaphore.
186	BA	Read/write ROM number active at last BRK (error).
187	BB	Read/write number of ROM socket containing BASIC.
188	BC	Read current ADC channel.
189	BD	Read/write maximum ADC channel number.
190	BE	Read ADC conversion type.
191	BF	Read/write RS423 use flag.
192	CO	Read RS423 control flag.
193	Cl	Read/write flash counter.
194	C2	Read/write space period count.
195	C3	Read/write mark period count.
196	C4	Read/write keyboard auto-repeat delay.
197	CS	Read/write keyboard auto-repeat period.
198	C6	Read/write *EXEC file handle.
199	C7	Read/write ***** SPOOL file handle.
200	C8	Read/write ESCAPE, BREAK effect.
201	C9	Read/write Econet keyboard disable.
202	CA	Read/write keyboard status byte.

203	CB	Read/write the ULA interrupt mask.
204	CC	Read/write Firm key pointer.
20S	CD	Read/write length of current firm key string.
206	CE	Read/write Econet OS call interception status.
207	CF	Read/write Econet OSRDCH interception status.
208	DO	Read/write Econet OSWRCH interception status.
209	Dl	Read/write speech suppression status.
210	D2	Read/write sound suppression status.
211	D3	Read/write BELL channel.
212	D4	Read/write BELL (CTRL G) sound information.
213	DS	Read/write BELL frequency.
214	D6	Read/write BELL duration.
21S	D7	Read/write startup message and !BOOT options.
216	D8	Read/write length of soft key string.
217	D9	Read/write number of lines printed since last page.
218	DA	Read/write number of items in VDU queue.
219	DB	Read/write External sound flag.
220	DC	Read/write ESCAPE character value.
221	DD	Read/write i/p buffer code interpretation status.
222	DE	Read/write i/p buffer code interpretation status.
223	DE	Read/write i/p buffer code interpretation status.
224	EO	Read/write i/p buffer code interpretation status.
225	El	Read/write function key status.
226	E2	Read/write firm key status.
227	E3	Read/write firm key status.
228	E4	Read/write CTRL±SHIFT±function key status.
229	ES	Read/write ESCAPE key status.
230	E6	Read/write flags determining ESCAPE effects.
231	E7	Reserved.
232	E8	Sound semaphore.
233	E9	Soft key pointer.
234	EA	Read flag indicating Tube presence.
235	EB	Read flag indicating speech processor presence.
236	EC	Read/write write character destination status.
237	ED	Read/write cursor editing status.
238	EE	Read/write OS workspace bytes.
239	EF	Read/write OS workspace bytes.
240	FO	Read country code.
241	Fl	Read/write user flag location.
242	F2	Read RAM copy of &FEO7.
243	F3	Read timer switch state.
244	F4	Read/write soft key consistency flag.

245	FS	Read/write printer destination flag.
246	F6	Read/write character ignored by printer.
247	F7	Read/write first byte of BREAK intercept code.
248	F8	Read/write second byte of BREAK intercept code.
249	F9	Read/write third byte of BREAK intercept code.
2S0	FA	Read/write OS workspace locations.
2S1	FB	Read/write OS workspace locations.
252	FC	Read/write current language ROM number.
253	FD	Read/write last BREAK type.
2S4	FE	Read/write available RAM.
2SS	FF	Read/write start up options.

OSBYTE &00 (0)

Identify OS version

See OSBYTE &81 for more information regarding OS

identification.

Entry parameters:

X=0	Execute BRK with a message giving the OS version
X<>0	RTS with OS version returned in X

On exit:

X=0, 05 1.00 or Electron 05 1.00
X=1, OS 1.20 or American OS
A and Y are preserved
C is undefined

OSBYTE &01 (1)

Set the user flag

Entry parameters:
The user flag is replaced by X

On exit:
X=old value

This call uses OSBYTE with A=&F1 (241). This OSBYTE call is left free for user applications and is not used by the operating system. The user flag has a default value is 0.

OSBYTE &02 (2)

Select input stream

In the Electron any call with X<>0 will result in an *unknown OSBYTE* service call being made to the paged ROMs unless a previous such call was recognised and thus changed the input source.

Entry parameters:
X determines input device(s)

*FX 2,0 X=0 keyboard selected, RS423 disabled
*FX 2,1 X=1 RS423 selected and enabled
*FX 2,2 X=2 keyboard selected, RS423 enabled

Default: *FX 2,0

On exit:
X=0 if previous input was from the keyboard X= 1 if previous input was from RS423

A is preserved
Y and C are undefined

OSBYTE &03 (3)

Select output stream

If RS423 output is selected in the Electron, paged ROM service calls are issued. In the absence of a suitable response this output is *sunk* (thrown away). The same applies to printer output if selected.

Bit 3 should not be used to enable the printer as this may conflict with the Econet protocol of claiming the printer.

Entry parameters:

X determines output device(s)

Bit	o/p selected if bit is set
0	Enables RS423 driver
1	Disables VDU driver
2	Disables printer driver
3	Enables printer, independent of CTRL B or C
4	Disables spooled output
5	Not used
6	Disables printer driver unless the character is preceded by a VDU 1 (or equivalent)
7	Not used

*FX 3,0 selects the default output options which are :

RS423 disabled
VDU enabled
Printer enabled (if selected by VDU 2)
Spooled output enabled (if selected by *SPOOL)

On exit:

A is preserved
X contains the old output stream status
Y and C are undefined

OSBYTE &04 (4)

Enable/disable cursor editing

Entry parameters:

X determines the status of the editing keys

*FX 4,0 X=0 Enable cursor editing (default setting)

*FX 4,1 X=1 Disable cursor editing and make them return normal ASCII values like the other keys.

The cursor control keys will return the following codes :

COPY &87 (13S)
LEFT &88 (136)
RIGHT &89 (137)
DOWN &8A (138)
UP &8B (139)

*FX 4,2 X=2 Disable cursor editing and make the keys act as soft keys with the following soft key associations :

COPY	11
LEFT	12
RIGHT	13
DOWN	14
UP	15

On exit:

A is preserved
X contains the previous status of the editing keys
Y and C are undefined

OSBYTE &05 (5)

Select printer destination

Entry parameters:
X determines print destination

*FX 5,0	X=0	Printer sink (printer output ignored)
*FX 5,1	X=1	Parallel output
*FX 5,2	X=2	RS423 output (sink if RS423 enabled)
*FX 5,3	X=3	User printer routine (see section 6.5)
*FX 5,4	X=4	Net printer (see section 6.5)

*FX 5,5 to *FX5,255 User printer routine (see section 6.5)

Default setting: *FX 5,0

On Exit:
A is preserved
X contains the previous *FX 5 setting
Y and C are undefined
Interrupts are enabled by this call
This call is not reset to default by a soft break

OSBYTE &06 (6)

Set character ignored by printer

Entry parameters:
X contains the character value to be ignored

*FX 6,10	X=10	This prevents LINE FEED characters being sent to the printer, unless preceded by VDU 1 (this is the default setting)

On exit:
A is preserved
X contains the previous *FX 6 setting
Y and C are undefined

This is not reset by soft BREAK.

OSBYTE &07 (7)

Set RS423 baud rate for receiving data

This routine is not implemented on the unexpanded Electron. If this OSBYTE is used on the electron an *unknown OSBYTE* service call is made to the paged ROMs.

This call is reserved for future expansion.

OSBYTE &08 (8)

Set RS423 baud rate for data transmission

This routine is not implemented on the unexpanded Electron. If this OSBYTE is used on the electron an *unknown OSBYTE* service call is made to the paged ROMs.

This call is reserved for future expansion.

OSBYTE &09 (9)

Set duration of the mark state of flashing colours

(Duration of first named colour)

Entry parameters:
X determines duration

*FX 9,0 X=0 Sets mark duration to infinity
Forces mark state if space is set to 0
*FX 9,n X=n Sets mark duration to n VSYNC periods
(n=25 is the default setting)

On exit:
A is preserved
X contains the old mark duration
Y and C are undefined

OSBYTE &0A (10)

Set duration of the space state of flashing colours

(Duration of second named colour)

Entry parameters:
X determines duration

*FX 10,0 X=0 Sets space duration to infinity Forces space state if mark is set to 0
*FX 10,n X=n Sets space duration to n VSYNC periods *(n=25* is the default setting)

On exit:
A is preserved
X contains the old space duration
Y and C are undefined

OSBYTE &0B (11)

Set keyboard auto-repeat delay

Entry parameters:
X determines delay before repeating starts

*FX 11,0 X=0 Disables auto-repeat facility
*FX 11,n X=n Sets delay ton centiseconds (n=S0 is the default setting)

After call,
A is preserved
X contains the old delay setting
Y and C are undefined

OSBYTE &0C (12)

Set keyboard auto-repeat period

Entry parameters:
X determines auto-repeat periodic interval

*FX 12,0 X=0 Resets delay and repeat to default vals
*FX 12,n X=n Sets repeat interval to n centiseconds (n=8 is the default value)

On exit:
A is preserved
X contains the old *FX 12 setting
Y and C are undefined

OSBYTE &0D (13)

Disable events

Entry parameters : X contains the event code, Y=0

*FX 13,0	X=0	Disable output buffer empty event
*FX 13,1	X=1	Disable input buffer full event
*FX 13,2	X=2	Disable character entering buffer event
*FX 13,3	X=3	Disable ADC conversion complete event
*FX 13,4	X=4	Disable start of vertical sync event
*FX 13,5	X=5	Disable interval timer crossing 0 event
*FX 13,6	X=6	Disable ESCAPE pressed event
*FX 13,7	X=7	Disable RS423 RX error event
*FX 13,8	X=8	Disable network error event
*FX 13,9	X=9	Disable user event

See section 6.4 for information on event handling.

On exit:
A is preserved
X contains the old enable state (0= disabled)
Y and C are undefined

OSBYTE &0E (14)

Enable events

Entry parameters:
X contains the event code, Y=0

*FX 14,0	X=0	Enable output buffer empty event
*FX 14,1	X=1	Enable input buffer full event
*FX 14,2	X=2	Enable character entering buffer event
*FX 14,3	X=3	Enable ADC conversion complete event
*FX 14,4	X=4	Enable start of vertical sync event
*FX 14,S	X=S	Enable interval timer crossing 0 event
*FX 14,6	X=6	Enable ESCAPE pressed event
*FX 14,7	X=7	Enable RS423 RX error event
*FX 14,8	X=8	Enable network error event
*FX 14,9	X=9	Enable user event

After call,
A is preserved
X contains the old enable state (>0= enabled)
C is undefined

See section 6.4 for information on event handling.

OSBYTE &0F (15)

Flush selected buffer class

Entry parameters:
X value selects class of buffer

X=0 All buffers flushed
X= 1 Input buffer flushed only
See OSBYTE call &16/*FX 21

On exit,
Buffer contents are discarded
A is preserved
X, Y and C are undefined

OSBYTE &l0 (16)

Select ADC channels which are to be sampled

This routine is not implemented on the unexpanded Electron but is passed on to paged ROMs as an *unknown OSBYTE* paged ROM service call.

OSBYTE &11 (17)

Force an ADC conversion

This routine is not implemented on the unexpanded Electron but is passed on to paged ROMs as an *unknown OSBYTE* paged ROM service call.

OSBYTE &12 (18)

Reset soft keys

This call clears the soft key buffer so the character strings are no longer available.

No parameters

On exit:

A and Y are preserved
X and C are undefined

OSBYTE &13 (19)

Wait for vertical sync

No parameters

This call forces the machine to wait until the start of the next frame of the display. This occurs SO times per second on the UK Electron. Its main use is to help produce flicker free animation on the screen. The flickering effect is often due to changes being made on the screen halfway through a screen refresh. Using this OSBYTE call graphics manipulation can be made to coincide with the flyback between screen refreshes.

N.B. User trapping of IROl may stop this call from working.

On exit:

A is preserved
X, Y and C are undefined

OSBYTE &14 (20)

Explode soft character RAM allocation

Entry parameters : X value explodes/implodes memory allocation

In the default state 32 characters may be user defined using the VDU 23 statement from BASIC (or the OSWRCH call in machine code). These characters use memory from &COO to &CFF. Printing ASCII codes in the range 128 (&80) to 159 (&9F) will cause these user defined characters to be printed up (these characters will also be printed out for characters in the range &AO—&BF, &CO—&DF, &EO—&FF), In this state the character definitions are said to be *imploded.*

If the character definitions are *exploded* then ASCII characters 128 (&80) to 1S9 (&9F) can be defined as before using VDU 23 and memory at &C00. Exploding the character set definitions enables the user to uniquely define characters 32 (&20) to 255

(&FF) in steps of 32 extra characters at a time. The operating system must allocate memory for this which it does using memory starting at the ‘operating system high-water mark’ (OSHWM). This is the value to which the BASIC variable PAGE is usually set and so if a totally exploded character set is to be used in BASIC then PAGE must be reset to OSHWM±&600 (i.e. PAGE=PAGE+&600).

ASCII characters 32 (&20) to 128 (&7F) are defined by memory within the operating system ROM when the character definitions are imploded.

See OSBYTE &83 (131) for details about reading OSHWM from machine code.

The memory allocation for ASCII codes in the expanded state is as follows : —

		ASCII code	Memory allocation
*FX 20,0	X=0	&80 — &8F	&COO to &CFF (imploded)
*FX 20,1	X= 1	&A0 — &BF	OSHWM to OSHWM+&FF (+above)
*FX 20,2	X=2	&C0 — &DF	OSHWM±&100 to OSHWM+&1FF (+above)
*FX 20,3	X=3	&E0 — &FF	OSHWM+&200 to OSHWM+&2FF (+above)
*FX 20,4	X=4	&20 — &3F	OSHWM+&300 to OSHWM+&3FF (+above)
*FX 20,5	X=S	&40 — &5F	OSHWM+&400 to OSHWM+&4FF (+above)
*FX 20,6	X=6	&60 — &7F	OSHWM+&500 to OSHWM+&5FF (+above)

The explosion state can be determined using OSBYTE &B6.

Before the OSHWM is changed during a font explosion a service call is made to the paged ROMs warning them of the impending change.

On exit:

A is preserved
X contains the new OSHWM (high byte)
Y and C are undefined

OSBYTE &15 (21)

Flush specific buffer

While the unexpanded Electron only has a single sound channel the operating system has been designed to enable the implementation of an external sound system. Each time any of the sound buffers are flushed a paged ROM service call is issued with A=&17, In the unexpanded Electron there is a single effective buffer which may be addressed as any of the four channels. Thus flushing any of the four buffers will extinguish any sound being produced at that time.

See section 10.1 for more information regarding the Electron sound paged ROM sevice calls.

Entry parameters:

X determines the buffer to be cleared

*FX 21,0	X=0	Keyboard buffer emptied
*FX 21,1	X= 1	RS423 input buffer emptied
*FX 21,2	X=2	RS423 output buffer emptied
*FX 21,3	X=3	Printer buffer emptied
*FX 21,4	X=4	Sound channel 0 buffer emptied
*FX 21,5	X=S	Sound channel 1 buffer emptied
*FX 21,6	X=6	Sound channel 2 buffer emptied
*FX 21,7	X=7	Sound channel 3 buffer emptied
*FX 21,8	X=8	Speech buffer emptied

See also OSBYTEs &0F (*FX1S) and &80 (128).

On exit:

A and X are preserved
Y and C are undefined

OSBYTE &16 (22)

Increment paged ROM polling semaphore

This call increments the semaphore which when non-zero makes the operating system issue a paged ROM service call with A=&15 at centi-second intervals.

See paged ROM service call &15, chapter 10.

Entry parameters:

None

On exit:

A and X are preserved
Y and C are undefined

Semaphore is incremented once per call.

OSBYTE &17 (23)

Decrement paged ROM polling semaphore

This call decrements the semaphore which when non-zero makes the operating system issue a paged ROM service call with A=&15 at centi-second intervals.

See paged ROM service call &15, chapter 10.

Entry parameters:

None

On exit:

A and X are preserved
Y and C are undefined

Semaphore is decremented once per call.

OSBYTE &18 (24)

Select external sound system

This call is used to select a sound system which is implemented by an external hardware/software sound system.

Entry parameters:
X contains an undefined parameter

On exit:
A is preserved
All other registers are undefined

OSBYTE &73 (115)

Blank/restore palette

This call is used to temporarily turn all colours in the palette black. It should be useful for NMI users who want to generate NMIs with a high resolution screen display. This will ensure that there is no *snow* seen on the screen.

Entry parameters:

X=0	Restores the palette
X<>0	Set palette to all black if in high res. mode

On exit:
All registers undefined

OSBYTE &74 (116)

Reset internal sound system

This call can be used to reset the internal sound system.

Entry parameters:
X contains an undefined parameter

On exit:
All registers are undefined

OSBYTE &75 (117)

Read VDU status

No entry parameters

On exit the X register contains the VDU status. Information is conveyed in the following bits :

Bit 0	Printer output enabled by a VDU 2
Bit 1	Scrolling disabled e.g. during cursor editing
Bit 2	Paged scrolling selected
Bit 3	Software scrolling selected i.e. text window
Bit 4	reserved
Bit 5	Printing at graphics cursor enabled by VDU 5
Bit 6	Set when input and output cursors are separated (i.e. cursor editing mode).
Bit 7	Set if VDU is disabled by a VDU 21

On exit:

A and Y are preserved
C is undefined

OSBYTE &76 (118)

Reflect keyboard status in keyboard LEDs

This routine is hardware dependent and is implemented differently on the BBC microcomputer and the Electron. This call should not be used on either machine.

OSBYTE &77 (119)

Close any SPOOL or EXEC files

This call closes any open files being used as *SPOOLed output or *EXECed input to be closed. This call is first offered to paged ROMs via a service call with A=&10. If the call is claimed then the operating system takes no further action. If the call is not claimed by a paged ROM the operating system closes any EXEC or SPOOL files itself. This call should be made by filing systems if they are deselected.

On exit:

A is preserved
X, Y and C are undefined

OSBYTE &78 (120)

Write current keys pressed information

This call should only be made by filing systems which have recognised a key pressed with BREAK and are initialising accordingly (see paged ROM service call with A=&03, section 10.1). This call should be used to write the old key pressed value to prevent its entry into the keyboard buffer.

The operating system operates a two key roll-over for keyboard input (recognising a second key press even when the first key is still pressed). There are two zero page locations which contain the values of the two key-presses which may be recognised at any one time. If no keys are pressed, location &EC contains 0 and location &ED contains 0. If one key is pressed, location &EC contains the internal key number+ 128 (see table below for internal key numbers) and location &ED contains 0. If a second key is pressed while the original key is held down, location &EC contains the internal key number+ 128 of the most recent key pressed and location &ED contains the internal key number+ 128 of the first key pressed.

Internal Key Numbers

hex.	dec.	key	hex.	dec.	key
&00	0	SHIFT	&40	64	CAPS LOCK
&01	1	CTRL	&41	65	A
&02	2	bitO	&42	66	X
&03	3	biti	&43	67	F
&04	4	bit2	&44	68	Y
&05	5	bit3	&45	69	J
&06	6	bit4	&46	70	K
&07	7	bit 5	&47	71	@
&08	8	bit6	&48	72	:
&09	9	bit 7	&49	73	RETURN
&l0	16	0	&50	80	SHIFT LOCK
&11	17	3	&51	81	5
&12	18	4	&52	82	C
&13	19	5	&53	83	G
&14	20	f4	&54	84	H
&15	21	8	&55	85	N
&16	22	f7	&56	86	L
&17	23	—	&57	87	;
&18	24	↑	&58	88	]
&19	25	left cursor	&59	89	DELETE
&20	32	fO	&60	96	TAB
&21	33	W	&61	97	Z
&22	34	E	&62	98	SPACE
&23	35	T	&63	99	V
&24	36	7	&64	100	B
&25	37	9	&65	101	M
&26	38	I	&66	102	,
&27	39	0	&67	103	.
&28	40	_	&68	104	/
&29	41	down cursor	&69	lOS	COPY
&30	48	1	&70	112	ESCAPE
&31	49	2	&71	113	fi
&32	50	D	&72	114	f2
&33	51	R	&73	115	f3
&34	52	6	&74	116	f4
&35	S3	U	&75	117	f6
&36	54	0	&76	118	f8
&37	SS	P	&77	119	f9
&38	56	[	&78	120	\
&39	57	up cursor	&79	121	right cursor

Bits 0 to 7 refer to the the start up option byte. See OSBYTE &FF for further information about this byte.

To convert these internal key numbers to the INKEY numbers they should be EOR (Exclusive ORed) with &FF (255).

Entry parameters :

X and Y contain values to be written

Value in X is stored as the *old key* information.

Value in Y is stored in the *new key* information.

See also OSBYTE calls with A=&AC and A=&AD.

On exit:

A, X and Y are preserved
C is undefined

OSBYTE &79 (121)

Keyboard scan

The keyboard is scanned in ascending numerical order. This call returns information about the first pressed key encountered during the scan. Other keys may also be pressed and a further call or calls will be needed to complete the entire keyboard scan.

Entry parameters:

X determines the key to be detected and also determines the range of keys to be scanned.

Key numbers refer to internal key numbers in the table above (see OSBYTE &78).

To scan a particular key:

X=key number EOR &80
on exit X<0 if the key is pressed

To scan the matrix starting from a particular key number:

X=key number

On exit X=key number of any key pressed or &FF if no key pressed

On exit:

A is preserved
X contains key value (see above)
Y and C are undefined

OSBYTE &7A (122)

Keyboard scan from 16 decimal

No entry parameters

Internal key number (see table above) of the key pressed is returned in X.

This call is directly equivalent to an OSBYTE call with A=&79 and X=16.

On exit:

A is preserved
X contains key number or zero if none pressed
Y and C are undefined

OSBYTE &7B (123)

Inform operating system of printer driver going dormant

Entry parameters:
X should contain the value 3 (printer buffer i.d.)

This OSBYTE call should be made by user printer drivers when they go dormant. The operating system will need to wake up the printer driver if more characters are placed in the printer buffer (see section 6.5).

On exit:
A and X are preserved
Y is preserved
C is undefined

OSBYTE &7C (124)

Clear ESCAPE condition

No entry parameters

This call clears any ESCAPE condition without any further action.

See OSBYTE &7E also.

On exit:
A, X and Y are preserved
C is undefined

OSBYTE &7D (125)

Set Escape condition

No entry parameters

This call partially simulates the ESCAPE key being pressed. The Tube is informed (if active). An ESCAPE event is not generated.

On exit:

A, X and Y are preserved
C is undefined

OSBYTE &7E (126)

Clear ESCAPE condition with side effects

No entry parameters

This call attempts to clear the ESCAPE condition. All active buffers will be flushed, any open EXEC files closed, the VDU paging counter will be reset and the VDU queue will be reset.

See OSBYTE &E6 (230) also.

On exit:

X=&FF	if the ESCAPE condition cleared
X=0	if no ESCAPE condition found

A is preserved
Y and C are undefined

OSBYTE &7F (127)

Check for end-of-file on an opened file

Entry parameters:

X contains file handle

On exit:

X<>0 If end-of-file has been reached
X=0 If end-of-file has not been reached

A and Y are preserved (Y not passed across Tube)
C is undefined

OSBYTE &80 (128)

Read ADC channel (ADVAL) or get buffer status

On the Electron this call will generate an *unknown OSBYTE* paged ROM service call when passed a positive value in the X register. If this service call is not claimed then the values in page 2 of memory allocated to storing ADC information are returned.

Otherwise this call is implemented identically on the BBC microcomputer and the Electron. Information about those buffers not used on the unexpanded Electron will be meaningless; these buffers have been implemented for expansion capability.

Entry parameters:

X determines action and buffer or channel number

If X=0 on entry:

Y returns channel number (range 1 to 4) showing which channel was last used for ADC conversion, Note that OSBYTE calls with A=&10 (16) and A=&11 (17) set this value toO. A value of 0 indicates that no conversion has been completed. Bits 0 and 1 of X indicate the status of the two ‘fire buttons’.

If X=1 to 4 on entry:

X and Y contain the 16 bit value (X-low, Y-high) read from channel specified by X.

If X<0 and Y=&FF on entry:

If X contains a negative value (in 2's complement notation) then this call will return information about various buffers.

X=255	(&FF)	keyboard buffer
X=254	(&FE)	RS423 input buffer
X=253	(&FD)	RS423 output buffer
X=252	(&FC)	printer buffer
X=251	(&FB)	sound channel 0
X=250	(&FA)	sound channel 1
X=249	(&F9)	sound channel 2
X=248	(&F8)	sound channel 3
X=249	(&F7)	speech buffer

For input buffers X contains the number of characters in the buffer and for output buffers the number of spaces remaining.

On exit:

A is preserved
C is undefined

OSBYTE &81 (129)

Read key with time limit (INKEY)

This call is functionally equivalent to the BASIC statement INKEY, It can be used to get a character from the keyboard within a time limit, scan the keyboard for a particular key press or return information about the OS type.

(a) Read key with time limit

Entry parameters:
X and Y specify time limit in centiseconds

If a time limit of n centiseconds is required,

X=n AND &FF (LSB)
Y=n DIV &100 (MSB)

Maximum time limit is &7FFF centiseconds (5.5 minutes aprox.)

On exit:
If key press detected, X=ASCII key value, Y=0 & C=0
If key press not detected by timeout then Y=&FF & C= 1
If Escape is pressed then Y=&1B (27) and C= 1

(b) Scan keyboard for key press

Entry parameters:
X=negative INKEY value for key to be scanned
Y=&FF

On exit:
X = Y = &FF, C= 1 if the key being scanned is pressed. X = Y = 0, C=0 if key is not pressed.

(c) Return information about OS type

Entry parameters:
X=0
Y=&FF

On exit:

X=0	BBCOSO.1
X=1	Electron 05 1.00
X=&FF	BBC 05 1.00 or 05 1.20
X=&FE	US BBC OS1.20

OSBYTE &82 (130)

Read machine high order address

No entry parameters

This call yields the high order address required for the most significant 16 bits of the 32 bit addresses used for filing systems. The high order address is different in a second processor to that in an i/o processor. The Tube operating system intercepts this call to return the second processor high order address.

On exit:

X and Y contain the address (X-high, Y-low)

A is preserved
C is undefined

OSBYTE &83 (131)

Return current OSHWM

The OSHWM (operating system high water mark) represents the top of memory used by the operating system. This value is set after the paged ROMs have claimed workspace and any font explosion carried out. On a second processor this value represents the OSHWM on the i/o processor.

The OSHWM indicates the start of user memory and so this call is made by BASIC to initialise the value of PAGE.

No entry parameters

On exit:

X and Y contain the OSHWM address (X= low-byte , Y = high-byte)

A is preserved
C is undefined

OSBYTE &84 (132)

Return HIMEM

HIMEM is an address indicating the top of the available user RAM. This is usually the bottom of screen memory address. On a second processor this will be the bottom address of any code copied across from the I/O processor and executed.

No entry parameters

On exit:

X and Y contain the HIMEM address (X-low,Y-high)

A is preserved
C is undefined

OSBYTE &85 (133)

Read bottom of display RAM address for a specified mode

This call may be used to investigate the consequences of an intended MODE change. This enables languages to determine whether the selection of a new MODE should be allowed.

Entry parameters:

X determines mode number

On exit:

X and Y contain the address (X-low byte,Y-high byte)

A is preserved
C is undefined

OSBYTE &86 (134)

Read text cursor position (POS and VPOS)

When in cursor editing mode this call returns the position of the input cursor not the output cursor.

No entry parameters

On exit:

X contains horizontal position of the cursor (POS)
Y contains vertical position of the cursor (VPOS)

A is preserved
C is undefined

OSBYTE &87 (135)

Read character at text cursor position and screen MODE

No entry parameters

On exit:

X contains character value (0 if character not recognised)
Y contains graphics MODE number

A is preserved
C is undefined

OSBYTE &88 (136)

Execute code indirected via USERV (*CODE equivalent)

This call JSRs to the address contained in the user vector (USERV &200). The X and Y registers are passed on to the user routine.

See *CODE, section 6.1.

OSBYTE &89 (137)

Switch cassette relay (*MOTOR equivalent)

Entry parameters:
X=0 relay off
X= 1 relay on

The cassette filing system calls this routine with Y=0 for write operations and Y= 1 for read operations. This enables the implementation of a dual cassette system with additional hardware and software

On exit:
A is preserved
X, Y and C are undefined

OSBYTE &8A (138)

Insert value into buffer

Entry parameters:
X identifies the buffer (See OSBYTE &15)
Y contains the to be value inserted into buffer

On exit:
C=0 if value successfully inserted
C= 1 if value not inserted e.g. if buffer full
A is preserved

OSBYTE &8B (139)

Select file options (*OPT equivalent)

Entry parameters:
X contains file option number Y contains the option value required

On exit:

A is preserved
C is undefined

OSBYTE &8C (140)

Select tape filing system (*TAPE equivalent)

No entry parameters

On exit:
A is preserved
C is undefined

OSBYTE &8D (141)

Select ROM filing system (*ROM equivalent)

No entry parameters

On exit:
A is.preserved
X, Y and C are undefined

OSBYTE &8E (142)

Enter language ROM

Entry parameters:
X determines which paged ROM is entered

The language ROM is entered via its entry point with A= 1. Locations &FD and &FE in zero page are set to point to the copyright message in the ROM.

There is no exit from this call.

OSBYTE &8F (143)

Issue paged ROM service call

See Service ROMs section 10.1

Entry parameters:

X=reason code
Y=parameter passed with service call

On exit:

Y may contain return argument (if appropriate) X=0 if a paged ROM claimed the service call

A is preserved
C is undefined

OSBYTE &90 (144)

Alter display parameters (*TV equivalent)

On the Electron this call is not implemented and returns with registers preserved.

OSBYTE &91 (145)

Get character from buffer

Entry parameters:

X contains buffer number (see OSBYTE &1S)

On exit:

Y contains the extracted character.
If the buffer was empty then C= 1 otherwise C=0.

A is preserved

OSBYTEs &92 to &97 (146 to 151)

Read or Write to mapped I/O

Entry parameters:
X contains offset within page
Y contains byte to be written (for write calls)

OSBYTE call		Memory addressed	Name
read	write		
&92 (146)	&93 (147)	&FCOO to &FCFF	FRED
&94 (148)	&95 (149)	&FDOO to &FDFF	JIM
&96 (150)	&97 (151)	&FEOO to &FEFF	SHEILA

Refer to the hardware section for details about these 1 MHz buses.

On exit:
Read operations return with the value read in the Y register

A is preserved
C is undefined

OSBYTE &98 (152)

Examine Buffer status

Entry parameters: X contains buffer number

On exit:
Y=character value read from buffer if buffer not empty
Y is preserved if buffer empty
C= 1 if buffer empty otherwise C=0

A and X are preserved

OSBYTE &99 (153)

Insert character into input buffer, checking for ESCAPE

Entry parameters:

X contains buffer number (0 or 1 only) Y contains the character value

X=0 keyboard buffer
X=1 RS423 input

If the character is an ESCAPE character and ESCAPEs are not protected (using OSBYTE &C8/*FX 200 or OSBYTE &E5/*FX229) then an ESCAPE event is generated instead of the keyboard event.

On exit:

A is preserved
X, Y and C are undefined

OSBYTE &9A (154)

Reset flash cycle

This call resets the flash cycle to the beginning of the mark state (i.e. to the first named colour of the pair) by manipulating the ULA registers.

There are no entry parameters.

On exit:

All registers are undefined

OSBYTE &9B (155)

Write to video ULA palette register and OS copy (BBC micro)

On the Electron this call is ignored by immediately executing an RTS instruction.

OSBYTE &9C (156)

Read/update 6850 control register and OS copy (BBC micro)

On the Electron this call causes the operating system to issue an *unknown OSBYTE* paged ROM service call but makes no further actions.

OSBYTE &9D (157)

Fast Tube BPUT

The byte to be output is channeled through the standard BPUT routine.

Entry parameters:
X = byte to be output
Y = file handle

On exit:
A is preserved
X, Y and C are undefined

OSBYTE &9E (158)

Read from speech processor

On the Electron this call causes the operating system to issue an *unknown OSBYTE* paged ROM service call but makes no further actions.

OSBYTE &9F (159)

Write to speech processor

On the Electron this call causes the operating system to issue an *unknown OSBYTE* paged ROM service call but makes no further actions.

OSBYTE &AO (160)

Read VDU variable value

This call is implemented on the Electron but is officially undefined and may change in future issues of the operating system software.

Entry parameters:

X contains the number of the variable to be read

On exit:

X=low byte of variable
Y=high byte of variable

A is preserved
C is undefined

OSBYTEs &A6 (166) and &A7 (167)

Read start address of OS variables

<NEW VALUE>=(<OLD VALUE> ANDY) EOR X

The old value is returned in X. The contents of the next location are returned in Y.

This call returns the start address of the memory used by the operating system to store its internal variables.

On exit:

X=low byte
Y=high byte

A is preserved
C is undefined

OSBYTEs &A8 (168) and &A9 (169)

Read address of ROM pointer table

This call is implemented on the BBC microcomputer and the Electron. When used across the Tube the address returned refers to the I/O processor's memory.

<NEW VALUE>=(<OLD VALUE> AND Y) EOR X

The old value is returned in X. The contents of the next location are returned in Y.

This table of extended vectors consists of 3 byte vectors in the form Location (2 bytes), ROM no. (1 byte). See Paged ROM section 10.3 for a complete description of extended vectors.

On exit:

X=low byte
Y=high byte
A is preserved
C is undefined

OSBYTEs &AA (170) and &AB (171)

Read address of ROM information table

<NEW VALUE>=(<OLD VALUE> ANDY) EOR X

The old value is returned in X. The contents of the next location are returned in Y.

This call returns the origin of a 16 byte table, containing one byte per paged ROM. This byte contains the ROM type byte contained in location & 8006 of the ROM or contains 0 if a valid ROM is not present.

On exit:

X=low byte
Y=high byte
A is preserved
C is undefined

OSBYTEs &AC (172) and &AD (173)

Read address of keyboard translation table

This call is implemented on the BBC microcomputer and the Electron. However it should be noted that this call is hardware specific due to the different keyboard matrix layout on different machines, When used across the Tube the address returned refers to the I/O processor's memory.

Use of this call is not recommended.

<NEW VALUE>=(<OLD VALUE> AND Y) EOR X

The old value is returned in X. The contents of the next location are returned in Y.

On exit:

X=low byte
Y=high byte

OSBYTEs &AE (174) and &AF *(175)*

Read VDU variables origin

<NEW VALUE>=(<OLD VALUE> AND Y) EOR X

The old value is returned in X. The contents of the next location are returned in Y.

This call returns with the address of the table of internal VDU variables.

On exit:

X=low byte
Y=high byte

OSBYTE &BO (176)

Read/write CFS timeout counter

<NEW VALUE>=(<OLD VALUE> AND Y) EOR X

The old value is returned in X. The contents of the next location are returned in Y.

This counter is decremented once every vertical sync pulse *(50* times per second) which is also used for OSBYTE &13/*FX 19. The timeout counter is used to time interblock gaps and leader tones.

OSBYTE &B1 (177)

Read input source flags

<NEW VALUE>=(<OLD VALUE> AND Y) EOR X

The old value is returned in X. The contents of the next location are returned in Y.

This location should contain 0 for keyboard input and 1 for RS423 input (i.e. contains buffer no.) and is used for OSBYTE &2. OSBYTE &2 should be used to change the input source as writing the flag with this call does not enable the relevant interrupts.

OSBYTE &B2 (178)

This call is undefined on the Electron.

OSBYTE &B3 (179)

Read/write primary OSHWM (for imploded font)

This call should not be used as it has been re-allocated on other products in the Acorn-BBC range.

<NEW VALUE>=(<OLD VALUE> AND Y) EOR X

The old value is returned in X. The contents of the next location are returned in Y.

This location contains the OSHWM page value for an imploded font (even when character definition RAM explosion has been selected) but after paged ROM workspace allocation has been made.

See OSBYTE &B4 and OSBYTE &14.

OSBYTE &B4 (180)

Read OSHWM (similar to OSBYTE &83)

<NEW VALUE>=(<OLD VALUE> AND Y) EOR X

This call returns the page number of OSHWM in X.

This location is updated by any character definition RAM explosion which may have been selected and returns with the high byte of the OSHWM address (the low byte always being 0).

See OSBYTE &14.

OSBYTE &B5 (181)

Read/write RS423 mode

On the unexpanded Electron this call will have no effect unless a suitable hardware and software expansion has been performed to implement R5423.

<NEW VALUE>=(<OLD VALUE> AND Y) EOR X

The old value is returned in X. The contents of the next location are returned in Y.

Flag=0	ESCAPEs are recognised soft keys are expanded character entering input buffer event generated cursor editing performed
Flag= 1	All characters enter input buffer
(default)	character entering buffer event not generated

OSBYTE &B6 (182)

Read character definition explosion state

Use of this call is not recommended as this OS BYTE has been reallocated on other products in the Acorn BBC range.

<NEW VALUE>=(<OLD VALUE> AND Y) EOR X

The old value is returned in X. The contents of the next location are returned in Y.

This location contains the state of font explosion as set by OSBYTE call with A=&14/*FX 20.

OSBYTE &B7 (183)

Read cassette/ROM filing system flag

<NEW VALUE>=(<OLD VALUE> AND Y) EOR X

The old value is returned in X. The contents of the next location are returned in Y.

This location contains 0 for *TAPE selection and 2 for *ROM selection. Other values are meaningless, and should not be used.

OSBYTE &B8 (184)

This call is undefined on the Electron.

OSBYTE &B9 (185)

Read/write timer paged ROM service call semaphore

<NEW VALUE>=(<OLD VALUE> AND Y) EOR X

The old value is returned in X. The contents of the next location are returned in Y.

This location contains a semaphore. If the contents of this location are non-zero the operating system will generate a paged ROM service call with a reason code of &15. This semaphore should only be read using this call. See OSBYTEs &16 and &17 for information about setting semaphore and service ROMs chapter 10 for information about the paged ROM service call.

OSBYTE &BA (186)

Read ROM number active at last BRK (error)

<NEW VALUE>=(<OLD VALUE> AND Y) EOR X

The old value is returned in X. The contents of the next location are returned in Y.

This location contains the ROM number of the paged ROM that was in use at the last BRK.

OSBYTE &BB (187)

Read number of ROM socket containing BASIC

<NEW VALUE>=(<OLD VALUE> AND Y) EOR X

The old value is returned in X. The contents of the next location are returned in Y.

BASIC is recognised by the fact that it is a language ROM which does not possess a service entry. This ROM is then selected by the *BASIC command. If no BASIC ROM is present then this location contains &FF.

OSBYTE &BC (188)

Read current ADC channel

This call is not implemented in the unexpanded Electron.

<NEW VALUE>=(<OLD VALUE> AND Y) EOR X

The old value is returned in X. The contents of the next location are returned in Y.

This location contains the number of the ADC channel currently being converted. This call should not be used to force ADC conversions, use OSBYTE &11/*FX 17.

OSBYTE &BD (189)

Read maximum ADC channel number.

This call is not implemented in the unexpanded Electron.

<NEW VALUE>=(<OLD VALUE> AND Y) EOR X

The old value is returned in X. The contents of the next location are returned in Y.

The maximum channel number to be used for ADC conversions in the range 0 to 4. Set by OSBYTE &16/*FX 10.

OSBYTE &BE (190)

Read ADC conversion type, 12 or 8 bits.

This call is not implemented in the unexpanded Electron.

<NEW VALUE>=(<OLD VALUE> ANDY) EOR X

The old value is returned in X. The contents of the next location are returned in Y.

Set to &00, default (12 bit)
Set to &08, 8 bit conversion
Set to &0C, 12 bit conversion

OSBYTE &BF (191)

Read/write RS423 use flag.

This location is reserved for expansion software on the Electron.

<NEW VALUE>=(<OLD VALUE> AND Y) EOR X

The old value is returned in X. The contents of the next location are returned in Y.

OSBYTE &C0 (192)

Read RS423 control flag

This location is reserved for expansion software on the Electron.

<NEW VALUE>=(<OLD VALUE> AND Y) EOR X

The old value is returned in X. The contents of the next location are returned in Y.

OSBYTE &C1 (193)

Read/write flash counter.

<NEW VALUE>=(<OLD VALUE> ANDY) EOR X

The old value is returned in X. The contents of the next location are returned in Y.

This location contains the number of 1/50th sec. units until the next change of colour for flashing colours.

OSBYTE &C2 (194)

Read/write space period count.

<NEW VALUE>=(<OLD VALUE> AND Y) EOR X

The old value is returned in X. The contents of the next location are returned in Y.

Similar to OSBYTE &0A.

OSBYTE &C3 (195)

Read/write mark period count.

<NEW VALUE>=(<OLD VALUE> AND Y) EOR X

The old value is returned in X. The contents of the next location are returned in Y.

Similar to OSBYTE &09.

OSBYTE &C4 (196)

Read/write keyboard auto-repeat delay.

<NEW VALUE>=(<OLD VALUE> AND Y) EOR X

The old value is returned in X. The contents of the next location are returned in Y.

This call is used by OSBYTE &0B.

OSBYTE &C5 (197)

Read/write keyboard auto-repeat period (rate).

<NEW VALUE>=(<OLD VALUE> AND Y) EOR X

The old value is returned in X. The contents of the next location are returned in Y.

This call is used by OSBYTE &0C.

OSBYTE &C6 (198)

Read *EXEC file handle.

<NEW VALUE>=(<OLD VALUE> AND Y) EOR X

The old value is returned in X. The contents of the next location are returned in Y.

This call should be used only to read this location as writing to it may have undefined effects. This location contains zero if no file handle has been allocated by the operating system.

OSBYTE &C7 (199)

Read *SPOOL file handle.

<NEW VALUE>=(<OLD VALUE> AND Y) EOR X

The old value is returned in X. The contents of the next location are returned in Y.

This call should be used to read this location only. This location contains the file handle of the current SPOOL file or zero if not currently spooling.

OSBYTE &C8 (200)

Read/write ESCAPE, BREAK effect

<NEW VALUE>=(<OLD VALUE> AND Y) EOR X

The old value is returned in X. The contents of the next location are returned in Y.

bit 0 = 0	Normal ESCAPE action
bit 0 = 1	ESCAPE disabled unless caused by OSBYTE &7D/125
bits l to 7 = 0	Normal BREAK action
bits l to 7 = 1	Memory cleared on BREAK

e.g. A value 000000lx (binary) will cause memory to be cleared on BREAK.

OSBYTE &C9 (201)

Read/write keyboard disable.

This call should only be made by the Econet filing system.

<NEW VALUE>=(<OLD VALUE> AND Y) EOR X

The old value is returned in X. The contents of the next location are returned in Y.

If this location contains 0 then the keyboard is scanned normally otherwise lock keyboard (all keys ignored except BREAK).

This call is used by the *REMOTE Econet facility.

OSBYTE &CA (202)

Read/write keyboard status byte.

<NEW VALUE>=(<OLD VALUE> AND Y) EOR X

The old value is returned in X. The contents of the next location are returned in Y.

bit 4=0	if CAPS LOCK active
bit5=1	ifFn active
bit 6=1	if SHIFT active
bit 7=1	if CTRL active

All bits except the CAPS LOCK bit will only change transiently and are subsequently unlikely to be of use.

See also OSBYTE with A=&76 (118).

OSBYTE &CB (203)

Read/write the ULA Interrupt Mask

See chapter 7 for a description of the interrupt handling routine.

OSBYTE &CC (204)

Read/write Firm Key Pointer

<NEW VALUE>=(<OLD VALUE> AND Y) EOR X

The old value is returned in X. The contents of the next location are returned in Y.

The value contained in this location is a pointer into the currently expanding firm key. For more information about the firm keys see language ROMs section 9.2.

OSBYTE &CD (205)

Read/write Length of current Firm key string.

<NEW VALUE>=(<OLD VALUE> AND Y) EOR X

The old value is returned in **X.** The contents of the next location are returned in Y.

This location contains the length of the string currently being expanded from a Firm key. For more information about Firm keys see language ROMs section 9.2.

OSBYTE &CE (206)

Read/write Econet OS call interception status.

<NEW VALUE>=(<OLD VALUE> AND Y) EOR X

The old value is returned in X. The contents of the next location are returned in Y.

If bit 7 of this location is set then all OSBYTE and OS WORD calls (except those sent to paged ROMs) are indirected through the Econet vector (&224) to the Econet. Bits 0 to 6 are ignored.

OSBYTE &CF (207)

Read/write Econet read character interception status.

<NEW VALUE>=(<OLD VALUE> AND Y) EOR X

The old value is returned in X. The contents of the next location are returned in Y.

If bit 7 of this location is set then input is pulled from the Econet vector.

OSBYTE &DO (208)

Read/write Econet write character interception status.

<NEW VALUE>=(<OLD VALUE> AND Y) EOR X

The old value is returned in X. The contents of the next location are returned in Y.

If bit 7 of this location is set then output is directed to the Econet. Output may go through the normal write character on return from the Econet code.

OSBYTE &D1 (209)

Read/write speech suppression status.

This location is not used in the unexpanded Electron and is reserved for future expansion.

<NEW VALUE>=(<OLD VALUE> AND Y) EOR X

The old value is returned in X. The contents of the next location are returned in Y.

OSBYTE &D2 (210)

Read/write sound suppression status.

<NEW VALUE>=(<OLD VALUE> AND Y) EOR X

Setting X to zero allows sound to be generated. Setting X non-zero will prevent any further sound being produced.

The old value is returned in X. The contents of the next location are returned in Y.

OSBYTE &D3 (211)

Read/write BELL (CTRL G) channel.

<NEW VALUE>=(<OLD VALUE> AND Y) EOR X

The old value is returned in X. The contents of the next location are returned in Y.

This location contains the channel number to be used for the BELL sound. Default value is 3.

OSBYTE &D4 (212)

Read/write BELL (CTRL G) SOUND information.

<NEW VALUE>=(<OLD VALUE> AND Y) EOR X

The old value is returned in X. The contents of the next location are returned in Y.

This location contains a byte which determines either the amplitude or the ENVELOPE number to be used by the BELL sound. If an ENVELOPE is specified then the value should be set to (ENVELOPE no.-1)*8. Similarly an amplitude in the range 15 to 0 must be translated by subtracting 1 and multiplying by 8.

The least significant three bits of this location contain the H and 5 parameters of the SOUND command (see User Guide).

Note that the internal sound system on the Electron will not allow the amplitude of the sound to be varied.

Default value 144 (&90) on the Electron.

OSBYTE &D5 (213)

Read/write bell (CTRL G) frequency.

<NEW VALUE>=(<OLD VALUE> AND Y) EOR X

The old value is returned in X. The contents of the next location are returned in Y.

This value contains the pitch parameter (as used by SOUND command third parameter) used for the BELL sound.

Default value 101 *(&65)* on the Electron.

OSBYTE &D6 (214)

Read/write bell (CTRL G) duration.

<NEW VALUE>=(<OLD VALUE> AND Y) EOR X

The old value is returned in X. The contents of the next location are returned in Y.

This value contains the duration parameter (as for SOUND command) used for the BELL sound.

Default value 6 on the Electron.

OSBYTE &D7 (215)

Read/write start up message suppression and !BOOT option status.

<NEW VALUE>=(<OLD VALUE> AND Y) EOR X

The old value is returned in X. The contents of the next location are returned in Y.

bit 0 If clear then ignore OS startup message. If set then print up OS startup message as normal.

bit 7 If set then if an error occurs in a !BOOT file in *ROM, carry on but if an error is encountered from a disc !BOOT file because no language has been initialised the machine locks up.
If clear then the opposite will occur, i.e. locks up if there is an error in *ROM.

This can only be over-ridden by a paged ROM on initialisation or by intercepting BREAK, see OSBYTE calls &F7 to &F9.

OSBYTE &D8 (216)

Read/write length of soft key string.

<NEW VALUE>=(<OLD VALUE> AND Y) EOR X

The old value is returned in X. The contents of the next location are returned in Y.

This location contains the number of characters yet to be read from the soft key buffer of the current soft key. To clear inpui buffer use *FX 15/OSBYTE &0F.

OSBYTE &D9 (217)

Read/write number of lines since last halt in page mode.

<NEW VALUE>=(<OLD VALUE> AND Y) EOR X

The old value is returned in X. The contents of the next location are returned in Y.

This location contains the number of lines printed since the last page halt. This value is used by the operating system to decide wether to halt scrolling when *paged mode* has been selected. This location is set to zero during OSWORD call &00 to prevent a scrolling halt occurrng during input.

OSBYTE &DA (218)

Read/write number of items in the VDU queue.

<NEW VALUE>=(<OLD VALUE> ANDY) EOR X

The old value is returned in X. The contents of the next location are returned in Y.

This contains the 2’s complement negative number of bytes still required for the execution of a VDU command.

Writing 0 to this location can be a useful way of abandoning a VDU queue, otherwise writing to this location is not recommended.

OSBYTE &DB (219)

Read/write External sound flag

<NEW VALUE>=(<OLD VALUE> ANDY) EOR X

The old value is returned in X. The contents of the next location are returned in Y.

This location contains a flag indicating that an external sound system has been selected using OSBYTE &18.

OSBYTE &DC (220)

Read/write Escape character.

<NEW VALUE>=(<OLD VALUE> AND Y) EOR X

The old value is returned in X. The contents of the next location are returned in Y.

This location contains the ASCII character (and key) which will generate an ESCAPE condition or event.

e.g. *FX 220,32 will make the SPACE bar the ESCAPE key. Default value &1B (27).

OSBYTEs &DD (221) to &EO (224)

Read/write I/P buffer code interpretation status.

<NEW VALUE>=(<OLD VALUE> AND Y) EOR X

The old value is returned in X. The contents of the next location are returned in Y.

These locations determine the effect of the character values &CO (192) to &FF *(255)* when placed in the input buffer. See OSBYTEs &E1 (225) to &E4 (228) for details about the different effects which may be selected. Note that these values cannot be inserted into the input buffer from the keyboard. RS423 input or a user keyboard handling routine may place these values into the input buffer.

OSBYTE &DD affects interpretation of values &CO to &BF
OSBYTE &DE affects interpretation of values &DO to &CF
OSBYTE &DF affects interpretation of values &EO to &EF
OSBYTE &EO affects interpretation of values &FO to &FF

Default values &01 ,&DO,&EO and &FO (respectively)

OSBYTE &E1 (225)

Read/write function key status *(soft* keys/codes/null). Input buffer characters &80 to &8F.

OSBYTE &E2 (226)

Read/write firm key status (soft key or code).

Input buffer characters &90 to &9F.

OSBYTE &E3 (227)

Read/write firm key status (soft key or code).

Input buffer characters &AO to &AF.

OSBYTE &E4 (228)

Read/write CTRL+SHIFT+function key Status (soft key or code).

Input buffer characters &BO to &BF.

<NEW VALUE>=(<OLD VALUE> AND Y) EOR X

The old value is returned in X. The contents of the next location are returned in Y.

These locations determine the action taken by the operating system when a function key is pressed.

value 0	totally ignore key.
value 1	expand as normal soft key.
value 2 to &FF	add n (base) to soft key number to provide ASCII' code.

The default settings are:-

fn keys alone	&01	expand using soft key strings
fn keys+ SHIFT	&01	expand using firm key strings
fn keys+CTRL	&01	expand using firm key strings
fn keys+SHIFT+CTRL	&00	key has no effect

When the BREAK key is pressed a character of value &CA is entered into the input buffer. The effect of this character may be set independently of the other soft keys using OSBYTE &DD (221). One of the other effects of pressing the BREAK key is to reset this OSBYTE call and so the usefulness of this facility is limited.

OSBYTE &E5 (229)

Read/write status of ESCAPE key (escape action or ASCII code).

<NEW VALUE>=(<OLD VALUE> AND Y) EOR X

The old value is returned in X. The contents of the next location are returned in Y.

If this location contains 0 then the ESCAPE key has its normal action. Otherwise treat currently selected ESCAPE key as an ASCII code.

OSBYTE &E6 (230)

Read/write flags determining ESCAPE effects.

<NEW VALUE>=(<OLD VALUE> AND Y) EOR X

The old value is returned in X. The contents of the next location are returned in Y.

If this location contains 0 then when an ESCAPE is acknowledged (using OSBYTE &7E/*FX 126) then :

EXEC file is closed (if open)
Purge all buffers (including input buffer)
Reset paging counter (lines since last halt)
Reset VDU queue
Any current soft key expansion is cleared

If this location contains any value other than 0 then ESCAPE causes none of these.

OSBYTE &E7 (231)

Read/write IRQ bit mask for the user 6522 (BBC micro)

<NEW VALUE>=(<OLD VALUE> AND Y) EOR X

The old value is returned in X. The contents of the next location are returned in Y.

This location is reserved for future Acorn expansion on the Electron.

OSBYTE &E8 (232)

Read/write sound semaphore

<NEW VALUE>=(<OLD VALUE> AND Y) EOR X

This location contains the sound semaphore.

OSBYTE &E9 (233)

Read/write soft key pointer

<NEW VALUE>=(<OLD VALUE> AND Y) EOR X

This location contains the soft key pointer.

OSBYTE &EA (234)

Read flag indicating Tube presence.

<NEW VALUE>=(<OLD VALUE> AND Y) EOR X

The old value is returned in X. The contents of the next location are returned in Y.

This location contains 0 if a Tube system is not present and &FF if Tube chips and software are installed.

No other values are meaningful or valid.

OSBYTE &EB *(235)*

Read flag indicating speech processor presence.

This location is used differently on the BBC micro and the Electron.

<NEW VALUE>=(<OLD VALUE> AND Y) EOR X

The old value is returned in X. The contents of the next location are returned in Y.

This location is reserved for future Acorn expansion on the Electron.

OSBYTE &EC (236)

Read/write write character destination status.

<NEW VALUE>=(<OLD VALUE> AND Y) BOR X

The old value is returned in X. The contents of the next location are returned in Y.

This call is used by OSBYTE &3/*FX 3.

OSBYTE &ED (237)

Read/write cursor editing status.

<NEW VALUE>=(<OLD VALUE> AND Y) EOR X

The old value is returned in X. The contents of the next location are returned in Y.

This call is used by OSBYTE &4/*FX 4.

OSBYTEs &EE (238) and &EF (239)

Read/write OS workspace bytes.

These locations are reserved for future Acorn expansion on the Electron.

<NEW VALUE>=(<OLD VALUE> AND Y) EOR X

The old value is returned in X. The contents of the next location are returned in Y.

OSBYTE &F0 (240)

Read country code

<NEW VALUE>=(<OLD VALUE> AND Y) EOR X

The old value is returned in X. The contents of the next location are returned in Y.

This location contains a value indicating the country for which this version of the operating system has been written.

country code	country
0	United Kingdom
1	United States

OSBYTE &F1 (241)

Read/write User flag location.

<NEW VALUE>=(<OLD VALUE> AND Y) EOR X

The old value is returned in X. The contents of the next location are returned in Y.

This call is not used by the operating system and is unlikely to be used by later issues either. This location is reserved as a user flag for use with *FX 1.

Default value 0.

OSBYTE &F2 (242)

Read RAM copy of location &FEO7

<NEW VALUE>=(<OLD VALUE> AND Y) BOR X

This location contains a RAM copy of the last value written to the ULA at address &FEO7.

The old value is returned in X. The contents of the next location are returned in Y.

OSBYTE &F3 (243)

Read timer switch state.

<NEW VALUE>=(<OLD VALUE> AND Y) EOR X

The old value is returned in X. The contents of the next location are returned in Y.

The operating system maintains two internal clocks which are updated alternately, As the operating system alternates between the two clocks it toggles this location between values of *5* and 10. These values represent offsets within the OS workspace where the clock values are stored. This OS workspace location should not be interfered with.

OSBYTE &F4 (244)

Read/write soft key consistency flag.

<NEW VALUE>=(<OLD VALUE> ANDY) EOR X

The old value is returned in X. The contents of the next location are returned in Y.

If this location contains 0 then the soft key buffer is in a consistent state. A value other than 0 indicates that the soft key buffer is in an inconsistent state (the operating system does this during soft key string entries and deletions). If the soft keys are in an inconsistent state during a soft break then the soft key buffer is cleared (otherwise it is preserved).

OSBYTE &F5 (245)

Read/write printer destination flag.

<NEW VALUE>=(<OLD VALUE> AND Y) EOR X

The old value is returned in X. The contents of the next location are returned in Y.

This call is used by OSBYTE &5/*FX 5. Using this call does not check for the printer previously selected being inactive or inform the user printer routine. See section 6.1.

OSBYTE &F6 (246)

Read/write character ignored by printer.

<NEW VALUE>=(<OLD VALUE> AND Y) EOR X

The old value is returned in X. The contents of the next location are returned in Y.

This call is used by OSBYTE &6/*FX 6.

OSBYTEs &F7 (247), &F8 (248) and &F9 (249)

Read/write BREAK intercept code.

<NEW VALUE>=(<OLD VALUE> AND Y) EOR X

The old value is returned in X. The contents of the next location are returned in Y.

The contents of these locations must be a JMP instruction for BREAKs to be intercepted (the operating system identifies the presence of an intercept by testing the first location contents equal to &4C _JMP). This code is entered twice during each break. On the first occasion C=0 and is performed before the reset message is printed or the Tube initialised. The second call is made with C= 1 after the reset message has been printed and the Tube initialised.

OSBYTEs &FA (250) and &FB (251)

Read/write OS workspace locations.

These locations are reserved for future Acorn expansions on the Electron.

<NEW VALUE>=(<OLD VALUE> AND Y) EOR X

The old value is returned in X. The contents of the next location are returned in Y.

OSBYTE &FC (252)

Read/write current language ROM number.

<NEW VALUE>=(<OLD VALUE> AND Y) EOR X

The old value is returned in X. The contents of the next location are returned in Y.

This location is set after use of OSBYTE &8E/*FX 126. This ROM is entered following a soft BREAK or a BRK (error).

OSBYTE &FD (253)

Read hard/soft BREAK.

<NEW VALUE>=(<OLD VALUE> AND Y) EOR X

The old value is returned in X. The contents of the next location are returned in Y

This location contains a value indicating the type of the last BREAK performed.

value 0 – soft BREAK
value 1 – power up reset
value 2 – hard BREAK

OSBYTE &FE *(254)*

Read/write available RAM (BBC micro)

<NEW VALUE>=(<OLD VALUE> AND Y) EOR X

The old value is returned in X. The contents of the next location are returned in Y.

This location is reserved for future Acorn expansion.

Default value 0 in the unexpanded Electron.

OSBYTE &FF *(255)*

Read/write start up options.

<NEW VALUE>=(<OLD VALUE> AND Y) EOR X

The old value is returned in X. The contents of the next location are returned in Y.

On the Electron the default value of this location is &FF *(255)* and this OSBYTE is the only way of resetting the start up options.

bits 0 to 2	screen MODE selected following reset. (MODE number = 3 bit value)
bit 3	if clear reverse action of SHIFT+BREAK.
bits 4 to 7	not used (reserved for future applications)

4 OSWORD CALLS

The OS WORD routines are very similar in concept to the OSBYTE routines. The major difference arises in the way of passing parameters. Instead of being passed in the X and Y registers, they are placed in a parameter block, The address of this parameter block is sent to the routine in the X (for the low byte) and Y (for the high byte) registers.

OSWORD **OS call specified by contents of A taking parameters in a parameter block.**

Call address &FFF1 Indirected through &20C

On entry,

A selects an OSWORD routine.
X contains low byte of the parameter block address.
Y contains high byte of the parameter block address.

OSWORDs which are called with accumulator values in the range &EO (224) to &FF *(255)* are passed to the USERV (&200). The routine indirected through the USERV is entered with the register contents unchanged from the original OSWORD call.

Other unrecognised OSWORD calls are offered to the paged ROMs (see service ROMs section 10.1, reason code 8).

OS WORD summary

A=0 Read line from currently selected input into memory.
A=1 Read system clock.
A=2 Write system clock.
A=3 Read interval timer.
A=4 Write interval timer.
A=5 Read byte of I/O processor memory.
A=6 Write byte of I/O processor memory.
A=7 Perform a SOUND command.
A=8 Define an ENVELOPE.

A=9 Read pixel value.
A=&A Read character definition.
A=&B Read palette value for a given logical colour.
A=&C Write palette value for a given logical colour.
A=&D Read previous and current graphics cursor positions.

OS WORD call with A=&0 Read line from input

This routine takes a specified number of characters from the currently selected input stream. Input is terminated following a RETURN or an ESCAPE. DELETE (&7F/127) deletes the previous character and CTRL U (&15/21) deletes the entire line. If characters are presented after the maximum line length has been reached the characters are ignored and a BEL (ASCII 7) character is output.

The parameter block

XY+ 0	Buffer address for input	LSB
1		MSB
2	Maximum line length	
3	Minimum acceptable ASCII value	
4	Maximum acceptable ASCII value	

Only characters greater or equal to XY+3 and less than or equal to XY+4 will be accepted.

On exit:

C=0 if a carriage return terminated input.
C= 1 if an ESCAPE condition terminated input.
Y contains line length, excluding carriage return if used.

OSWORD call with A = & 1 Read system clock

This routine may be used to read the system clock (used for the TIME function in BASIC). The five byte clock value is written to the address contained in the X and Y registers. This clock is incremented every hundredth of a second and is set to 0 by a hard BREAK.

OSWORD call with A=&2 Write System Clock

This routine may be used to set the system clock to a five byte value contained in memory at the address contained in the X and Y registers.

OS WORD call with A=&3 Read interval timer

This routine may be used to read the interval timer (Used for events, see section 6.4). The five byte clock value is written to the address contained in the X and Y registers.

OS WORD call with A=&4 Write interval timer

This routine may be used to set the interval timer to a five byte value contained in memory at the address in the X and Y registers.

OSWORD call with A=&5 Read I/O processor memory

A byte of I/O processor memory may be read across the Tube using this call. A 32 bit address should be contained in memory at the address contained in the X and Y registers.

XY+	0	LSB of address to be read
	1	
	2	
	3	MSB of address to be read
	4	

If the I/O processor uses 16 bit memory addressing only least significant two bytes need to be specified.
On exit:

The byte read will be contained in location XY+4.

OSWORD call with A=&6 Write I/O processor memory

This call permits I/O processor memory to be written across the Tube. A 32-bit address is contained in the parameter block addressed by the X and Y registers and the byte to be written should be placed in XY+4. For compatibility with future products it is recommended that XY+2 and XY+3 be set to zero.

OSWORD call with A=&7 SOUND command

This routine takes an 8 byte parameter block addressed by the X and Y registers. The 8 bytes of the parameter block may be considered as the four parameters used for the SOUND command in BASIC.

e.g. To perform a SOUND 1,-15,200,20

XY+ 0	Channel	LSB	1	&01
1		MSB		&00
2	Amplitude	LSB	-15	&F1
3		MSB		&FF
4	Pitch	LSB	200	&C8
5		MSB		&00
6	Duration	LSB	20	&14
7		MSB		&00

This call has exactly the same effect as the SOUND command.

OS WORD call with A=&8 Define an ENVELOPE

The ENVELOPE parameter block should contain 14 bytes of data which correspond to the 14 parameters described in the ENVELOPE command. This call should be entered with the parameter block address contained in the X and Y registers.

OSWORD call with A=&9 Read pixel value

This routine returns the status of a screen pixel at a given pair of X and Y co-ordinates. A four byte parameter block is required and the result is contained in a fifth byte.

XY+	0	LSB of the X co-ordinate
	1	MSB of the X co-ordinate
	2	LSB of the Y co-ordinate
	3	MSB of the Y co-ordinate

On exit:

XY+4 contains the logical colour at the point or &FF if the point specified was outside the window.

OS WORD call with A=&A Read character definition

The 8 bytes which define the 8 by 8 matrix of each character which can be displayed on the screen may be read using this call. The ASCII value of the character definition to be read should be placed in memory at the address stored in the X and Y registers. After the call the 8 byte definition is contained in the following 8 bytes.

XY+	0	Character required
	1	Top row of character definition
	2	Second row of character definition
	.	
	.	
	.	
	8	Bottom row of character definition

OSWORD call with A=&b Read palette

The physical colour associated with each logical colour may be read using this routine. On entry the logical colour is placed in the location at XY and the call returns with 4 bytes stored in the following four locations corresponding to a VDU 19 statement.

e.g. Assuming that a VDU 19,2,3,0,0,0 had previously been issued then OS WORD &B with 1 at XY would yield

XY+	0	2	logical colour
	1	3	physical colour
	2	0	padding for future expansion
	3	0	
	4	0	

OS WORD call with A=&C Write palette

This call performs the same task as a VDU 19 command (which can be used from machine code using OSWRCH). The advantage **of** using this OSWORD call rather than the conventional VDU route is that there is a significant saving in time. Another advantage is that OS WORD calls can be used in interrupt routines while VDU routines cannot. This call works in the same way as OS WORD &B (see above); a parameter block should be set up with the logical colour being defined at XY, the physical colour being assigned to it in XY+1 and XY+2 to XY+4 containing padding 0s.

OSWORD call with A=&D **Read last two graphics cursor positions**

The operating sytem keeps a record of the last two graphics cursor, positions in order to perform triangle filling if requested. These cursor postions may be read using this call. X and Y should provide the address of 8 bytes of memory into which the data may be written.

XY+	0	previous X co-ordinate, low byte
	1	high byte
	2	previous Y co-ordinate low byte
	3	high byte
	4	current X co-ordinate, low byte
	5	high byte
	6	current Y co-ordinate, low byte
	7	high byte

5 Filing System Calls

Any filing system implemented on the Electron offers its facilities by intercepting the standard OS filing system calls. The tape and
*ROM filing system code is contained within the operating system ROM. Other filing system software may be implemented in service type paged ROMs. The currently selected filing system must place pointers to relevent routines in the vectors provided for this purpose in page two of memory.

The description of the filing system calls given in this chapter covers a general filing system. The actual implementation will differ slightly between filing systems depending on the suitability of certain calls to their filing system medium.

The filing system calls are:

name	call address	indirection vector
OSFILE	&FFDD	&212
OSARGS	&FFDA	&214
OSBGET	&FFD7	&216
OSBPUT	&FFD4	&218
OSGBPB	&FFD1	&21A
OSFIND	&FFCE	&21C
OSFSC	n/a	&21E

Each of these calls should respond in an appropriate and relevant manner as described in the sections below. Even though the nature of certain filing system's hardware implementation may appear to vary widely, the user is presented with a standard filing system interface wherever possible. Software can be written which functions identically using a number of different filing systems. Where both X and Y are used to point to a parameter block. X holds the low byte and Y holds the high byte of the address.

5.2 OSFILE Read/write entire file or its attributes

Call address &FFDD Indirected through &212

This routine is used to manipulate an entire file. The precise function perfomed by this routine depends on the value in the accumulator. This call can be used to load a file into memory, save a file from memory, delete a file and re-write the file's attributes (e.g. load address, execution address, name etc.). Any information required by the routine to perform its task should be placed in memory. The address of this information should then be passed to the routine in the X and Y registers.

Entry parameters:

A contains a value indicating what action is required
X+Y contain the address of a parameter block

The format of the information placed in the parameter block addressed by X and Y is as follows:

&00 - &01	Address of file name
&02 - *&05*	Load address of file
&06 - &09	Execution address of file
&0A - &0D	Start address of data (write operations) or Length of file (read operations)
&0E - &11	End address of data (read/write operations) or File attributes (write attributes operation)

The file name should be stored in another part of memory (not sideways ROMs) and be terminated by a carriage return character (&0D) or a space (&20). The least significant byte of the address should be stored in the first of the two bytes. All other parameters are stored in the same order, least significant byte stored first.

The file attributes when required should be provided in the last four bytes of the parameter block. The least significant 8 bits (i.e. the first byte) have the following meanings:

Bit	Meaning if set	
0	not readable	by you
1	not writable	by you
2	not executable	by you
3	not deletable	by you
4	not readable	by others
5	not writable	by others
6	not executable	by others
7	not deletable	by others

The term *you* here means the originator of the call and the term *others* means other users of a network filing system.

The action.codes passed to OSFILE in the accumulator have the following effects:

A=0

Save a section of memory as a named file using the information supplied in the parameter block.

A=1

Re-write the catalogue information of an existing file using the information provided in the parameter block. i.e. load and execution addresses.

A=2

Re-write the load address (only) of an existing file identified by the name passed in the parameter block.

A=3

Re-write the execution address (only) of an existing file identified by the name passed in the parameter block.

A=4

Re-write the file attributes (only) of an existing file identified by the name passed in the parameter block.

A=5

Read the named file's catalogue entry and return the file type in the accumulator. These are as follows:

0 returned in A	Nothing found
1 returned in A	File found
2 returned in A	Directory found

A=6

Delete the named file.

A=7

Create a file with a catalogue entry representing the parameter block information but instead of transfering any data pad with null characters.

A=&FF

Load the named file into memory. If the first byte of the execution address field of the parameter block is zero then load to the load address given in the parameter block. If the first byte of the execution address is non-zero then use the file's own load address.

During this call if an error occurs a BRK instruction will be executed which may be trapped if required. During this call interrupts may be enabled but the interrupt status is preserved.

On exit:

A contains the file type
X and Y are preserved
C, N, V and Z are undefined
Information may be written to the parameter block addressed by X+Y.

5.2 OSARGS Read/write open file's attributes
Return current filing system

Call address &FFDA Indirected through &214

This routine is used to manipulate files which are being used for random access. Files used in this way have to be opened using the OSFIND call. When data is being written to or read from the file OSBPUT, OSBGET and OSGBPB can be used but this call should be used to move the sequential pointer used by these calls when data is not transferred. This call is the only way of moving the sequential pointer backwards through a file. OSARGS may also be used to force an update of files onto the medium in use i.e. ensuring that the latest copy of the memory buffer is saved. A number of other functions are performed by this call as detailed below.

Entry parameters:

A contains a value determining the call's actions
X contains a zero page address of a parameter block
Y contains the file handle (see OSFIND) or zero

The parameter block in zero page should be in the user's allocation of zero page. A block of four bytes is required, this will contain the value of the sequential file pointer for read operations or should be set up with a value prior to the call for a write operation. It should be noted that because filing systems should not be languages and so are not copied across to a second processor this parameter block will always exist in the I/O processor even when a Tube is active. If called from the second processor, the parameter block will be copied across into the I/O processor before the filing system is called.

Interrupts may be enabled during a call but the interrupt status will be preserved.

If Y=0 and A=0 then return the current filing system in A.

value returned	filing system
0	no current filing system
1	1200 baud cassette

2	300 baud cassette
3	ROM filing system
4	Disc filing system
5	Econet filing system
6	Telesoftware filing system
7	IEEE filing system
8	ADFS
9	Reserved
10	Acacia RAM filing system

If Y=0 and A= 1 then return the address in the I/O processor of the rest of the command line will be returned in the two least significant bytes of the zero page parameter block. This enables software to access the parameters passed with * commands.

If Y=0 and A=&FF then update all files onto the filing system medium; this ensures that the medium has the latest copy of the buffers.

If Y is non-zero then the value in Y is assumed to be a file handle (see OSFIND). The value passed in A determines the action on the open file specified by Y

A=0

Read sequential file pointer (written to the zero page parameter block). This pointer is the same as that used by BASIC called PTR#.

A=1

Write sequential file pointer.

A=2

Read length of sequential file. This value is the same as that returned by EXT# in BASIC.

A=3

Write length of sequential file. This call is not implemented in all filing systems but where implemented may be used either to truncate a file or to extend it (in which case it will be padded with zeroes).

A= &FF

Update this file onto the filing system medium.

On exit:

A is preserved except on a call with A=0 and Y=0
X and Y are preserved

C, N, V and Z are undefined

5.3 OSBGET Get a single byte from an open file

Call address &FFD7 Indirected through &216

This routine returns the value of a byte read from a file opened for random access. The file should have been previously opened using OSFIND, The file handle required by this call will have been provided from this OSFIND call.

Entry parameters:

Y contains file handle

A byte is read from that point in the file determined by the sequential file pointer. During each call of OSB GET the sequential file pointer is incremented by one. Thus successive OSBGET calls can be used to read bytes from the file sequentially. This pointer may be read or written using the OSARGS call thus enabling the use of random access.

Interrupts may be enabled during a call but the interrupt status will be preserved.

On exit:

X and Y are preserved
C= 1 if the end of file was reached i.e. invalid call in which case A=&FE.

N, V and Z are undefined

5.4 OSBPUT Write a single byte to an open file

Call address &FFD4 Indirected through &218

This call is the complement to the OSBGET call described above. A file handle should be provided from a prior OSFIND call and the sequential file pointer is used to locate the point in the file where the byte is written.

Entry parameters:

A contains the byte to be written to the file.
Y contains the file handle.

During the call a byte will be written to the file and the sequential pointer will be incremented. If the sequential file pointer reaches the end of the file the file will be extended to accommodate any new data written where possible.

Interrupts may be enabled during a call but the interrupt status will be preserved over a call.

On exit:

A, X and Y are preserved

C, N, V and Z are undefined

5.5 OSGBPB Read/write a group of bytes to/from an open file

Call address &FFD1 Indirected through &21A

This routine enables the transfer of a group of bytes to or from an open file. This routine is implemented particularly for filing systems which have a high time overhead associated with each data transfer e.g. the Econet.

Entry parameters:

A contains a value which determines the action performed

X+Y contain a pointer to a parameter block in memory

The parameter block should contain information in the following format:

&00	file handle
&01 - &04	address of data for transfer
&05 - &08	number of bytes to transfer
&09 - &0C	sequential file pointer to be used

The bytes in each parameter should be placed least significant byte first.

The address should include a high order address (see OSBYTE &82) to indicate if the data is in an i/o processor or a second processor.

The sequential file pointer passed in the parameter block will only replace the old value of this pointer when appropriate.

The action codes passed to the routine will have the following effects:

A=1

Write a group of bytes to the open file. The sequential pointer given will indicate the point in the file where these bytes are put and this pointer will be incremented by the number of bytes written.

A=2

Write a group of bytes to the open file without using the sequential file pointer value given in the parameter block. The existing value of the pointer will mark the point in the file where these bytes are put and the pointer will then be incremented by the number of bytes written.

A=3

Read a group of bytes from an open file. The sequential pointer given in the parameter block will indicate where the bytes should be read from within the file. The pointer will then be incremented by the number of bytes read.

A=4

Read a group of bytes from an open file disregarding the sequential file pointer value given in the parameter block. The existing pointer value will be used and subsequently incremented by the number of bytes read.

A=5

Return the title associated with the currently active medium and return boot/startup attribute, This information is written to the address pointed at by the X andY registers. The format of the data is:

&00	n, the length of the title string
&01 .n+ 1	the title string, ASCII characters
n+2	value indicating boot/start up options

The start up information is filing system dependent.

A=6

Return the currently selected directory and device identity. Two items of data are written to the parameter block. The format of the data is:

&00	n, the length of the directory name
&01 - n+1	directory name, ASCII string
n±2	m, the length of the device identity
n+3 - n+m+3	the device identity

A=7

Read the currently selected library, and device, The data format is the same as that used for A=6.

A=8

This call is used to read file names from the current directory. The parameter block should be set up so that the number of file names to transfer is placed in the ‘No. of bytes to transfer’ field, For the first call the ‘sequential file pointer’ field should be set to zero. The sequential file pointer is incremented each time this call is made so that it points to the next file name for transfer.

The data is transferred to the specified address in the form of a list of file names. Each file name takes the form of an ASCII string preceded by a single byte value indicating the length of the string. The number of filenames in this list is determined by the value passed in the parameter block unless the end of the directory is reached.

This call also returns a cycle number in the ‘file handle’ field of the parameter block. This cycle number represents the number of times the current catalogue has been written to.

Exit conditions:

A, X and Y are preserved
N, V and Z are undefined
C= 1 if the transfer could not be completed

In the event of a transfer not being completed the parameter block contains the following information:

(a) the number of bytes or names not transferred in the ‘number of bytes to transfer’ field

(b) the ‘address’ field contains the next location of memory due for transfer

(c) the ‘sequential pointer’ field contains the sequential file pointer value indicating the next byte in the file due for transfer

5.6 OSFIND Open or close file for random access

Call address &FFCE Indirected through &21C

This call is used to allocate a file handle for subsequent use by OSARGS, OSBGET, OSBPUT and OSGBPB. This call should also be used to close a file when no further access is required. In this instance the file handle is released for re-allocation and the file medium is updated from the buffers in memory.

The file handle is a single byte value which uniquely identifies an open file. This provides a less cumbersome method of addressing the file in question than using the filename each time. The number of files which can be open at any one time is filing system dependent. The actual range of handle values allocated by each filing system is different. The ranges which have been allocated by Acorn are listed under OSFSC with A=&07.

Entry parameters

(a) To open a file

The accumulator contains a code indicating the type of access for which the file should be opened:

A=&40 input only
A=&80 output only (i.e. will attempt to delete file first)
A=&CO input and output

X and Y contain the address of a file name string (low byte, high byte). The filename string should be terminated by a carriage return character (&0D).

The accumulator will be returned containing the file handle which has been allocated or zero if the file could not be opened. Note that if the filename is syntactically bad, or involves a non-existent directory, a BRK 'Not found' error may occur.

(b) To close a file

A=0 Y contains the handle of the file to be closed or Y=O to close all currently open files.

On exit:

A returns file handle on opening otherwise preserved
X and Y are preserved

C, N, V and Z are preserved
Interrupts may be enabled during call, status preserved

5.7 OSFSC Miscellaneous filing system control

No OS call address Indirected through &21E

This vector contains an entry point into the current filing system which may be used to invoke a number of miscellaneous filing system functions. Because there is no direct call address this call can only be made from within an I/O processor and is not

available for code running on a second processor. However many of the facilities are indirectly available via other OS calls which subsequently make calls through this vector.

Entry parameters:

The accumulator contains an action code determining which control function is performed.

A=0 *OPT command

The operating system makes this call in response to '*OPT' being submitted to the command line interpreter or in response to OSBYTE &8B. X andY contain the parameters passed with the **'*OPT' command.**

A= 1 Check for end of file (EOF)

This call is made by the operating system in response to OSBYTE &7F. The call is entered with a file handle value in the X register. The X register should be returned containing the value &FF if an EOF condition exists, otherwise it should be returned containing zero.

A=2 '*/' command

The filing system should attempt to *RUN the file whose name follows the '/' character. The operating system command line interpreter will make this call in response to a command begining '*/'. The X andY registers contain the address of the file name string (not including the '*/' characters).

A=3 Unrecognised *command

The operating system issues this call when an unrecognised command has been submitted to the command line interpreter. This call is made after the 'unrecognised *command' paged ROM service call has been made (see paged ROMs section 10.1). The command name string is addressed by the X and Y registers.

Filing systems will respond to this call by attempting to *RUN the file having the command name. The idea behind this is to enable the implementation of command like utilities which are stored on the filing system media. However in the case of a filing system being unable to execute the file without delay the filing system should respond to this call with a ‘Bad Command’ message instead.

A=4 *RUN attempted

The operating system passes on the file name given with a *RUN command to the current filing system using this call. The X and Y registers contain the address of the file name string, The filing system should then load and execute the code in this file.

A=5 *CAT attempted

This call is made by the operating system in response to a *CAT command. The X and Y registers contain the address of the rest of the command string where any parameters required by the routine may be found.

A=6 New filing system selected

This call is issued when the current filing system is being changed. The deselected filing system should respond by closing any
*SPOOL or *EXEC files using OSBYTE &77 and prepare itself for the handover.

A=7 Return handle range

This call may be made to determine the range of values allocated as file handles by the currently selected filing system. Below is a list of the handle ranges that have been allocated by Acorn.

filing sysem	handle range, inclusive	
Tape filing system	1 (&01)	2 (&02)
*ROM filing system	3 (&03)	3 (&03)
Teletext filing system	14 (&0E)	15 (&0F)
Disc filing system	17 (&12)	21 (&15)
Network filing system	32 (&20)	39 (&29)

Winchester DFS	48 (&30)	57 (&39)
reserved values	64 (&40)	71 (&49)
Acacia RAM filing system	96 (&60)	101 (&65)
IEEE filing system	240 (&FO)	255 (&FF)

The X register is returned with the lowest value which may be allocated as a file handle and the Y register returned with the highest value used.

A=8 OS *command about to be processed

The operating system makes this call prior to executing a *command. Acorn DFS uses this call to implement the '*ENABLE' protection mechanism. This call may also be used by filing systems to output extra messages e.g. 'Compaction recommended' when free space has become highly fragmented on a disc.

On exit:

Registers returned as described above
Otherwise registers undefined
Status flags undefined
Interrupts may be enabled, status preserved

6 Operating System Vectors

Many of the operating system routines are indirected through addresses stored in RAM. This enables other software to intercept these calls as they are made.

During a reset the operating system stores the addresses of its internal routines for such things as reading and writing characters in locations in page two. The *official* entry point of these routines point to instructions like JMP (vector). If another piece of software replaces the address stored in the vector then each subsequent call is passed to the intercepting software.

Consider the following example:

This program assembles a routine which intercepts **‘$‘** and ‘£’ characters passed to the OSWRCH routine and exchanges them.

```
 10 DIM code% 100
 20 WRCHV=&20E
 30 FOR opt%=0 TO 3 STEP3
 40 P%=code%
 50 [
 60       OPT opt%
 70 .init LDA WRCHV              \ A=lo byte of vector
 80       STA ret_vec            \ make a copy
 90       LDA WRCHV+1            \ A=hi byte of vector
100       STA ret_vec+1          \ make a copy
110       LDX #intrcpt AND &FF   \ X=lo byte of new routine
120       LDY #intrcpt DIV &100  \ Y=hi byte of new routine
130       SEI                    \ disable interrupts
140       STX WRCHV              \ store new routine address
150       STY WRCHV+1            \ in WRCH Vector
160       CLI                    \ enable interrupts
170       RTS                    \ finished initialisation
180 .intrcpt CMP #ASC"£"         \ trying to print a £ ?
190       BEQ pound              \ if so branch
200       CMP #ASC"$"            \ trying to print a $ ?
210       BEQ doLlar             \ if so branch
220       JMP (ret_vec)          \ neither goto old routine
```

```
230 .pound                      LDA #ASC"$" \ replace £ with $
240       JMP (ret_vec)         \ goto old routine
250 .dollar                     LDA #ASC"£" \ replace $ with £
260       JMP (ret_vec)         \ goto old routine
270 .ret_vec EQUW 0             \ space for return vector
280 ]
290 NEXT
300 CALL init
```

This program, although not very long, illustrates a few points regarding the way in which vectors should be intercepted.

One of the most important aspects concerning the interception of calls through vectors is to make sure that the call is passed on to the previous owner of the vector. There are occasions when a routine is intended to be the sole replacement of a vector but as a rule it is good programming practice to copy the old vector contents to a returning vector. By returning via the old vector contents any number of intercepting routines can be daisy chained into the operating system call.

While the initialising routine is changing the vector contents to point at the new routine it is wise to disable interrupts, It would obviously be quite catastrophic if the OSWRCH routine were to be called when the vector was only half changed. An interrupt handling routine is unlikely to use the WRCHV but there is no reason why it should not.

The intention in this section has been to make programmers aware of the problems which may occur when intercepting these vectors. They have been implemented so that they may be used to insert extra code into some of the operating system routines and individuals should not be afraid of using them to this end. However, careful thought is required; take full account of the ramifications of altering the operating systems usual response to calls. If in doubt try out a routine. Play about with trivial examples such as the one given above. There is nothing to be lost and much to be
learnt.

Os and filing system calls indirection vectors

The vector addresses associated with those operating system calls which are indirected are given in the detailed description of each call in chapter 2. The entry conditions with which the routine whose address is containedwithin these vectors will be unchanged from the initial OS call.

Other page 2 vectors

The other vectors reserved for containing the addresses of other operating system and miscellaneous routines are described below. These are :

Name	addr.	description
USERV	&200	The user vector
BRKV	&202	The BRK vector
IRO1V	&204	Primary interrupt vector
IRO2V	&206	Unrecognised IRO vector
FSCV	&21E	File system control entry
EVNTV	&220	Event vector
UPTV	&222	User print routine
NETV	&224	Econet vector
VDUV	&226	Unrecognised VDU commands
KEYV	&228	Keyboard vector
INSV	&22A	Insert into buffer vector
REMV	&22C	Remove from buffer vector
CNPV	&22E	Count/purge buffer vector
IND1V	&230	unused/reserved for future expansion
IND2V	&232	unused/reserved for future expansion
IND3V	&234	unused/reserved for future expansion

6.1 The User Vector &200

The user vector is called by the operating system in three circumstances.

(a) When *CODE is passed to the command line interpreter

The *CODE command takes two parameters which are placed in the X and Y registers. The user vector is then called with an accumulator value of zero. OSBYTE &88 may also be used to generate a *CODE command.

(b) When *LINE is passed to the command line interpreter

The *LINE command takes a line of text as a parameter. The user vector is entered with the X and Y registers containing the address of this text and A= 1.

(c) When an OS WORD call &EO to &FF has been made The user vector is entered with the register values they were when the original OS WORD call was made.

The default address stored in this vector points to a routine which generates an error with the message ‘Bad command’ and error number &FE.

This vector is fully implemented on the BBC microcomputer and the Electron. On a Tube machine only the vector on the I/O processor is offered these calls.

Listed below is a program which assembles a routine to intercept calls made to the user vector. It may be noticed that this routine does not offer the calls back to the original vector routine, this is because the default routine generates an error. There should only be one user vector handling routine active at any one time.

```
0REM User vector handling routine

10DIM code% &100
20OSASCI=&FFE3
30USERV=&200
40FOR opt%=0 TO 3 STEP 3
   50  P%=code%
   60  [
   70  OPT opt%
   80  .init    LDX #userrt AND &FF   \ X=lo byte of routine addr.
   90           LDY #userrt DIV &100  \ Y=hi byte of routine addr.
  100           SEI                   \ disable interrupts
  110           STX USERV             \ set up vector with addr.
  120           STY USERV+1
  130           CLI                   \ enable interrupts
  140           RTS                   \ and return
  150  .userrt CMP #1                 \ compare contents of A with1
  160           BCC code              \ A<1 then must be *CODE
  170           BNE osword            \ now if A<>1 must be OSWORD
  180           STX &70               \ *LINE routine
  190           STY &71               \ store text address in page0
  200           LDY #&FF              \ set Y as loop counter
  210  .loop    INY                   \ beginining of loop Y=Y+1
  220           LDA (&70),Y           \ load first byte of string
  230           JSR OSASCI            \ print it
  240           CMP #&D               \ was character a cr?
  250           BNE loop              \ if not get the next char.
  260           RTS                   \ if it was return
  290  .code    TXA                   \ A=X
  300           JSR prntbt            \ print value of X
  310           JSR space             \ print a space
  320           TYA                   \ A=Y
  330           JSR prntbt            \ print value of Y
  340           JMP new_ln            \ print newline and return
350 .osword    PHA                   \ save contents of A
  360           LDX #&FF              \ set X as loop counter
  370  .loop1   INX                   \ beginning of loop, X=X+1
  380           LDA string,X          \ load character from string
  390           JSR OSASCI            \ print it
  400           CMP #ASC"&"           \ & char. is end of string
  410           BNE loopi             \ loop if not end of string
  420           PLA                   \ reload the value of A
  430           JSR prntbt            \ print it out in hex
  440           JMP new_ln            \ print cr and return
```

```
450  .space  LDA #&20              \ A=space character
460          JMP OSASCI            \ print space and return
470  .new_ln LDA #&D               \ A=carriage return character
480  JMP OSASCI                    \ print cr and return

490  .string EQUS “OSWORD &“       \ string for OSWORD routine


499  \*** This routine prints hex number given in A
500  .prntbt PHA                   \ save copy of accumulator
510  LSR A
520  LSR A
530  LSR A
540  LSR     A                     \ shift nibble hi to lo
550  JSR     nibble                \ print hi nibble hex digit
560  PLA                           \ reload accumulator
570  .nibble AND #&0F              \ mask out high nibble
580  CMP     #&0A                  \ digit or letter?
590  BCC     number                \ A<10 print number
600  ADC     #&06                  \ otherwise add 7 (C=1)
610  .number ADC #&30              \ add &30 to convert to ASCII
620  JMP     OSASCI                \ print character and return
630  ]
640  NEXT
650  CALL init
```

Once assembled this routine will respond to *CODE by printing out the parameters passed with the command. A *LINE command will result in the parameter string being repeated on the screen and an OS WORD in the region &EO to &FF will print out the number of the call.

e.g.

```
>*CODE 1,2
01 02
>*LINE SOME TEXT
SOME TEXT
>A%=&EO:CALL &FFF1
OSWORD &EO
>
```

6.2 The BRK Vector &202

When a BRK instruction (op code value 0) is executed an interrupt is generated. The operating system stores the address of the byte following the BRK instruction in &FD and &FE, offers the BRK to paged ROMs with service call &06, stores the ROM number of the currently active paged ROM for recovery using OSBYTE &BA (ROM active at last BRK), restores registers, selects the current language ROM and then passes the call to the BRKV code.

The BRK instruction is normally used on Acorn machines to represent an error condition and the BRK vector routine is an error handling routine. In BASIC this error handling routine starts *off* by putting its house in order and then prints out an error message.

In addition to the use of BRKs for the generation of errors it is often useful in machine code programming to include BRKs (break-points) as a debugging aid.

If a BRK instruction is executed on the Electron, the BRK vector is entered with the following conditions:

(a) The A, X and Y registers are unchanged from when the BRK instruction was executed.

(b) An RTI instruction will return execution to the address two bytes after the BRK instruction (i.e. jumps over the byte following the BRK). The RTL instruction also restores the status register value from the stack.

(c) The address of the byte following the BRK instruction is stored in zero page locations &FD and &FE, This address can then be used for indexed addressing.

Error handling BRK routines should not return to the code which executed the BRK but should reset the stack (using a TXS instruction) and JMP into a suitable reset entry point. In fact the convention used by Acorn is to follow the BRK instruction by:

a single byte error number
an error message
a zero byte to terminate the message

and the BRK routine prints out the error name. The BRK handling routine should normally be implemented by the current language. Service paged ROMs should copy a BRK instruction followed by the error number and message down into RAM when wishing to generate an error. This has to be done because otherwise the current language ROM is paged in and the BRK handling routine tries to print out the error message from the wrong ROM. The bottom of page 1 is often used and is quite safe as long as the BRK handling routine resets the stack pointer.

The use of BRKs as break-points in machine code programming can be of great use to the machine code programmer. The example below shows how a BRK handling routine may be used to print out the register values. This routine could be further enhanced by printing out the value of the byte following the BRK instruction which would then give the programmer *256* individually identifiable break-points.

```
 10 REM Primitive BRK handling routine
 20 DIM code% &100
 30 OSASCI=&FFE3
 40 OSRDCH=&FFE0
 50 BRKV=&202
 60 FOR opt%=0 TO 3 STEP 3
 70 P%=code%
 80  [
 90 OPT opt%
100 .init   LDX #brkrt AND &FF     \ load registers with address
110         LDY #brkrt DIV &100
120         SEI                    \ disable interrupts
130         STX BRKV               \ set up BRK vector
140         STY BRKV+1
150         CLI                    \ enable interrupts and return
160         RTS
170 .brkrt  PHA                    \ save A CX and Y not used)
180         STA byte               \ store A in workspace
190         LDA #ASC"A             \ register id
200         JSR prntrg             \ print register value
210         STX byte               \ store X in workspace
220         LDA #ASC"X"            \ register id
```

```
230         JSR prntrg            \ print register value
240         STY byte              \ store Y in workspace
250         LDA #ASC"Y"           \ register id
260         JSR prntrg            \ print register value
270         JSR new_ln            \ print carriage return
280         JSR OSRDCH            \ wait for key press
290         PLA                   \ restore A
300         RTI                   \ return

310 .prntrg JSR OSASCI            \ print register id
320         LDA #ASC":"
330         JSR OSASCI            \ print colon
340         JSR space             \ print space
350         LDA #ASC"&"
360         JSR OSASCI            \ print ampersand
370         LDA byte              \ get register value
380         JSR prntbt            \ print hex number
390         JSR space
400         JSR space             \ print two spaces
410         RTS
420 .space  LDA #&20
430 JMP OSASCI                    \ print space

440 .new_ln LDA #&D
450         JMP OSASCI            \ print carriage return
460 .prntbt PHA                   \ for comments refer to
470         LSR A                 \ previous example
480 LSR A
490 LSR A
500 LSR A
510 JSR nibbLe
520 PLA
530 .nibble AND #&OF
540 CMP #&OA
550 BCC number
560 ADC #&06
570 .number ADC #&30
580 JMP OSASCI
590 .byte   EQUB 0                \ workspace byte
600 .test   BRK                   \ cause an error
610         EQUB 0                \ RTI returns to next byte
620         DEX                   \ Loop X times
630         BNE test              \ if X=0 Loop again
640 RTS
650 ]
660 NEXT
670 CALL init
680 A%=1:X%=8:Y%=&FF:CALL test
```

6.3 The interrupt vectors, IRQ1V &204 and !RQ2V &206

The interrupt system on the Electron is described in chapter 7. The function of the two interrupt vectors are described there.

6.4 The event vector, EVNTV &220

This vector is called by the operating system during its interrupt routine to provide users with an easy to use interrupt, A number of 'events' may cause the event handling routine to be called via `this vector but unlike an interrupt the reason for the call is passed` to the routine. The value in the accumulator indicates the type of event:

event no.	cause of event
0	output buffer becomes empty
1	input buffer becomes full
2	character entering input buffer
3	ADC conversion complete
4	start of VSYNC
5	interval timer crossing zero
6	ESCAPE condition detected
7	RS423 error detected
8	Econet event
9	user event

To avoid unecessary and time consuming calls to the event vector two OSBYTE calls are used to enable and disable these event calls being made. These are &D (13) for disabling and &E (14) for enabling events.

The event handling routine should not enable interrupts and not last for more than about 2 milliseconds. So that event handling routines may be daisy chained they should preserve registers and return using the old vector contents.

Output buffer empty 0

This event enters the event handling routine with the buffer number (see OSBYTE &15/*FX21) in X. It is generated when a buffer becomes empty (i.e. just after the last character is removed).

Input buffer full 1

This event enters the event handling routine with the buffer number (see OSBYTE *&151*FX* 21) in X. It is generated when the operating system fails to enter a character into a buffer because it is full. Y contains the character value which could not be inserted.

Character entering input buffer 2

This event is normally generated by a key press and the ASCII value of the key is placed in Y, It is generated independently of the input stream selected.

ADC conversion complete 3

When an ADC conversion is completed on a channel this event is generated. The event handling routine is entered with the channel number on which the conversion was made in Y. This event is generated by the Plus 1 expansion software.

Start of vertical sync 4

This event is generated *50* times per second coincident with vertical sync. One use of this event is to time the change to a video ULA register so that the change to the screen occurs during fly back and not while the screen is being refreshed. This avoids flickering on the screen.

Interval timer crossing zero 5

This event uses the interval timer (see OSWORD calls &3 and &4, in chapter 4). This timer is a *5* byte value incremented 100 times per second. The event is generated when the timer reaches zero.

ESCAPE condition detected 6

When the ESCAPE key is pressed or an ESCAPE is received from the RS423 (if RS423 ESCAPEs are enabled) this event is generated.

RS423 error event 7

This event should be generated by software servicing expansion RS423 hardware.

Network error event 8

This event is generated when a network event is detected. If the net expansion is not present then this could be used for user events.

User event 9

This event number has been set aside for the user event, This is most usefully generated from a user interrupt handling routine to enable other user software to trap an interrupt easily (e.g. an event generated from an interrupt driven utility in paged ROM). An event may be generated using OSEVEN, see section 2.10

6.5 User print vector, UPTV &222

A user print routine can be implemented by intercepting this vector, Whenever a change in printer type is made using OSBYTE &05 the print vector is called. A user print routine should respond when printer type 3 is called.

The operating system will activate the user printer routine and there after call it regularly at intervals of 10 milliseconds. Characters will be placed in the printer buffer and it is up to the user printer routine to remove characters and send them to the printer hardware. When the printer routine finds that the buffer is empty it should then declare itself inactive. The operating system will then re-activate the routine when characters start entering the buffer again.

The user printer driver should preserve all registers and return via the old UPTV value.

On entry:

X contains the buffer number to be used
Y contains the printer number (i.e. the *FX *5* value)

N. B. The routine should only respond if it recognises the printer number as its own.

The accumulator contains a reason code for the call:

A=0

When the printer driver is active the operating system makes this call every 10 ins. The printer driver should examine its hardware and if it is ready for another character should remove a character from the assigned buffer and send it to the printer. A call to the REMV vector should be made to obtain the character (see section 6.9.2) or use OSBYTE &91, When the printer driver has emptied the printer buffer it should then declare itself inactive by making an OSBYTE call &7B. This will allow the user to select a new printer driver using OSBYTE *&5*, will stop further calls with A=0 and thereafter when the printer buffer is used again will cause a call with A=1 to be made (see below).

A=1

When a printer driver is inactive this call is made to tell the routine that the printer buffer is no longer empty and the printer driver should now become active. If the printer driver is able to become active it should remove a character from the assigned

buffer and if the buffer is still not empty it should return with the carry flag clear to indicate that it is now active. Having thus signalled itself as active the printer driver will receive the 10 ms calls with A=0.

A=2

When the VDU drivers receive a VDU2 this call is made. Characters may be printed even when this control character has not been received if certain *FX3 options are selected.

A=3

This call is made when a VDU3 is received.

A=5

The selection of a new printer driver will cause this call to be made to the printer vector. Any OSBYTE &5 call causes this call to be made.

6.6 Econet vector, NETV &224

The Econet vector allows the Network filing system to intercept a wide range of operating system functions. This vector is called with a reason code in the accumulator. The conditions under which this vector is called are:

A=0,1,2,3 and *5*

These codes are used to control the net printer. These calls are made under identical circumstances as for the user print vector described above. The net printer is assigned the printer number 4.

A=4

OSWRCH call made. This call is indirected through the net vector after OSBYTE &DO has been used. The Y register contains the value originally passed in the accumulator. If, on exit, the carry flag is set then the output call is not performed.

A=6

OSRDCH call made. This call is indirected through the net vector after OSBYTE &CF has been used. The ASCII value for a key read should be returned in the accumulator.

A=7

OSBYTE call made. This indirection is performed after OSBYTE &CE has been used. The OSBYTE parameters are stored in locations &EF, &FO and &F1. If the overflow flag is set on return from this call then the OSBYTE call is not performed.

A=8

OS WORD call made. Circumstances as for call with A=7.

A=&0D

After completion of a line of input using OS WORD &01 this call is made. This is implemented so that the Network filing system doesn't takeover the RDCH routine in the middle of line input.

6.7 VDU extension vector, VDUV &226

This vector is called when the VDU drivers are presented with an unknown command or a known command in a non-graphics MODE.

A VDU 23,n command with a value of n in the range 2 to 31 will cause a call to be made to this vector with the carry flag set. The accumulator will contain the value n.

An unrecognised PLOT command or the use of a PLOT command in a non-graphics MODE will result in this call being made with the carry flag clear. The accumulator will contain the PLOT number used.

This vector is used whenever the keyboard is being looked at. There are four different calls made through this vector on the Electron.

(a) Test SHIFT and CTRL keys On entry: C=O, V=O

Should exit with the N (negative) flag set *if* the CTRL key is pressed and with the V (overflow) flag set *if* the SHIFT key is pressed.

(b) Scan keyboard as for OSBYTE &79

On entry: C= 1 , V=O other parameters identical to OSBYTE **&79**

Should exit with the appropriate register values (see OSBYTE details) but with A=X.

(c) Timer interrupt service with keys active

On entry: C=1, V=1

This entry is actually used for the bulk of all keyboard processing. After an interrupt the actual keyboard scan is carried out during this call. On the Electron which doesn't use an interrupt driven
keyboard, intercepting this call to the KEYV routine and returning it speeds up the machine enormously.

(d) Timer interrupt service with no keys active

On entry: C=0, V=1

6.9 The buffer maintenance vectors

This vector and the two following vectors enable the user to intercept or use the operating system buffer maintenance routines.

The operating system uses buffers for keyboard input, RS423 input and output, the printer, the sound system (4 buffers) and the speech system. These buffers contain data which should be processed by the various routines. Even though the servicing routine may not be able to respond to the request immediately the calling routine returns (unless the buffer is full) and is able to get on with its foreground task. While a buffer contains a queue of data for processing, the interrupt routine (the background task) sees to it that the relevant routines service this data.

In this way the user is able to type ahead when the machine is unable to respond immediately and may initiate sounds which then continue while he issues further commands.

Buffers operate on a first in first out (FIFO) basis for obvious reasons.

The Acorn BBC range of machines use the following numbers as buffer IDs:

title	**number**
keyboard buffer	0
RS423 input buffer	1
RS423 output buffer	2
printer buffer	3
SOUND channel 0 buffer	4
SOUND channel 1 buffer	*5*
SOUND channel 2 buffer	6
SOUND channel 3 buffer	7
speech buffer	8

On the BBC microcomputer and the Electron memory is reserved for each of these buffers even though the software/hardware using the buffer may not be present. The buffer maintenance calls still service these buffers but the contents will

not be processed by the relevant service routine. The expansion software/hardware will use the appropriate buffer when installed. Thus when the speech expansion is fitted on a BBC microcomputer the speech buffer is used and on an Electron with a Plus 1 the printer buffer is used.

The following OSBYTE calls may also be of interest when considering the buffer facilities:

Description	**OSBYTE number**
flush selected buffer class	&0F (15)
flush particular buffer	&15 (21)
get buffer status	&80 (128)
insert value into buffer	&8A (138)
get character from buffer	&91 (145)
examine buffer status	&98 (152)
insert value into i/p buffer	*&99* (153)

6.9.1 Insert value into buffer vector, INSV &22A

This vector contains the address of a routine which inserts a value into a selected buffer.

Entry parameters:

A=value to be inserted
X=buffer id

On exit:

A and X are preserved
Y is undefined

C flag is set if insertion failed (i.e.buffer full)

6.9.2 Remove value from buffer vector, REMV &22C

This vector contains the address of a routine which removes a value from the selected buffer. This routine may also be used to examine the next character to be removed from a buffer without actually removing it.

Entry parameters:

X=buffer ID
V= 1 (overflow flag set) if only examination requested

On exit:

A contains next byte to be removed (examination call)
(A undefined for removal call)
X is preserved
Y contains the value of the byte removed from the buffer
(Y undefined for examination call)
C flag is set if buffer empty when call made

6.9.3 Count/purge buffer vector, CNPV &22E

This vector contains the address of a routine which may be used to clear the contents of a buffer or to return information about the free space or contents of a buffer.

Entry parameters:

X=buffer ID
V= 1 (overflow flag set) to purge buffer
V=0 (overflow flag clear) for count operation
C= 1 count operation returns amount of free space
C=0 count operation returns length of buffer contents

On exit:

X and Y contain value of count (low byte, high byte)
X and Y are preserved for a purge operation
A is undefined
V and C are preserved

6.9.4 Using the buffer vectors

It should be noted that none of the buffer maintenance routines check for valid buffer IDs. Using a buffer ID outside the assigned range will have undefined effects unless specifically intercepted.

None of these vectors are implemented on second processors and so none of the buffer maintenance calls are sent across the Tube. Calls using the buffer vectors should always be made by code

resident in the I/O processor. It should be noted that considerable manipulation of the buffers may be carried out using OS routines such as OSBYTE, OSWRCH, OSWORD etc. which may affect buffer contents either directly or indirectly. Routines intercepting these vectors must always be resident on the I/O processor, ideally in service type paged ROMs.

The program below illustrates how the buffer vectors can be intercepted to implement a much larger printer buffer. The standard printer buffer is less than &lOO bytes long and since printers as a rule tend to be quite sluggish peripherals this buffer rapidly fills up. A buffer is required which will hold a reasonable sized listing, or a document before filling up and refusing to accept further input. Having placed the item for printing in an enlarged buffer the user may return to word processing or programming leaving the operating system to get on with the printing.

The routine used below creates a buffer of variable size as defined by the variable ‘size’. The usefulness of this program is limited. For the reasons given above it will only work when run on a non-Tube mahine. It will only work as long as its code is not corrupted; this means that renumbering the program after it has been run will *crash* the machine as BASIC tramples all over the area originally reserved for the assembled code. Similarly another language ROM is unlikely to allow the routine to run in peace. If this routine becomes corrupted the machine is totally disabled because each time a key is pressed this routine is called. Experimenting with this example will provide valuable experience in the use of critical operating system routines. One note of warning however, be sure to save a copy of the program before trying to run it; it is quite possible for the program to corrupt itself or even *crash* the machine irrevocably so that a power on reset is required (that is, the machine will have to be turned off, then on again).

This program consists of three main routines which intercept the buffer maintenance calls for the printer buffer. Calls for any of the other buffers are carefully handed on to the original routines pointed to by the contents of the buffer vectors. An area of RAM is reserved for use as a buffer by using a DIM statement. Four bytes of zero page memory are used to house two 16 bit pointers.

One pointer is used as an index for the insertion of values into the buffer and the other pointer is used as an index for the removal of bytes. When a pointer reaches the end of the buffer it is pointed to the beginning again, In this way the two pointers cycle through the buffer space. A full buffer is detected by incrementing the input pointer and comparing it to the output pointer. If the two pointers are equal the buffer is full, the character cannot be inserted; the input pointer is restored. If after the removal of a character the output pointer becomes equal to the input pointer then the buffer is now empty. By using this system the full size of the buffer is always available to contain data.

```
 10 REM user printer buffer routine
 20 MODE7
 30 size=&2000
 40 DIM buffer size
 50 DIM code% &400
 60 INSV~&22A
 70 RMV=&22C
 80 CNPV=&22E
 90 ptrblk=&80: !ptrblk=buffer+buffer*&10000
100 ip_ptr=ptrblk:op_ptr=ptrblk+2
110 FOR I=0 TO 3 STEP 3
120  P%=code%
130 [
140 OPT I
150 .init    LDA INSV          \ make copies of old vector
160          STA reti          \ contents to pass on calls
170          LDA INSV+1
180          STA retl+1
190          LDA RMV
200          STA ret2
210          LDA RMV+1
220          STA ret2+1
230          LDA CNPV
240          STA ret3
250          LDA CNPV+1
260          STA ret3+1
270          LDX #ins AND &FF   \ store address of new
280          LDY #ins DIV &100  \ routines in vectors
290          SEI                \ disable interrupts
300          STX INSV
310          STY INSV+1
320          LDX #rem AND &FF
330          LDY #rem DIV &100
340          STX RMV
350          STY RMV+1
360          LDX #cnp AND &FF
```

```
370           LDY #cnp DIV &100
380           STX CNPV
390           STY CNPV+1
400           CLI                 \    enable interrupts
410           RTS                 \    finished
420 .wrkbt    EQUB 0              \    byte of RAM workspace
430 .retl     EQUW 0              \    reserve space for vectors
440 .ret2     EQUW 0
450 .ret3     EQUW 0
460 .wrngbfl  PLP:PLA:JMP (reti) \restore S & A, call OS
470 \New insert char. into buffer routine
480 .ins      PHA:PHP             \    save A and status register
490           CPX #3              \    is buffer id 3 ?
500           BNE wrngbfl         \    if not pass to old routine
510           PLP                 \    not passing on, tidy stack
520           LDA ip_ptr          \    A=lo byte of input pointer
530           PHA                 \    store on stack
540            LDA ip_ptr+l       \    A=hi byte of input pointer
550            PHA                \    store on stack
560            LDY #0             \    Y=0 so ip_ptr incremented
570            JSR inc_ptr        \     by the inc_ptr routine
580            JSR compare        \    compare the two pointers
590            BEQ insfail        \    if ptrs equal, buffer full
600            PLA:PLA:PLA        \    don't need ip_ptr copy now
610            STA (ip_ptr),Y     \    A off stack, insrt in bufr
620            CLC                \    insertion success, C=0
630            RTS                \    finished
640 .insfail   PLA                \    buffer was full so must
650            STA ip_ptr+1       \     restore ip_ptr which was
660            PLA                \     stored on the stack
670            STA ip_ptr
680            PLA
690            SEC                \    insertion failes so C=a
700            RTS                \    finished
710 .wrngbf2   PLP:JMP (ret2)     \    restore 5, call OS
720 \New remove char. from buffer routine
730 .rem      PHP                 \    save status register
740           CPX #3              \    is buffer id 3 ?
750           BNE wrngbf2         \    if not use OS routine
760           PLP                 \    restore status register
770           BVS examine         \ V=1, examine not remove
780 .remsr    JSR compare         \ compare i/p and o/p ptrs
790           BEQ empty           \ if the same, buffer empty
800           LDY #2              \ Y=2 so that increment ptr
810           JSR inc_ptr         \ routine inc's op_ptr
820           LDY #0              \ Y=0, for next instruction
830           LDA (op_ptr),Y      \ fetch character from bufr
840           TAY                 \ return it in Y
850           CLC                 \ buffer not empty, C=0
860            RTS                \ return
```

```
 870 .empty    SEC                \ buffer empty, C=a
 880           RTS                \ return
 890 .examine  LDA op_ptr         \ examine only, so store a
 900           PHA                \ copy of the oip pointer
 910           LDA op_ptr+1       \ on the stack to restore
 920           PHA                \ ptr after fetch
 930           JSR remsr          \ fetch byte from buffer
 940           PLA                \ restore ptr from stack
 950           STA op_ptr+1       \ (if buffer was empty
 960           PLA                \ C=1 from fetch call)
 970           STA op_ptr
 980           TYA                \ examine requires ch, in A
 990           RTS                \ finished
1000 .wrngbf3 PLP:JMP (ret3)     \ restore 5, call OS
1010 \ New count/purge buffer routine
1020 .cnp     PHP                \ save status reg. on stack
1030          CPX #3             \ is buffer id 3 ?
1040          BNE wrngbf3        \ if not pass toold subr
1050          PLP                \ restore status register
1060          PHP                \ save again
1070          BVS purge          \ if V=1, purge required
1080          BCC len            \ if C=0, amount in buffer
1090          LDA ip_ptr         \ o/w free space request
1100          PHA
1110          LDA ip_ptr+1       \ store ip_ptr on stack
1120          PHA
1130          LDX #0             \ X=0 for use as counter
1140          STX wrkbt          \ wrkbt=0 for hi counter
1150          LDY #0             \ Y=0, so ip_ptr incr'd
1160 .loopl   JSR inc_ptr        \ increment ip_ptr
1170          JSR compare        \ does it equalop_ptr
1180          BEQ finshdl        \ if so count~free space
1190          INX                \ X=X+1
1200          BNE no_inc         \ if X=0 don't inc wrkbt
1210          INC wrkbt          \ hi byte of count inc'd
1220 .no_inc  JMP loopi          \ loop round again
1230 .finshdl PLA                \ restore ip_ptr off stack
1240          STA ip_ptr+1
1250          PLA
1260          STA ip_ptr
1270          LDY wrkbt          \ Y=hi byte of free space
1280          PLP                \ restore status register
1290          RTS                \ finished
1300 .len      LDA op_ptr        \ store op_ptr on stack
1310          PHA
1320           LDA op_ptr+1
1330          PHA
1340           LDX #0            \ X=0 for use as counter
1350           STX wrkbt         \ wrkbt=0 hi byte of count
1360           LDY #2            \ Y=2 so op_ptr incremented
1370 .loop2     JSR compare      \ are ptrs equal ?
```

```
1380          BEQ #nshd2         \ if so buffer empty
1390          JSR inc_ptr        \ increment op_ptr
1400          INX                \ increment count
1410          BNE no_inc2        \ if X=0 then increment hi
1420          INC wrkbt          \ byte of count
1430 .no_inc2 JMP loop2          \ loop round again
1440 .finshd2 PLA                \ restore op_ptr off stack
1450          STA op_ptr+1
1460          PLA
1470          STA op_ptr
1480          LDY wrkbt          \ Y=hi byte of length
1490          PLP                \ restore status register
1500          RTS                \ finished
1510 .purge   LDA #buffer AND &FF\ to purge buffer reset
1520          STA ip_ptr         \ oip and i/p ptrs to
1530          STA op_ptr          \ start of buffer
1540          LDA #buffer DIV &100
1550          STA ip_ptr+1
1560          STA op_ptr+1
1570          PLP                \ restore status register
1580          RTS                \ return
1590 \ Increment pointer routine. Y=0 op_ptr, Y=2 ip_ptr
1600 .inc_ptr CLC                \ C=0
1610          LDA ptrblk,Y       \ A=?(ptrblk+Y)
1620          ADC #1             \ A=A+1+C
1630          STA ptrblk,Y       \ ?(ptrblk+Y)=A
1640          LDA ptrblk+1,Y     \ A=?(ptrblk+1+Y)
1650          ADC #0             \ A=A+0+C
1660          STA ptrblk+1,Y     \ ?(ptrblk+1+Y)=A
1670          CMP #(buffer+size) DIV &100 \ hi byte end of bufr
1680          BNE home           \ not end of buffer
1690          LDA ptrblk,Y       \ A=low byte of pointer
1700          CMP #Cbuffer+size) AND &FF \ end of buffer ?
1710          BNE home
1720          LDA #buffer AND &FF     \ if the end of buffer has
1730          STA ptrblk,Y       \ been reached set pointer
1740          LDA #buffer DIV &100 \ to the beginning again
1750          STA ptrblk+1,Y
1760 .home    RTS                \ return
1770 \ Compare pointers, if equal Z=1 don't care otherwise
1780 .compare LDA ip_ptr+1
1790          CMP op_ptr+1       \ compare ptr high bytes
1800          BNE return         \ if not equal return
1810          LDA ip_ptr
1820          CMP op_ptr         \ compare pointr low bytes
1830 .return  RTS                \ return
1840 ]
1850 NEXT
1860 CALL init
```

This program requires the presence of the Plus 1 expansion to be of any use. It could however be modified to replace any of the operating system's buffers. A paged ROM version of this program can be found in chapter 10.

6.10 Unused vectors, IND1V IND2V & IND3V &230

These vectors are reserved by Acorn for future expansion. Software which uses these vectors cannot be guaranteed to be compatible with any future versions of operating system software or other Acorn products.

6.11 The default vector table

The BBC microcomputer operating system (version 1.2 onwards) and the Electron operating system contain a table of default values in a block of data. This may be accessed using the following addresses:

&FFB6 – contains the length of the data in bytes
&FFB7 – contains the low byte of the data's address
&FFB8 – contains the high byte of the data's address

7 Interrupts

7.1 An introduction to interrupts

An interrupt is a hardware signal to the microprocessor. It informs the 6502 that a hardware device, somewhere in the Electron or on an expansion module, requires immediate attention. When the microprocessor receives an interrupt, it suspends whatever it was doing, and executes an interrupt servicing routine. Upon completion of the servicing routine, the 6502 returns to whatever it was doing before the interrupt occured.

A simple analogy of an interrupt is a man working hard at his desk writing a letter (a foreground task). Suddenly the telephone rings (an interruption). The man has to stop writing and answer the telephone (the interrupt service routine). After completion of the call, he has to put the telephone down, and pick up his writing exactly where he left off (return from interrupt).

In an Electron, the main objective is to perform foreground tasks such as running BASIC programs. This is equivalent to writing the letter in the above example. The computer may however be concerned with performing lots of other functions in the background (equivalent to the man answering the telephone). An Electron which is running the house heating system for example would not wish to keep on checking that the temperature in every room is correct — this would take up too much of its processing time. However, if the temperature gets too high or too low in any of the rooms it must do something about it very quickly. This is where interrupts come in. The thermostat could generate an interrupt, causing the computer to jump quickly to the interrupt service routine, switch a heater on or off, and return to the main program.

There are two basic types of interrupts available on the 6502. These are maskable interrupts (IROs) and non-maskable interrupts (NMIs). To distinguish between the two types, there are two separate pins on a 6502. One of these is used to generate IROs (maskable) and the other is used to generate NMIs (non-maskable).

7.1.1 Non-Maskable Interrupts

In order to generate a non-maskable interrupt, a piece of hardware must pull the NMI line low. This forces the 6502 to stop whatever it was doing, and to start executing the NMI service routine at &0DOO. NMLs are extremely powerful, because they cannot be turned off under software control. If the ULA is currently accessing RAM to produce the video display in modes 0 to 3, it is also forced to give the memory back to the 6502. NMIs can therefore create *snow* on the screen — the urgency of this signal is such that even the screen cannot take priority over the interrupting device.

Only very high priority devices, such as the Floppy Disc or Econet interfaces, are allowed to generate NMIs. This ensures that the *6502* is only interrupted in very urgent situations. These high priority devices are then guaranteed to get immediate attention from the 6502. To return to the main program from an NMI, an RTI instruction is executed. It is always necessary to ensure that all of the 6502 registers are restored to their original state before returning to the main program. If they are modified , the main program will suddenly find garbage in its registers in the middle of some important processing. It is highly probable that a total system *crash* would result from this.

7.1.2 Maskable Interrupts

Maskable interrupts are similar to non-maskable interrupts in most respects. A hardware device can generate a maskable interrupt to which the 6502 must normally respond. The difference is that the 6502 can choose to ignore all maskable interrupts, if it so desires, using software control. To disable interrupts (only the maskable ones though), an SEL (set interrupt disable flag) instruction is executed. Interrupts can be re-enabled at a later time using the CLI (clear interrupt disable flag) instruction.

When an interrupt is generated, the processor knows that an interrupt must have come from either the ULA, or an expansion module device. Initially though, it can’t tell where the interrupt has come from. If there was only one device that could have caused the interrupt, then there would be no problem. However ,

since there is more than one device causing interrupts in the

Electron, each device must be interrogated. Each device is asked whether it caused the interrupt, This is normally quite easy, because all of the standard Electron devices are controlled by the ULA register at address &FEOO. Any other devices connected to the expansion bus would have to be interrogated seperately.

When the interrupt processing routine has discovered the source of a maskable interrupt, it must decide upon the type of action is required. This usually involves transferring some data to or from the cassette interface, incrementing the clock, or flashing the colours on the screen. The interrupt condition must then be cleared by writing to &FEO5, This is because most devices (except the cassette receive and transmit registers) continue to signal an interrupt until they have been serviced. The completion of servicing often has to be signalled by the processor writing to a special register in the device, or, in the case of interrupts from the ULA, to address &FEO5.

Interrupts must never affect the interrupted program. All of the processor registers and flags must therefore be exactly the same after return from an interrupt routine as they were before the interrupt occured. Thus an interrupt routine must either not alter any registers (which is difficult) or restore all register contents to their original values before returning.

Interrupt routines are entered with interrupts disabled. An additional interrupt will therefore not be recognised whilst the first interrupt routine is still processing. If the interrupt service routine is going to take an appreciable time, this could create problems. Other more urgent interrupts may occur, and have to wait until the previous one has finished processing. The solution is normally to ensure that interrupt routines are not too long. However, if care is taken, interrupts can be re-enabled inside a long interrupt routine, In this case, fixed memory locations must not be used to store variables within the routine, because these locations will be overwritten if another interrupt routine uses them (or indeed if the same interrupt occurs again!). All variables should therefore be stored on the stack so they can be restored at the end of any routine.

Interrupts are required on the Electron to process all of the *background* operating system tasks. These tasks include incrementing the clock, processing envelopes, or transferring keys pressed to the input buffer. All of these tasks must continue whilst the user is typing in, or running his program. Using interrupts gives the impression that there is more than one processor; one for the user, one for updating the clock, one for processing envelopes, etc.

As was mentioned in the introduction, normal (maskable) interrupts can be disabled. Interrupts should only be disabled for critical operations. For example, when changing the two bytes of a vector. If an interrupt occurs in the middle of the change, it might be indirected to an erroneous address.

When interrupts are disabled, the clock stops, and all other interrupt activities cease. Interrupts are disabled by the SEL assembler instruction, and re-enabled with CLI. Most devices that generate interrupts will continue to signal an interrupt until it is serviced. The cassette read register is one exception. If it isn't serviced within 2ms, data from the cassette will almost certainly be lost forever.

7.3 Using Non-Maskable Interrupts

Generally, NMIs are reserved for specialised pieces of hardware which require very fast response from the 6502. NMIs are not used on a standard system. They are used on DISC and ECONET systems. An NMI causes a jump to location &0DOO to be made.

7.4 Using Maskable Interrupts

Most of the interrupts on the Electron are maskable. This means that a machine code program can choose to ignore the interrupts by disabling them. Since all of the operating system features such as scanning the keyboard, updating the clock, and running the cassette system are run on an interrupt basis, interrupts should never be disabled for more than about 2ms.

There are two levels of priority for maskable interrupts, defined by two indirection vectors in page &02. The priority of an interrupt indicates its relative importance with respect to other interrupts. If two devices signal an interrupt simultaneously, the higher priority interrupt is serviced first.

7.5 Intercepting interrupts

Maskable interrupts can be intercepted on the Electron, and re-directed to a user specified address. This interception process consists of changing the value of a vector.

There are two interrupt interception vectors called IRO1V and IRO2V, The first of them is indirected via the vector stored at &204,5 and the second via &206,7. If either of the vectors stored in these locations is changed to point at a user supplied routine, that user routine will be called when there is next an interrupt.

Interrupt Request Vector 1 (IRQ Vi)

Indirects through &204,5

This is the highest priority vector through which all maskable interrupts are indirected, This is nominally reserved for the system interrupt processing routine, which copes with all of the interrupts from the ULA. Any interrupt which cannot be dealt with by the operating system routine (those which are generated by a user expansion module) are passed on through the second interrupt vector, IRO2V. Occasionally, IRO1V can be intercepted before the operating system gets hold of it. This will only be necessary for high priority user interrupts.

Interrupt Request Vector 2 (IRQ2V)

Indirects through &206,7

This vector is normally used to deal with any interrupts which cannot be dealt with by the operating system. On an unexpanded Elecctron, the vector simply points to a couple of lines of code to restore the A register from &FC, then return from the interrupt service.

Several points should be born in mind when producing interrupt service routines.

a) When the vector value is changed to point at the new user supplied routine, the previous contents of the vector should be saved somewhere. This will allow the user routine to go on to the correct address after it has finished, Note that this method of linking into LRO1V or IRO2V allows several independent routines to link in seperately. Each stores the previous contents of the vector (which point to the next routine).

b) Disable interrupts using the SEI instruction before changing the contents of the interrupt vectors, This is merely a precaution to guard against the possibility of interrupts occuring between writing the low and high bytes of the vector If an interrupt were to occur in the middle of this operation, the indirection vector would be erroneous, and would probably cause the machine to crash.

c) The conditions which will be in force when the user routine is entered are that; the original 6502 status byte and return address are already stacked on the 6502 stack (ready for an RTI instruction to resume normal operation). The X and Y registers are still in their original states, but haven't been saved anywhere. The original A register contents are in location &FC.

d) Operating system calls should not normally be made from within an interrupt service routine, This is because they may not be re-entrant (eg. if any zero page locations are used). Most OSBYTEs and some OSWORDs are 'IRO-proof'. Avoid *FX0, OSBYTE &81 (positive INKEY), fast Tube BPUT, OS WORD 0, and all VDU OS WORDs except palette write/read. Such use of OS calls will often cause the foreground task to be disturbed and crash.

e) The user's interrupt routine should be *re-entrant.* This means that if there is a possibility of interrupts being re-enabled during the routine (eg. because it is very long), the code can be run again without affecting the first foreground interrupt. This can only be done by pushing the X and Y registers plus

the contents of &FC onto the stack, and restoring them after the call. It is also important to ensure that no fixed memory locations are used for storing variables, since these will be overwritten by an interrupting routine.

The following example illustrates most of these points. When run, it will cause the Electron to make a continuous decreasing pitch tone.

Several points in the program are worthy of note. The first is that IRO1V is used instead of IRO2V. On an unexpanded Electron, all interrupts are serviced by IRO1V, so the OS doesn't bother to pass them on to IRO2V, When the tone is running, switch the listing to page mode (by pressing CTRL N). Then list the program. The sound is totally messed up because the OS is writing to the ULA as well. This illustrates one of the reasons why the *official* operating system calls should normally be used —to avoid clashes like that.

```
 10  REM Interrupt utilisation example
 20  REM Must operate in mode 6
 30  MODE 6
 40  REM AlLocate space for program
 50  DIM M% 100
 60  FOR opt%= 0 TO 3 STEP 3
 70  P%=M%
 80    [
 90    OPT opt%
100    .init SEI           \ Disable interrupts
110    LDA &204            \ Save old IRQ1V vector
120    STA oldv
130    LDA &205
140    STA oldv+1
150    LDA Mint MOD 256    \ Low byte of address
160    STA &204            \ IRQ1V Low
170    LDA #int DIV 256    \ High byte of address
180    STA &205
190    CLI                 \ Turn interrupts on again
200    RTS                 \ Exit initialisation routine
205
210  \ This is the interrupt service routine
220    .int TXA            \Save X register
230    PHA
240    TYA                 \Save Y register
250    PHA
260    INC &70             \ Counter in zero page
270    LDA &70
```

```
280    STA &FE06           \ Load into ULA counter
290    LDA #&32            \ Set sound mode
300    STA &FEO7           \ Write to ULA control register
310    PLA                 \ Restore the registers
320    TAY
330    PLA
340    TAX
350    JMP (oldv)          \ Go on to next service routine
355
360    .oldv EQUW0         \ Reserve space for old vector
370    ]
380    NEXT opt%
390  REM Grab the interrupt vector
400  CALL init
410  REM Bleeping should   now start
420  END
```

8 PAGED ROMs

The Acorn Electron and the BBC microcomputer both support the concept of a number of ROM based programs being resident in a machine in the same address space. Each ROM is *paged* in as required and then *paged* out as software in another ROM is required.

Paged ROMs work broadly in one of two ways. They act either as languages such as BASIC and LISP or they act as utilities such as filing systems and device drivers. Languages may also include such things as word processors and CAD graphics packages.

At any one time only one language should be active. Thus most Electrons will enter BASIC as the default language. The current language has access or control over the user RAM which it in turn may allocate to users e.g. for BASIC programs or word processing text.

While the one language is active any other ROM offering a service may be called upon as is appropriate, When a request for a service is generated the operating system interrogates each paged ROM in turn until the request is acknowledged and acted upon. Different types of request are indicated to each ROM by the operating system entering the service entry point of that ROM with an accumulator value representing the reason. These calls are called *paged ROM service calls.* **If the service entry point** is entered with A=7 this indicates that someone has asked the operating system for an OSBYTE call which the operating system failed to recognise and so is now asking the paged ROMs if they wish to claim it. If a service call is recognised then the ROM should act upon it and clear the accumulator before returning control back to the operating system. If the ROM does not wish to claim the call it should return control to the operating system with the accumulator value unchanged.

There are two sets of paged ROMs, service ROMs and language ROMs. All language ROMs should respond to paged ROM service calls and so should be service ROMs as well. BASIC is an exception to this rule and the operating system recognises it by virtue of the fact that it is a language ROM not offering a service entry.

In order to enable the operating system to recognise ROM types and treat them accordingly, a protocol has been drawn up for a standard ROM format.

ROM offset	size	description
0	3	language entry (JMP address)
3	3	service entry (JMP address)
6	1	ROM type flag
7	1	copyright string offset pointer (=10+t+v)
8	1	version number (binary)
9	[t]	title string
9+t	1	zero byte
10+t	[v]	version string
10+t+v	1	zero byte
11+t+v	[c]	copyright string
11+t+v+c	1	zero byte
16+t+v+c	4	2nd Processor relocation address
16+t+v+c....		rest of ROM, code and data

Below is a full description of each field of the paged ROM format.

8.2 Language Entry

This should consist of a three byte JMP instruction referring to the language entry point. This code is called upon when a language is initialised, When a Tube is active the language may be copied across to the second processor and then entered, When a language is copied across the tube it may be relocated to a different address (see section 8.4 below).

If a ROM is not a language ROM this field should contain zeros.

8.3 Service Entry

This should consist of a three byte JMP instruction referring to the service entry point. This should point to code which responds to paged ROM service calls acting if and when appropriate.

If a ROM is not a service ROM this field may contain user code.

8.4 ROM Type Byte

The value of this byte gives information to the operating system about the nature of the ROM. The setting of each bit indicates a separate thing.

Bit No.	Meaning if set
0	processor/language bit
1	ditto
2	ditto
3	ditto
4	Controls Electron firm key expansions
5	Indicates that ROM has a relocation address
6	Indicates that this is a language ROM
7	Indicates that this ROM has a service entry

The first 4 bits indicate the processor type for which the code is intended, This is of importance to second processors who may get languages copied across to them. A second processor will look for the correct value of these bits before attempting to run the language. The following values have been assigned:

0	6502 BASIC
1	reserved
2	6502 code (not BASIC)
3	68000 code
8	Z80 code
9	16032 (or 32016)

If bit *5* is set this indicates that the language code in this ROM has been assembled at a different address and the ROM should be copied across the Tube to the second processor to this address. Service routines are not executed from the Tube copy.

If bit 6 is set this indicates that this is not a language ROM. This does not mean that the ROM cannot have a language entry point. If this bit is not set a language will not be considered for initialisation following a hard reset. However, if the language is entered via a service call (i.e. *<name> *)* a soft reset will reinitialise that language.

8.5 Copyright Offset Pointer

This is an offset value from the begining of the ROM to the zero byte preceding the copyright string, It is important that this points to a zero byte followed by '(', **'C' and** ')' **ASCII character values** because the operating system uses this fact to determine whether a ROM physically exists in a ROM position.

8.6 Binary Version Number

This eight bit version number of the software contained in a ROM helps identify software. This byte is not used by any operating system and need not correspond to the version string.

8.7 Title String

This is a string which is printed out as the operating system enters the ROM as a language.

8.8 Version String (optional)

This should be a string identifying the release number of the software. The format of this string should be A.BB where A and B are ASCII characters of decimal digits.

On entry to a language the error pointer is set to this or if there is no version string the error pointer is directed to the copyright string.

8.9 Copyright String

This string is essential for the operating system recognition of a paged ROM (see section *8.5* above). The copyright string should always be preceded by a zero byte and start with the characters '(C)'.

8.10 The Tube Relocation address

This is the address which is used when a ROM is relocated when copying across the Tube to a second processor.

The language code should be assembled to run at that address but the service code should be assembled to run from &8000 as it will be executed within the ROM in the I/O processor.

Executing Software in Paged ROMs

It is possible to execute machine code in a paged ROM in one of three ways, via the language entry point after a reset, via the service entry point when the operating system performs a service call or via an extended vector (which is usually set up by a paged ROM in response to a service call). The following two chapters describe how the two types of paged ROMs may be implemented.

9 Language ROMs

The term *language ROM* is something of a misnomer given most peoples' idea of what a language is. In the context of paged ROM software the language is the primary paged ROM. Other paged ROMs may perform functions transiently but control is then returned to the current language ROM. The language ROM receives a large allocation of zero page workspace and is allocated pages 4 through to 7 as private workspace. In addition to this the language has control of the *user RAM* which may or may not be used as additional workspace. BASIC, for example, uses a variable portion of the *user RAM* (from LOMEM to HIMEM) for the storage of program variables.

Languages are most typically implemented in language ROMs as would be expected. Thus BASIC, FORTH, LISP and BCPL are all language ROMs but other software implemented as language ROMs include word processors and terminal emulators.

No paged ROM software should be executed unless a service call has been performed first with the possible exception of a language entered following a reset. The language entered after a hard reset will be the language ROM identified by the ROM type byte in its header occupying the highest priority socket. Following a soft reset the language active when the reset occurred will be reinitialised. Any language should respond to a **command* to enable its activation when this command is issued. This mechanism allows the user to switch between languages. This command would be unrecognised by the operating system which would then issue an *unrecognised * command* paged ROM service call to which the language ROM would respond via its service entry point.

9.1 Language initialisation

A language ROM will be entered via the language entry point with an accumulator value of &01 when the language is selected. The language is entered with a JMP instruction and no return is expected. The stack pointer should be reinitialised as the stack state is undefined on entry.

The language ROM should also be able to respond to service calls which may affect it (see below) e.g. be able to respond to the service call which warns of a changing OSHWM due to font explosion.

9.2 Firm keys

On the Electron the function keys are implemented as a combination key press requiring the use of the CAPS LK/FUNC key with the number keys. In addition to these soft keys there are *a* number of non-programmable *firm keys* which also produce text strings when pressed. The other character keys (A to Z plus the comma, full stop and slash keys) pressed in combination with the CAPS LOCK/FUNC key constitute the *firm keys.*

A language ROM indicates that it has the facility to expand these keys by bit 4 of the ROM type byte being set (see section 8.4).

When the operating system detects that a firm key has been pressed it calls the language via its entry point to request the expansion of the key. The language should then yield the firm key string one character at a time in response to further calls.

The two calls made through the language entry point are:

A=2 This call expects the next key in the firm key expansion to be returned in Y.

A=3, Y=firm key code This call is an initialising call. The language should return the length of the firm key string in Y.

The key values passed to the language with this call are:

&90 to &A9	FUNC+A to FUNC+Z
&AA	FUNC+:
&AB	FUNC+;
&AC	FUNC+,
&AD	FUNC+=
&AE	FUNC+.
&AF	FUNC+/

The operating system inserts these key values into the input buffer as they are received.

OSBYTE &CC (204) may be used to read or write the OS copy of its firm key pointer and OSBYTE &CD (205) may be used to read or write the length of the current firm key string being expanded.

9.3 Language ROM compatability

It is quite feasible to write a language ROM which will work with the entire range of Acorn machines supporting paged ROMs in all their configurations.

The first question that a programmer should consider before implementing software in a Language type ROM is whether it actually needs to be a language ROM? Many utilities are only required transiently and it is better to implement them as service type ROMs. A routine in a service type ROM can then be used from the language environment.

As has been mentioned above the language should have a service entry point so that it may be selected by a **command* and be able to respond to changes in OSHWM, For information about *service* type ROMs read the next chapter. It must be remembered however that a language ROM is copied across to the second processor when a Tube is active. Therefore, when executing, the language must not rely on receiving service calls (i.e. the only

ones the *language* code should respond to are those of relevance when on an I/O processor such as the *font explosion warning).* The *service* code should not share or use the language work space (&400-&7FF or language zero page) because the service code is executed in the I/O processor of a Tube machine where the Tube code has the status of the current ‘language’ and the actual language is across on the second processor. The language code should not attempt to perform any manipulation of hardware by direct poking because this would make it machine dependent. The programmer may wish to implement hardware dependent routines in the service section of the ROM. The language code should communicate with the service code using *unknown OSBYTE* calls etc. for this purpose.

It is always easier to write ROM code to create software with limited compatability, It is often the case that software written originally with just one machine or configuration in mind will be just as useful on another machine. A programmer should always have confidence in his or her skills such that they consider the extra effort worthwhile. The discipline in thought required to adhere to the compatability protocols represents a professional attitude. The Electron and other Acorn products were designed by experts, and while ultimately human and thus fallible, have put great consideration into making it possible to run software over a wide a range of machines.

10 Service ROMs

Service ROMs are ROMs which contain code which is entered via the *service entry point.* Service ROM code will always be executed in the ROM itself i.e. always in the I/O processor c.f. language ROMs. The calls made by the operating system to service ROMs are called *paged ROM service calls* but will usually be referred to as just ‘service calls’.

The type of software which might be implemented in service type ROMs are filing systems, user printer drivers, extension VDU commands and languages; In fact just about anything. It should be noted that extreme care should be taken to implement routines in service ROMs correctly.

To understand how software can be incorporated into a paged ROM, be interfaced correctly with the operating system and thus executed at the appropriate time an understanding of paged ROM service calls is essential.

When a hard reset occurs the operating system makes a note of where physical ROMs exist in paged ROM sockets. Subsequently as the machine carries out its various tasks each time something which may be of significance to software in paged ROMs occurs these ROMs are given an opportunity to respond.

10.1 Paged ROM service calls

The mechanism by which this is performed is as follows. The operating system pages in each paged ROM in turn starting with that ROM in the highest priority socket (paging is performed by writing a value to a hardware latch, the hardware responds to the value written to this location and performs the relevant switching **of the chip** select signals). If the ROM has a service entry point this code is executed. Before entering the code the accumulator is loaded with a *reason code*, the X register will contain the current ROM number (a ROM is thus able to tell which socket it is in) and the Y register will be loaded with any further relevant information. The paged ROM can return control to the operating system following an RTS instruction. If the ROM has responded

and does not wish any further action to be taken, the accumulator should be set to zero to *claim* the call otherwise all registers should be unchanged.

Below is a list of the reason codes which may be presented to a paged ROM when a service call is performed.

Reason code &00: No operation

No operation, this service call should be ignored because a higher priority ROM has already claimed it.

Reason code &01: Absolute filing system space claim

This call is made during a reset. The operating system is interrogating each ROM to determine how much workspace memory would be required if that ROM was called. This workspace is available temporarily while the filing system ROM is active. Pages &EOO and above are available as a fixed area on the BBC micro and the Electron. Each paged ROM is entered with A=&O1 , X=ROM number and Y=top of fixed area. For the highest priority ROM on a BBC micro the Y register will contain &E. The Y register value should be increased in accordance to the requirements of the ROM. If the Y register setting is sufficient or greater than required then the service routine should return the Y register unaltered.

Before using this workspace, the new filing system ROM should deselect the old filing system with OSFSC with A=6 (indirected through (&20E), see section *5.7);* and the workspace must be claimed with OSBYTE &8F, X=&0A (see Reason Code &0A of this section).

Reason code &02: Relative space claim

This call is made by the operating system during a reset to determine how much private RAM workspace is required by each ROM. The position of this private area will start from the top of the absolute space claimed by the ROMs and on the relative

space claimed by higher priority ROMs. This call is made with the Y register containing the value of the first available page. This value should be stored in the ROM workspace table at &DFO to &DFF (for ROMs 0 to 15 respectively) and the Y register returned increased by the number of pages of private workspace required.

Reason code &03: Auto-boot call

This call is issued during a reset to allow each service ROM to initialise itself. This enables the highest priority filing system to set up its vectors automatically rather than require explicit selection with a *command. To allow lower priority sevices to be selected the service ROM should examine the keyboard and initialise only if either no key is pressed or if its own ROM specific key is being pressed (e.g. D+BREAK for Acorn DFS). If the ROM initialises it should attempt to look for a boot file (typically !BOOT) to RUN, EXEC or LOAD if the Y register contains zero. This call is made during a reset after the start-up messages have been printed.

Reason code &04: Unrecognised *command

When a line of text is offered to the command line interpreter (CLI) the operating system will pass on any unrecognised command firstly to each of the paged ROMs and then if still unrecognised to the currently active filing system. When the unrecognised command is offered to the paged ROMs this service call is made.

Entry parameters:

A=&04
X=ROM number
Y contains an offset which if added to the contents of &F2 and &F3 point to the beginning of the text with the asterisk and leading spaces stripped off and terminated with a carriage return

On exit:

Registers restored
A=0 if recognized

Filing systems should not intercept filing system commands (which will be common to all filing systems) using this service call but may intercept some filing system utilities (e.g. *DISC, *NET).

Reason code &05: Unknown interrupt

An interrupt which is not recognised by the operating system or which has been masked out by software will result in this call being generated. A service ROM which services devices which might cause interrupts should interrogate such devices to determine if they have generated this interrupt. If the interrupt has been recognised and processed the accumulator should be returned with zero to prevent other ROMs being offered the interrupt. The routine should terminate with an RTS not an RTI.

Reason code &06: BRK has been executed

If a BRK instruction is encountered this call will be generated before indirecting through the BRK vector (BRKVEC, &202). BRKs are usually used to indicate that an error condition has occurred, service ROMs are informed before the current language is able to respond to the BRK via the BRKVEC.

Entry parameters:

A=&06
X=ROM number
Y is undefined but should be preserved &FO contains the value of the stack pointer &FD and &FE point to the error number which is not necessarily in the current ROM (OSBYTE &BA yields this ROM number)

On exit:

All registers should be preserved

Reason code &0: Unrecognised OSBYTE call

When an OSBYTE call has been made and is not recognised by the operating system it is offered to the paged ROMs by this service call. The contents of the A, X and Y registers at the time of the OSBYTE call are stored in locations &EF, &FO and &F1 respectively.

Reason code &08: Unrecognised OS WORD call

This service call is performed in response to the user issuing an OS WORD call not catered for in the operating system. The contents of the A, X and Y registers at the time of the call are stored in locations &EF, &FO and &F1 respectively. Unrecognised OSWORD calls with accumulator values greater than or equal to &EO are offered to the user vector (USERV, &200). An OS WORD call with A=7 (equivalent to the SOUND command in BASIC) given an unrecognised channel will also generate this service call.

Reason code &09: *HELP command interception

When the *HELP command is passed through the CLI this service call is generated. The remainder of the command line is pointed to by the address stored in locations &F2 and &F3 plus an offset in Y. Each ROM is required to respond to this call. If the remainder of the command line is blank the ROM should print its name and version number followed by a list of subheadings to which the ROM will respond.

e.g. Acorn DFS (version 0.90) outputs:

```
DFS 0.90
  DFS
  UTILS
```

Indicating that this ROM responds to *HELP DFS and *HELP UTILS

If the rest of the command line is not blank the service routine should compare it against its subheadings and if a match occurs should output the information under that subheading.

e.g. Acorn DES responds to *HELP UTILS with:

```
DFS 0.90
  BUILD <fsp>
  DISC
  DUMP <fsp>
  TYPE <fsp>
```

If there is more than one item on a line then the ROM should deal with them individually. All registers should be preserved across the service routine.

Reason code &0A: Claim absolute workspace

This service call originates from a paged ROM which requires the use of the absolute workspace. When a filing system ROM is active and requires use of this workspace it should perform an OSBYTE call &8E with X=&0A which will generate this service call. The previous owner of the absolute workspace is then able to save any valuable contents of this memory in its own private data area in the relative workspace. The previous owner should also update a flag within its private data area indicating that it no longer owns the absolute workspace.

The active filing system is selected independently of the ownership of the absolute workspace. Thus while a filing system ROM may have ownership of this workspace the tape filing system may be selected (the tape ES does not require any absolute workspace). Problems may arise when the active filing system paged ROM is called upon but does not have ownership of the absolute workspace. The active filing system should then issue this service call to obtain the use of the absolute workspace. This call should only be made by a filing system starting (see also Reason code &01).

Reason code &0B: NMI released

This service call also originates from paged ROMs and should be generated by performing an OSBYTE call &8F. This call should be issued when a ROM no longer requires the NMI. This releases the zero page locations &AO to &A7 and the space for the NML routine in page &DOO. On entry the Y register contains the filing system number of the previous owner (see OSARGS, section *5.2)* and this should be compared to the ROM's own identity before reasserting control of the NMI.

Reason code &0C: NMI claim

This call should be generated by a paged ROM using OSBYTE &8F when it wishes to take posession of the NMI. The service call should be generated passing &FF in the Y register (i.e. OSBYTE A=&8F, X=&0C and Y=&FF). The current owner should relinquish control returning its filing system number in the Y register in response to this call.

Reason code &0D: ROM filing sytem initialise

When the ROM filing system (RES) is activated in response to a *ROM command this call will be issued when a file is being searched for. On entry the Y register contains 15 minus the ROM number of the next ROM to be scanned. If this ROM number is less than the current ROM's ID this call should be ignored. Otherwise the active ROM number should be stored in &F5 (in the form 15-ROM number) where the RFS active ROM number is stored. The current ROM should indicate that the service call has been claimed by returning zero in the accumulator and should store a pointer to the data stored within the ROM in locations &F6 and &F7 set aside for use by the RFS.

See chapter 11.

Reason code &0E: ROM filing system get byte

This service call may be issued after a ROM containing RFS data has been initialised with service call &0D, A ROM should respond only if it is the active RFS ROM as indicated by the value in location &F5 (stored in the form 15-ROM number). The fetched byte should be returned in the Y register.

See chapter 1 1.

Reason code &0F: Vectors claimed

This service call should be generated by any paged ROM (using OSBYTE &8F) which has been initialised and then changed any operating system vector. This call warns paged ROMs that a vector change has occurred.

Reason code &10: SPOOL/EXEC file closure warning

This service call should be produced by the operating system prior to closure of any SPOOL or EXEC files when there is a change of the current filing system. This enables any paged ROM using such a file to respond to the possibly premature closure of these files. SPOOL/EXEC file closure may be prevented by returning a zero in the accumulator otherwise all registers should be preserved.

Reason code & 11 : Font implosion/explosion warning

When OSBYTE &14 is used to change the RAM allocation for user defined characters this service call is issued. This call is issued to warn languages that the OSHWM has been changed and thus the user RAM allocation has changed.

Reason code &12: Initialise filing system

This call enables third party software to switch between one or more filing systems without having to issue *commands. A program may want to switch between two filing systems in order to transfer files. A filing system ROM should respond to this call if the value in the Y register corresponds to its filing system number. All filing systems should allow files to be open while inactive and so on receiving this call should restore any such files.

Reason code &13: Character placed in RS423 buffer

This call is made when the Electron OS has placed a character in the RS423 buffer. Expansion software handling RS423 hardware should respond to this call. If not claimed the operating system purges the RS423 buffer.

Reason code &14: Character placed in printer buffer

This call is made when the Electron OS has placed a character in the printer buffer. Expansion software controlling printer hardware should respond to this call.

Reason code &15: 100 Hz poll

The Electron operating system will provide a 100 Hz polling call for the use of paged ROMs. A paged ROM requiring this call should increment the polling semaphore using OSBYTE &16 (22) on initialisation and decrement it using OSBYTE &17 (23) when it no longer requires polling. The operating system will issue this service call when the semaphore is non-zero. The semaphore itself may be read using OSBYTE &B9 (185). This facility is implemented mainly so that hardware devices may be supported as a background task without being interrupt driven. This would be suitable for hardware not requiring particularly urgent servicing.

The Y register contains the semaphore value, and should be decremented by the service routine if it is being polled. If a service routine finds it has decremented the Y register to zero, it should claim the call (set A to 0) to improve machine speed (there are no more ROMs which require polling).

Reason code &16: A BEL request has been made

When the external sound **flag (OSBYTE &DB/219)** is set this call is issued by the OS in response to an ASCII BEL code being output (VDU 7). This is to enable the external sound system to respond appropriately.

Reason code &17: SOUND buffer purged

This call is made when an external sound system is flagged on the
Electron and an attempt has been made to purge any of the SOUND buffers.

Reason code &FE: Post initialisation Tube system call

The operating system makes this call during a reset after the OSHWM has been set. The Tube service ROM responds to this by exploding the user defined character RAM allocation.

Reason code &FF: Tube system main initialisation

This call is issued only *if* the Tube hardware has been detected. This call is made prior to message generation and filing system initialisation.

The fact that these calls are shared by all the service ROMs can lead to wide spread consequences if a service call is misused by one of the ROMs. The programmer should consider the consequences of his ROM claiming calls (or not claiming calls) when present.

10.2 Service ROM example

The program below is a ROM based version of the enlarged printer buffer program originally described in chapter 6, and will only be of use to machines with the Plus 1 expansion. It is short by paged ROM standards but the assembler program is not a short example.

This program should only be taken as an illustration of the use of some of the service calls described above : it does not conform to paged service ROM standards, as it uses Econet zero page workspace. This may be of little consequence to the vast majority of Electrons, but properly implemented service ROMs should *never* assume that they won't be used with any particular system configuration.

```
 10  REM AssembLer program printer buffer ROM

 20  DIM code% &400
 30  INSV=&22A:nI=&2A/2
 40  RMV=&22C:nR=&?C/?
 50  CNPV=&22E:nC=&2E/?
 60  ptrblk=&90
 70  ip_ptr=ptrbLk+2
 80  op_ptr=ptrbLk+4
 90  old_bfr=&880
100  begin=old_bfr
110  end=old_bfr+2
120  wrkbt=old_bfr+4
130  size=old_bfr+5
140  vec_cpy=old_bfr+6
150  line=&F2
160  OSASCI=&FFE3
170  OSBYTE=&FFF4
180  FOR I=4 TO 7 STEP 3
190  P%~&8000:O%=code%
200  [
210  OPT 1
220  .romstrt  EQUB 0            \ null language entry point
230            EQUB 0
240            EQUB 0
250            JMP service       \ service entry point
260            EQUB &8?          \ ROM type byte, service ROM
270            EQUB (copyr—romstrt)\ offset to copyright
string
```

```
     280            EQUB 0            \ null byte
     290  .title    EQUB &A           \ title string
     300            EQUS “BUFFER”
     310            EQUB &0           \ null byte
     320            EQUS “1.00”       \ version string
     330            EQUB &D           \ carriage return
     340  .copyr    EQUB 0            \ terminator byte
     350            EQUS “(C)1984 Mark HoLmes”\ copyright message
     360            EQUB 0            \ terminator byte

     370  \ End of ROM header, start of code
     380  .name     EQUS “REFFUB”     \ command name

     390  \ Service handling code, A=reason code, X=ROM id &
Y=data
     400  .service  CMP #4            \ is reason unknown command?
     410            BEQ command       \ if so goto ‘command’
     420            CMP #9            \ is reason *HELP
     430            BEQ help          \ if so goto ‘help’
     440            CMP #2            \ is reason private wrkspace
     450            BEQ wkspclm       \ if so goto ‘wkspclm’
     460            CMP #3            \ is reason autoboot call
     470            BNE notboot       \ if NOT goto ‘notboot’
     480            JMP autorun       \ BEQ autorun, out of range
     490  .notboot  RTS               \ other reason, pass on

     500  \ Unknown command, is it *BUFFER ?
     510  \ (command Line address in &F?,&F3 (line) + offset Y)
     520  .command                    TYA:PHA:TXA:PHA       \
save registers
     530            LDX #6            \ X=length of name
     540  .loopl    LDA (Line),Y      \ A=next Letter of command
     550            CMP name—1,X      \ compare with my name
     560            BNE notme         \ not equal, goto ‘notme’
     570            INY               \ for next letter of command
     580            DEX               \ for next Letter of name
     590            BNE loopi         \ if X<>0 round again
     600            BEQ parmch        \ 6 Letters matched, do jump
     610  .notme    PLA:TAX:PLA:TAY   \ no match, restore registrs
     620            LDA #4            \ restore reason code
     630            RTS               \ pass on call

     640  \ *HELP response (parameters as for call above)
     650  .heLp     TYA:PHA:TXA:PHA   \ save registers
     660            LDX #0            \ use X as index counter
     670  .loop2    LDA title,X       \ A=next Letter from title $
     680            BNE over1         \ if A<>0 jump next instrctn
     690            LDA #&20          \ replace 0 by space char.
     700  .overl    JSR OSASCI        \ write character
```

```
 710           INX               \ increment index counter
 720           CPX #(copyr-titLe)       \ end of title ?
 730           BNE Loop2         \ if not get another char.
 740           PLA:TAX:PLA:TAY          \ restore registers
 750           LDA #9            \ restore A
 760           RTS               \ pass on *HELP call

 770 \ Oportunity to claim private workspace
 780 \ (Y=lst page free, call inc's Y by no. pages claimed)
 790 .wkspclm  TYA               \ copy page no. to A
 800           STA &DFO,X        \ table for ROMs' workspace
 810           PHA               \ save page no. on stack
 820           LDA #&FD
 830           LDX #0
 840           LDY #&FF          \ OSBYTE call to read last
 850           JSR OSBYTE        \ BREAK type
 860           CPX #0            \ X=0 after soft reset
 870           BEQ softrst       \ soft brk, dont reset size
 880           LDA #8            \ 8 pages for printer buffr
 890           STA size          \ location for buffer size
 900 .softrst  CLC               \ clear carry, for add
 910           PLA               \ original Y on stack
 920           ADC size          \ A=A+?size
 930           TAY               \ Y=A
 940           LDX &F4           \ X=ROMid
 950           LDA #2            \ restore A (reason code)
 960           RTS               \ pass on workspace call

 970 \ *BUFFER command issued, reset buffer size
 980 .parmch   LDA (line),Y      \ get char. from cmnd line
 990           CMP #&D           \ car.ret.? end of line ?
1000           BNE ok_init       \ if not, cont. line input
1010           LDA #1            \ no parameters so set
1020           JMP defauLt       \ default buffer size
1030 .ok_init  INY               \ increment index counter
1040           CMP #&20          \ was char. a space?
1050           BEQ parmch        \ if so get next character
1060           SEC               \ set carry for subrtact
1070           SBC #&30          \ A=A-ASC"0"
1080           CMP #0            \ was character zero
1090           BEQ deinit        \ if so, switch off
1100           BMI rngerr        \ char.<0, out of range
1110           CMP #6            \ compare char. to 6
1120           BPL rngerr        \ A>=6, out of range
1130 .defauLt  CLC               \ clear carry for ASL
1140           ASL A:ASL A:ASL A \ A=A*8
1150           STA size          \ store for buffer size
1160 .prntmes  LDA #&87          \ Use OSBYTE &87 to read
1170           JSR OSBYTE        \ current screen MODE
```

```
    1180            TYA               \ A=Y
    1190            TAX               \ X=A
    1200            LDY #&F8          \ Use OSBYTE &FF to write
    1210            LDA #&FF          \ MODE selected on reset
    1220            JSR OSBYTE        \ (i.e. MODE preserved)
    1230            TAX               \ X=&FF
    1240  .loop6    INX               \ increment index counter
    1250            LDA message,X     \ A=next byte of message
    1260            JSR OSASCI        \ print character
    1270            CMP #&D           \ was it carriage return
    1280            BNE loop6         \ if not get next character
    1290            PLA:TAX:PLA:TAY   \ restore registers
    1300            LDA #0            \ claim call, 0 reason code
    1310            RTS               \ return
    1320  .message   EQUB &A           \ message string
    1330            EQUS “Press BREAK to change buffer size”
    1340            EQUB &D
    1350  .rngerr    LDX #&FF          \ set index counter
    1360  .loop7     INX               \ increment index counter
    1370            LDA errdata,X     \ A=character from string
    1380            STA &100,X        \ copy to bottom of stack
    1390            CMP #&FF          \ was byte terminator
    1400            BNE loop7         \ if not Loop again
    1410            JMP &l00          \ goto &l00 CBRK)
    1420  .errdata   EQUB 0           \ BRK opcode
    1430            EQUB 0            \ error number 0
    1440            EQUS “Invalid buffer size”       \error
message
    1450            EQUB 0            \ message string end
    1460            EQUB &FF          \ terminator byte

1470 \ Routine for deselecting buffer ROM routines
    1480  .deinit    LDA #3            \ VDU3, just in case
    1490            JSR OSASCI
    1500            SEI               \ disable interrupts
    1510            LDY #0
    1520            STY size          \ size=0
    1530  .loop8     LDA vec_cpy,Y     \ Load old vector contents
    1540            STA INSV,Y        \ store in vector
    1550            INY               \ increment index counter
    1560            CPY #6            \ copied 6 bytes yet
    1570            BNE loop8         \ if not Loop again
    1580            CLI               \ enable interrupts
    1590            JMPprntmes        \ print message + return

    1600  \ Initialise buffer routines automaticalLy

    1610  .autorun   TYA:PHA:TXA:PHA   \ preserve registers
    1620            LDA size          \ A=buffer size in pages
    1630            BEQ no_init       \ A=0, don’t initialise
    1640            LDA #&84          \ HIMEM OSBYTE number
```

```
    1650            JSR OSBYTE        \ make call
    1660            STY end           \ store page address
    1670            LDA #&83          \ OSHWM OSBYTE number
    1680            JSR OSBYTE        \ make call
    1690            CPY end           \ is OSHWM > HIMEM
    1700            BCC room          \ if so continue
    1710            JMP no_room       \ no room so cause error
    1720  .room      JSR init          \ call initialise routine
1730 .no_init       PLA:TAX:PLA:TAY   \ restore registers
    1740            LDA #3            \ restore A
    1750            RTS               \ return
    1760  .init      LDA #&A8
    1770            LDX #0
    1780            LDY #&FF          \ OSBYTE to read address of
    1790            JSR OSBYTE        \ extended vector table
    1800            STX ptrbLk        \ set up zero page Locations
    1810            STY ptrblk+l      \ for indirect indexed adr.
    1820            LDY #3*nI         \ offset into table CINSV)
    1830            LDA #ins AND &FF  \ address of new routine
    1840            SEI               \ disable interrupts
    1850            STA (ptrblk),Y    \ copy address to vector
    1860            INY               \ Y=Y+1
    1870            LDA #ins DIV &l00 \ high byte of address
    1880            STA CptrbLk),Y    \ copy to extended vector
    1890            INY               \ Y=Y+1
    1900            LDA &F4           \ A=ROMid
    1910            STA CptrbLk),Y    \ complete extended vector
    1920            INY               \ Y=Y+1
    1930            LDA #rem AND &FF  \ REMV new routine address
    1940            STA (ptrbLk),Y    \ lo byte to extended vector
    1950            INY               \ YY+1
    1960            LDA #rem DIV &l00 \ Hi byte of new routine
    1970            STA (ptrblk),Y    \ place in extended vector
    1980            INY               \ Y=Y+l
    1990            LDA &F4           \ A=ROMid
    2000            STA (ptrbLk),Y    \ complete REMV 3 byte vect.
    2010            INY               \ Y=Y+1
    2020            LDA #cnp AND &FF  \ repeat, store address of
    2030            STA CptrbLk),Y    \ new CNPV routine in the
    2040            INY               \ extended vector together
    2050            LDA #cnp DIV &l00 \ with ROM number.
    2060            STA (ptrbLk),Y
    2070            INY
    2080            LDA &F4
    2090            STA (ptrblk),Y
    2100            TAX               \ X=ROMid
    2110            LDY #0            \ Y=0
    2120  .Loop3     LDA INSV,Y        \ Aold vector contents
    2130            STA vec_cpy,Y     \ copy to workspace
    2140            INY               \ YY+1
    2150            CPY #6            \ copied 6 bytes yet ?
```

```
    2160            BNE Loop3         \ if not loop again
    2170            LDA &DFO,X        \ Aworkspace addr. hi byte
    2180            STA begin+1       \ store in zero page
    2190            CLC               \ clear carry for add
    2200            ADC size          \ add begin+size
    2210            STA end+1:DEC end+1      \ store in zero
page, –1
    2220            LDY #&10          \ lo byte of begin
    2230            STY               begin   \  (room for return
vect's)
    2240            LDY #&FF          \ lo byte of end
    2250            STY end           \ store in zero page
    2260            JSR rstptrs       \ reset ip+op ptrs
    2270            LDA #nI*3         \ for the extended vector
    2280            STA INSV          \  system the vectors must
    2290            LDA #nR*3         \  now point to &FFOO +
    2300            STA RMV           \  vector number*3
    2310            LDA #nC*3
    2320            STA CNPV
    2330            LDA #&FF
    2340            STA INSV+1
    2350            STA RMV+1
    2360            STA CNPV+1
    2370            CLI               \ enable interrupts
    2380            RTS               \ return
    2390  .noroom   CLI               \ clear interrupts
    2430  .Loop9    LDA nrmerr,X      \ fetch next byte of data
    2440            STA &100,X        \ store at bottom of stack
    2450            INX               \ increment index counter
    2460            CMP #&FF          \ reached terminator ?
    2470            BNE Loop9         \ if not loop again
    2480            JMP &l00          \ execute BRK (not in ROM)
    2490  .nrmerr   EQUB 0            \ BRK instruction opcode
    2500            EQUB 0            \ error number 0
    2510            EQUS "Not enough room for print buffer, Press
BREAK"
    2520            EQUB 0            \ string terminator
    2530            EQUB &FF          \ data end

    2540  \ Purge buffer by setting i/p + o/p ptrs to buffer start

    2550  .rstptrs  LDA begin         \ lo byte bufr start address
    2560            STA ip_ptr        \ store input pointer
    2570            STA op_ptr        \ store output pointer
    2580            LDA begin+1       \ hi byte of buffer start
    2590            STA ip_ptr+1      \ store input pointer
    2600            STA op_ptr+1      \ store output pointer
    2610            RTS               \ return

    2620  .wrngbfl  PLA:PLP:JMP (vec_cpy)\ old INSV routine

    2630            \ New insert char. into buffer routine
    2640  .ins      PHP:PHA           \ save 5 and A on stack
```

```
2650            CPX #3              \ is buffer id 3 ?
2660            BNE wrngbfl         \ if not pass to old routine
2670            PLA:PLP:PHA         \ not passing on, tidy stack
2680            LDA ip_ptr          \ Alo byte of input pointer
2690            PHA                 \ store on stack
2700            LDA ip_ptr+1        \ Ahi byte of input pointer
2710            PHA                 \ store on stack
2720            LDY #0              \ YO so ip_ptr incremented
2730            JSR inc_ptr         \ by the inc_ptr routine
2740            JSR compare         \ compare the two pointers
2750            BEQ insfail         \ if ptrs equal, buffer full
2760            PLA:PLA:PLA         \ don't need ip_ptr copy now
2770            STA (ip_ptr),Y      \ A off stack, insrt in bufr
2780            CLC                 \ insertion success, C=0
2790            RTS                 \ finished
2800  .insfaiL  PLA                 \ buffer was full so must
2810            STA ip_ptr+1        \ restore ip_ptr which was
2820            PLA                 \ stored on the stack
2830            STA ip_ptr
2840            PLA
2850            SEC                 \ insertion failes so C=1
2860            RTS                 \ finished

2870  .wrngbf2  PLP:JMP (vec_cpy+2) \ old REMV routine

2880  \ New remove char. from buffer routine
2890  .rem      PHP                 \ save status register
2900            CPX #3              \ is buffer id 3 ?
2910            BNE wrngbf?         \ if not use OS routine
2920            PLP                 \ restore status register
2930            BVS examine         \ V1, examine not remove
2940  .remsr    JSR compare         \ compare i/p and o/p ptrs
2950            BEQ empty           \ if the same, buffer empty
2960            LDY #2              \ Y2 so that increment ptr
2970            JSR inc_ptr         \  routine inc's op_ptr
2980            LDY #0              \ YO, for next instruction
2990            LDA (op_ptr),Y      \ fetch character from bufr
3000            TAY                 \ return it in Y
3010            CLC                 \ buffer not empty, C=0
3020            RTS                 \ return
3030  .empty    SEC                 \ buffer empty, C=1
3040            RTS                 \ return
3050  .examine  LDA opptr           \ examine only, so store a
3060            PHA                 \  copy of the o/p pointer
3070            LDA op_ptr+1        \  on the stack to restore
3080            PHA                 \  ptr after fetch
3090            JSR remsr           \ fetch byte from buffer
3100            PLA                 \ restore ptr from stack
3110            STA op_ptr+1        \ (if buffer was empty
3120            PLA                 \ C1 from fetch call)
```

```
    3130            STA op_ptr
    3140            TYA               \ examine requires ch, in A
    3150            RTS               \ finished

    3160  .wrngbf3  PLP:JMP (vec_cpy+4) \ old CNPV routine

3170 \ New count/purge buffer routine
    3180  .cnp       PHP               \ save status reg. on stack
    3190            CPX #3            \ is buffer id 3 ?
    3200            BNE wrngbf3       \ if not pass to old subr
    3210            PLP               \ restore status register
    3220            PHP               \ save again
    3230            BVS purge         \ if V1, purge required
    3240            BCC Len           \ if CO, amount in buffer
    3250            LDA ip_ptr        \ o/w free space request
    3260            PHA
    3270            LDA ip_ptr+1      \ store ipptr on stack
    3280            PHA
    3290            LDX #0            \ X=0 for use as counter
    3300            STX wrkbt         \ wrkbt0 for hi counter
    3310            LDY #0            \ YO, so ip_ptr incr'd
    3320  .loopl     JSR inc_ptr       \ increment ipptr
    3330            JSR compare       \ does it equal op_ptr
    3340            BEQ finshdl       \ if so countfree space
    3350            INX               \ XX+1
    3360            BNE noinc         \ if X=0 don't inc wrkbt
    3370            INC wrkbt         \ hi byte of count inc'd
    3380  .no_inc    JMP Loopi         \ Loop round again
    3390  .finshdl   PLA                     \ restore ip_ptr off
stack
    3400            STA               ip_ptr+1
    3410            PLA
    3420            STA               ip_ptr
    3430            LDY wrkbt         \ Yhi byte of free space
    3440            PLP               \ restore status register
    3450            RTS               \ finished
    3460  .Len       LDA opptr         \ store op_ptr on stack
    3470            PHA
    3480            LDA op_ptr+1
    3490            PHA
    3500            LDX #0            \ X=0 for use as counter
    3510            STX wrkbt         \ wrkbt0 hi byte of count
    3520            LDY #2            \ Y? so op_ptr incremented
    3530  .loop2     JSR compare       \ are ptrs equal ?
    3540            BEQ finshd2       \ if so buffer empty
    3550            JSR inc_ptr       \ increment op_ptr
    3560            INX               \ increment count
    3570            BNE no_inc2       \ if X=0 then increment hi
    3580            INC wrkbt         \ byte of count
    3590  .no_inc2   JMP Loop?         \ loop round again
    3600  .finshd2   PLA               \ restore op_ptr off stack
```

```
3610            STA op_ptr+1
3620            PLA
3630            STA op_ptr
3640            LDY wrkbt         \ Yhi byte of length
3650            PLP               \ restore status register
3660            RTS               \ finished
3670  .purge    JSR rstptrs       \ reset i/p & o/p pointers
3680            PLP               \ restore status register
3690            RTS               \ return

3700  \ Increment pointer routine. YO op_ptr, Y? ipptr
3710  .inc_ptr  CLC               \ clear carry for add
3720            LDA ip_ptr,Y
3730            ADC 111
3740            STA ip_ptr,Y
3750            LDA ip_ptr+1,Y
3760            ADC =0
3770            STA ip_ptr+1,Y    \ pointerpointer+1
3780            CMP end+1         \ hi byte reached buffr end?
3790            BNE home          \ if not finish
3800            LDA ip_ptr,Y
3810            CMP end           \ Lo byte reached end ?
3820            BNE home          \ if not finish
3830            LDA begin         \ reached end of buffer
3840            STA ip_ptr,Y      \ so reset pointer to
3850            LDA begin+1       \ start address of buffer
3860            STA ip_ptr+1,Y
3870  .home     RTS               \ return

3880  \ Compare pointers, if equal Z1 don't care otherwise
3890  .compare                    LDA ip_ptr+l
3900            CMP opptr+1       \ compare ptr high bytes
3910            BNE return        \ if not equal return
3920            LDA ipptr
3930            CMP op_ptr        \ compare pointr low bytes
3940  .return   RTS               \ return
3950  ]

3960  NEXT

3970  OSCL1"*S.BRM "+STR$code%+" "+STR$'0%
```

When this program is run, the ROM image blown into an EPROM and then inserted in an Electron with a Plus 1 expansion an enlarged printer buffer of 2k is automatically initialised.

Typing '*BUFFERn' with n from 1 to 5 selects a buffer size of n*2K at the next BREAK. '*BUFFERO' deselects the enlarged buffer and re-initialises the normal OS routines. '*BUFFER' (no parameters) reselects the default buffer size (2K).

10.3 Extended Vectors

In the example above the operating system buffer maintenance vectors had to be set to point to routines held within the service ROM. The operating system supports a system of extended vectors to enable each of the OS vectors to point to routines held in paged ROMs.

Each OS vector is identified by a number which may be calculated by subtracting &200 (the vector space base address) from the vector address and dividing by two (each vector is two bytes).

The operating system vector should be pointed to a routine at &FF00 plus the vector number multiplied by 3. This routine will use a three byte vector stored in the extended vector space (this address returned by OSBYTE &A8) with an offset of the buffer number multiplied by 3. This vector should contain the address of the routine in the paged ROM followed by its ROM number.

The procedure for a paged ROM to intercept a vector is:

(a) Determine buffer number n
(b) Establish extended vector space, V using OSBYTE &A8
(c) Store new routine's address in (V+3*n)
(d) Store ROM number following address
(e) Make copy of OS vectors contents if required for return
(f) Store address (&FF00+3*n) in OS vector (&200+2*n)

It is usually a good idea to disable interrupts during this change-over so that an interrupt routine is not able to use the vector in the middle of the change.

11 Serially accessed ROMs and the *ROM filing system

The Electron has been designed to use software contained in ROM cartridge packs. The ROM packs which plug into the Plus 1 expansion may contain up to two paged ROMs, The ROM pack paged ROMs may contain up to about 16K of data and/or programs which is paged into memory as required. On the BBC microcomputer the facility also extends to phrase ROMs (PHROMS) associated with the speech upgrade. When the programs or data stored in these ROM packs are required it may be loaded into user RAM in the same way as programs or data may be loaded off tape or disc.

These ROM packs are intended to provide a reliable and rapidly accessible medium for the distribution of programs. The market for such a product being amongst owners of tape based machines who would otherwise have to rely upon the much slower and inherently less reliable medium.

The advantage to the software producer is that there is no requirement for a special version of the program to be written. A system is required for the formatting of the program for inclusion in a ROM pack but no modification of the program itself is required.

The *ROM filing system is a subset of the tape filing system. Paged ROMs are interrogated to determine whether they contain information intended for this filing system and are then serially accessed by the *ROM filing system.

Paged ROMs containing information intended for access via the *ROM filing system are no different from other paged ROMs. They are service type ROMs and as such have sevice entry points. They are distinguishable as *ROM filing system ROMs only by their response to paged ROM service calls issued by the *ROM filing system code. When the user selects the *ROM filing system

any further requests for files result in the *ROM filing system section of the operating system scanning the paged ROMs for these files. A paged ROM containing files intended for the *ROM filing system should respond to one of two paged ROM service calls.

The two service calls and the responses expected from ROMs containing *ROM data are described in detail below. One call expects the ROM to prepare to yield any data it has and the second call is used to extract this data, one byte at a time. The data should be formatted in a similar way to the data stored on tape but is modified in such a way as to minimise the storage overheads involved in using such a format. The reason for adopting this format is to minimise the requirements for extra code in the operating system while utilising the exhaustive error checking already in existence. Accompanying these advantages there is a concurrent reduction in response time performance but this is of little importance to the users of tape based machines who are still able to appreciate a substantial improvement on their system's existing performance.

11.1 Converting files to *ROM format

In order to produce a ROM containing files which will be recognised by the *ROM filing system it is necessary to fulfill two criteria, The first requirement is for some header code which will recognise the *ROM filing system paged ROM service calls and respond accordingly. The second requirement is that the data which makes up the files is formatted in the manner in which the *ROM filing system expects to find it.

11.2 The header code

As has been stated above a paged ROM which is to be recognised by the *ROM filing system is a perfectly standard paged ROM which responds to the apporpriated service calls. As a result of this requirement the first part of each *ROM filing system ROM consists of a standard format paged ROM header followed by a small amount of code which responds to the necessary service calls. By convention *ROM paged ROMs do not respond to the

*HELP sevice call but should these ROMs anounce their presence in this way it would obviously leave less space for programs and data.

The two paged ROM service calls which should elicit a response from *ROM paged ROMs are described in the next two paragraphs.

11.3 Paged ROM service call with A=&D

This call is the *ROM filing system initialise call. When the filing system is active and wishes to scan the next ROM this call is issued.

The initialise service call is made with the ROM number of the next ROM to be scanned in the Y register. Having received this service call a filing system ROM should only respond if its own ROM ID (stored in location &F4) is greater than or equal to the ROM number passed in the Y register.

Having decided to claim this service call the ROM should place its own ROM number in location &F5 which marks it as the currently active *ROM filing system ROM. It should then write the address of the start of the data it contains in locations &F6 and &F7. This provides a zero page pointer which is used by the filing system code to extract bytes of data serially from the ROM.

Having performed these two operations the service routine should return with the accumulator containing zero to indicate that the call has been claimed, In the case of the paged ROM ID being less than the ROM number in the Y register the service routine should exit with &D in the accumulator and the operating system will then offer the call to the next ROM.

The actual mode in which the *ROM filing system ROM numbers are represented differs from the way in which the paged ROM IDs are usually represented (i.e. as stored in &F4, a number 0 to *15).* The filing system ROM numbers are represented by a value which is 15 minus the physical paged ROM number. One way of converting numbers from one form to another is, given the number to be converted in the accumulator,

```
EOR #&FF
AND #&F
```

which returns the inverted number in the accumulator. These instructions will always convert a number into the other representation.

11.4 Paged ROM service call with A=&E

Having obtained a response from a paged ROM to service call &D the *ROM filing system will use this service call to read bytes from the data contained in the ROM.

There is a difference in how the service routine can be implemented on the BBC Microcomputer OS 1.00 and later OS versions (including the Electron). The actual response required from the service call is essentially the same however.

When called by OS 1.00 a paged ROM should only respond to this call if its own ROM ID is the same as the current *ROM filing system ROM number. A comparison of the contents of memory location &F4 (current paged ROM) should be made with the inverted contents of &F5 (current *ROM) If these are not the same the call should be returned unclaimed.

The service routine for OS 1.00 should return the byte of data pointed to by the pointer in &F6 and &F7 in the Y register (e.g. LDA (&F6),Y:TAY) and increment this pointer so that it is ready for the next call.

Later operating system versions contain a routine (OSRDRM) which given the paged ROM ID of the current *ROM filing system ROM in the Y register will read a byte from this paged ROM using the pointer at &F6+&F7. Thus this paged ROM service call may be serviced by the highest priority *ROM filing system ROM and the operating system does not have to scan all the ROMs before getting a response. This leads to a significant improvement in performance of the *ROM filing system.

The service routines are able to determine which operating system has called them by the value of the Y register passed with this service call. On operating systems supporting the OSRDRM call the Y register contains a negative value while other versions of the operating system make this call with a positive value in the Y register.

The example given at the end of this section shows how the service routine at the head of a *ROM filing system ROM detects the operating system type and responds appropriately. This example will function on both types of operating system but will take advantage of OSRDRM routine if available. *ROM filing system ROMs designed for use on the earlier operating systems will still work with later versions.

11.5 *ROM data format

The format in which data should be stored in *ROM filing system ROMs is very similar to the tape data format. The data is divided into blocks which may be up to *255* bytes long. Each block of data is preceded by a header which contains information about the block. Both the block of data itself and the header are followed by a 16 bit cyclic redundancy check (CRC) value, The filing system calculates its own values for these CRCs during the loading process and compares them. If the filing sysem’s value differs from the stored value then the filing system flags an error and rejects the data. (A routine for calculating CRCs is included in the example at the end of this section.)

The *ROM filing system data format is as follows:

offset	description	length
	Block Header	
0	&2A, a synchronisation byte	1
1	a file name (ito 10 chars.)	n
1+n	&O0, a file name terminator	1
2+n	load address (low byte first)	4
6+n	execution address	4
10+n	block number (low byte first)	2
12+n	block length (in, in bytes)	2
14+n	block flag (see below)	1
15+n	address of next file	2
17+n	header CRC(1 to n + l6 incl.)	2
	Block Data	
19+n	data	m
19+n+m	datablockCRC	2
	(next blocks)	
z	&2B end of ROM marker	1

The block flag:

bit 0 Protection bit (file only allowed to be *RUN)
bit 6 Set if block contains no data
bit 7 Set if this is the last block of the file

For the *ROM filing system the headers for all but the first and last blocks may be replaced by a single byte header of value &23 (‘#‘) with no CRC. This is implemented to reduce the memory overheads inherent with the tape style data format.

By convention the first file in a *ROM filing system ROM should be a title file. This is a file of zero length which serves to identify the ROM. The name of this file will appear on catalogue listings of the ROM. The file name of this title file should consist of a name and a version number preceded and followed by an asterisk e.g.'*Mon00*' or '*GAMESO5*'.

11.6 An example of a *ROM filing system ROM

The program below is written in BASIC 2 to assemble a ROM image which can be 'blown' into an EPROM and placed in a BBC microcomputer paged ROM socket or into a ROM cartridge slot on the Electron Plus 1 expansion.

Included in the program below is a routine for calculating CRC values (FNdo_crc). The actual CRC values required for this ROM image are included in the comments so that the actual values may be inserted directly if someone wanted to reduce the typing load when trying out this example.

```
 10  REM ************************************
 20  REM *                                  *
 30  REM *   *ROM filing system ROM example  *
 40  REM *                                  *
 50  REM ************************************

 60  REM Assemble CRC caLcuLating routine

 70  DIM MC% &100:PROCassm

 80  REM Set up constants required for ROM assembLy

 90  serROM=&F5
100  ROMid=&F4
110  ROMptr=&F6
120  OSRDRM=&FFB9
130  version0

140  REM Reserve space for ROM image and prepare to assemble

150  DIM code% &4000
160  FORI4 TO 7 STEP3
170  P%=&8000:O%=code%
180  [
```

```
  190  OPT 1
  200  .R0Mstart EQUB 0               \ null language entry
  210            EQUB 0
  220            EQUB 0
  230            JMP service          \ service entry point
  240            EQUB &82             \ ROM type, service ROM
  250            EQUB copyr—RoMstart  \ offset to copyrights
  260            EQUB version         \ binary version number
  270            EQUS “Serial Rom”    \ ROM titLe string
  280            EQUB 0
  290            EQUS “0”             \ ROM version string
  300  .copyr    EQUB 0
  310            EQUS “(C) 1982 Acorn Computers” \ copyright$
  320            EQUB 0               \ end of paged ROM header
  330  .service  CMP #&D              \ service routine
  340            BEQ initsp           \ initialise call?
  350            CMP #&E
  360            BEQ rdbyte           \ read byte call?
  370            RTS                  \ not my call

380 \ Routine for paged ROM service call &D
  390  .initsp   PHA                  \ save accumulator
  400            JSR invsno           \ invert *ROM number
  410            CMP ROMid            \ compare with ROM id
  420            BCC exit             \ if *ROM > me, not my
call
  430            LDA #data AND 255    \ low byte of data address
  440            STA ROMptr           \ store in pointer
location
  450            LDA #data DIV &100   \ high byte of data
address
  460            STA ROMptr+1         \ store in pointer
location
  470            LDA ROMid            \ get my paged ROM number
  480            JSR invert           \ invert it
  490            STA serROM           \ make me current *ROM
  500  .claim    PLA                  \ restore
accumulator/stack
  510            LDA #0               \ service call claimed
  520            RTS                  \ finished
  530  .exit     PLA                  \ call not claimed restore
  540            RTS                  \ accumulator and return

550 \ Routine for paged ROM service call &E
  560  .rdbyte   PHA                  \ save accumulator
  570            TYA                  \ copy Y to A
  580            BMI osl2O            \ if Y —ye OS has OSRDRM
  590  \ this part for OS with no OSRDRM
  600            JSR invsno           \ invert *ROM number
  610            CMP ROMid            \ is it my paged ROM no.
  620            BNE exit             \ if not do not claim call
  630            LDY #0               \ Y=0
```

```
   640            LDA (ROMptr),Y       \ load A with byte
   650            TAY                  \ copy A to Y
   660  .claiml   INC ROMptr           \ increment ptr low byte
   670            BNE claim            \ no overflow
   680            INC ROMptr+1         \ increment ptr high byte
   690            JMP claim            \ claim call and return
   700  \ this part for OS with OSRDRM
   710  .os120    JSR invsno           \ A=current *ROM number
   720                                 \ not necessarily me
   730            TAY                  \ copy A to Y
   740            JSR OSRDRM           \ OS will select ROM
   750            TAY                  \ byte returned in A
   760            JMP claimi           \ incremnt ptr & claim
call
   770  \ Subroutine for inverting *ROM numbers
   780  .invsno   LDA serROM           \ A=*ROM number
   790  .invert   EOR #&FF             \ invert bits
   800            AND #&F              \ mask out unwanted bits
   810            RTS                  \ finished
   820  \ End of header code/beginning of data
   830  .data     EQUB &2A             \ synchronisation byte
   840  .hdstrt   EQUS "*EXAMPLE*"     \ *R0M title
   850            EQUB 0               \ name terminator
   860            EQUD 0               \ Load address0
   870            EQUD 0               \ execution address=0
   880            EQUW 0               \ block number0
   890            EQUW 0               \ block length=0
   900            EQUB &CO             \ block flag
   910            EQUD eof             \ pointer to next file
   920  .hdcrc    EQUW FNdocrcChdstrt,hdcrc) \ CRC C&246F)
   930  .eof
   940  \ No data block for this file
   950            EQUB &2A             \ synchronisation byte
   960  .filel    EQUS "TEXT"          \ file title
970EQUB 0
   980            EQUD 0               \ null load address
   990            EQUD 0               \ null execution address
  1000            EQUW 0               \ first block
  1010            EQUW dat2–datl       \ length of data
  1020            EQUB &80             \ first & last block
  1030            EQUD eofl            \ pointer to end of file
  1040  .hdcrcl   EQUW FNdo_crc(filel,hdcrcl) \ CRC (&E893)
  1050  .datl     EQUS "REM This is a very short text file."
```

```
1060            EQUB &D                 \ The file contents
1070  .dat2     EQUW FNdocrc(datl,dat2) \ Block CRC (&655D)
1080  .eofl
1090            EQUB &2B                \ end of ROM marker
1100  .eor
1110  ]
1120  NEXT
1130  PRINT1'    *S.ROM ";~code%;" ";~O%
1140  END

1150  REM Define function which calculates CRC
1160  REM Requires start and end of block up to 255 bytes
1170  DEF FNdocrc(start,end)
1180  ?&82=(start-&8000+code%) AND &FF
1190  ?&83=(start-&8000+code%.) DIV &100
1200  ?&84=end—start
1210  CALL crc
1220   =(!&80) AND &FFFF

1230  REM Define procedure which assembles CRC routine
1240  DEF PROCassm
1250  startaddr=&82
1260  Locrc&81
1270  Hicrc&80
1280  len&84
1290  FORI=0 TO 3 STEP3
1300  P%MC%
1310  [
1320            OPT I
1330  .crc      LDA #0
1340            STA Hi_crc
1350            STA Lo_crc
1360            TAY
1370  .labell   LDA Hi_crc
1380            EOR (startaddr),Y
1390            STA Hicrc
1400            LDX #8
1410  .label2   LDA HLcrc
1420            ROL A
1430            BCC label3
1440            LDA Hicrc
1450            EOR #8
1460            STA Hi_crc
1470            LDA Lo_crc
1480            EOR #&10
1490            STA Locrc
1500  .label3   ROL Locrc
1510            ROL HLcrc
1520            DEX
1530            BNE label2
```

```
 1540            INY
 1550            CPY Len
 1560            BNE Labell
 1570            RTS
 1580  ]
 1590  NEXT
 1600  CALL crc:ENDPROC
```

When the resultant ROM is installed in the machine the following dialogue may ensue.

```
>*ROM
>*CAT

*EXAMPLE*
TEXT

>*EXEC TEXT
>REM This is a very short text file.
```

12 Memory allocation and usage

Two fundamental points have been stressed in various parts of this book.

The first is that programs should only use memory allocated for their general use or memory designated for specific functions when requiring or performing that function.

The second point is that software should not make assumptions about its environment, The amount of *user* RAM available depends on the screen MODE selected and the amount of workspace RAM claimed by paged ROMs.

The Electron microcomputer's memory map:

&FFFF Operating system ROM

&FFOO
&FEFF Memory mapped I/O

&FCOO
&FBFF Operating system ROM

&C000
&BFFF Paged ROM space

&8000
&7FFF Screen memory

HIMEM

OSHWM Paged ROM workspace/exploded font

&EOO

&DFF NMI routine and paged ROM information
(WARNING, not for user programs)
&D00

&CFF Operating system private workspace

&A00
&9FF Sound system workspace/OS workspace

&800
&7FF Current language private workspace

&400
&3FF Operating system private workspace

&236
&235 OS call indirection vectors

&200
&1FF 6502 stack

&100
&FF Zero page

Zero page

Zero page locations are very valuable due to the necessity of their use with certain types of indexed addressing. In absolute terms there are no allocations to the user as such. However the current language should re-allocate some of its zero page to the user if appropriate. Should the user be executing machine code independently of any language the language's zero page allocation is totally available.

&00 Current language

&8F
&90 Econet zero page

&9F
&A0 Current NMI owner

&A7
&A8 Utility workspace

&AF
&B0 Filing system transient zero page

&BF
&C0 Filing system exclusive zero page

&CF
&D0 OS reserved workspace

&FF

Current language zero page &00 to &8F

The currently selected language has exclusive use of these locations. BASIC re-allocates &70 to &8F for user's assembly language routines.

Econet zero page &90 to &9F

These locations are allocated for the exclusive use of the Econet filing system if fitted. If software is produced which is designed to run only on those machines not having the Econet upgrade then these locations may be used but only after confirming that Econet is not present.

Current NMI owner zero page &A0 to &A7

These locations are allocated to the current owner of the NMI. This will normally be the Disc or Econet filing systems. Paged ROM service calls are issued to claim and release the ownership of the NMI (see section 10.1).

Utility workspace zero page **&A8 to &AF**

This memory is allocated for use by the code executed via the command line interpreter, It is used by the operating system for its own *commands. It may also be used by paged ROM and file based utilities when invoked by the ‘unknown *command’ mechanism (see sections 10.1 (paged ROMs) and *5.7* (OSFSCV))

Filing system transient zero page **&BO to &BF**

These locations are allocated for use by the currently selected filing system but they may be corrupted by other software between filing system calls.

Filing system exclusive zero page **&CO to &CF**

This memory is reserved for the exclusive use of the currently selected filing system. This memory should not be used by the filing system’s NMI routine.

Operating sytem reserved workspace **&DO to &FF**

This region of zero page memory is exclusively reserved for operating system use. Within this area there are a number of locations in which the operating system stores information which will be of use for certain routines.

&EE — 1MHz bus page number

&EF — This location contains the accumulator value passed with the most recent OSBYTE or OS WORD call.

&FO — This location contains the X register value passed with the most recent OSBYTE or OSWORD call.

&F1 — This location contains the Y register value passed with the most recent OSBYTE or OSWORD call.

&F2 and &F3 — These locations contain an address which points to the text offered to the command line interpreter.

&F4 — This location contains the ROM number of the currently active paged ROM. (The operating system maintains this as a RAM copy of the paged ROM selection latch.)

&F5 to &F7 — These locations are used for the *ROM filing system (see chapter 11).

&FA to &FC — These locations are available for use by routines which have set the interrupt flag. The operating system interrupt routines use these locations but do not expect the contents to remain unchanged between calls.

&FD and &FE — These locations are written to after a BRK instruction has been executed. They contain the address of the next byte of memory following the BRK instruction. Thus these locations normally point to an error message (see section 6.2). Upon selection of a language these locations are set to point at the version string of the newly selected language ROM.

&FF — This location contains the ESCAPE flag. Bit 7 of this location is set to mark an ESCAPE condition. This flag is cleared when an ESCAPE is serviced.

Page 1

This page is used for the 6502 stack. The stack grows from the last byte in this page (&1FF) down towards the bottom of the page. Paged ROM service routines may use the bottom of this page to store error messages.

Page 2

The operating system routines' indirection vectors are located from &200 to &235. The rest of this page is used as private operating system workspace. The way in which private operating system workspace is used may change between different software versions and different machines in the Acorn BBC range.

This page is designated private operating system workspace and should not be used by any other software. The BBC microcomputer and the Electron operating systems use this page for the VDU routines' workspace, some miscellaneous tape filing system workspace and for the keyboard buffer.

Pages 4, 5, 6 and 7

These four pages are allocated for the exclusive use of the currently selected language. Should a user be executing code independently of a language this memory may be used by that code. The user's code should not re-enter a language without ensuring that the language has had an opportunity to reset its workspace.

Page 8

This page is allocated for the sound system and for buffers:

&800 to &83F	general sound workspace
&840 to &84F	sound channel 0 buffer
&850 to &85F	sound channel 1 buffer
&860 to &86F	sound channel 2 buffer
&870 to &87F	sound channel 3 buffer
&880 to &8BF	printer buffer
&8C0 to &8FF	envelope storage area (env.no's 1—4)

On the Electron this area is available for the implementation of external sound and the printer buffer area is used by the Plus 1 expansion software. Locations in this page should only be used by system software performing the appropriate task e.g. user printer routines, sound expansion routines.

Page 9

This page is used as workspace for the sound system and the serial system (tape and RS423). Theoretically clashes of use could occur but in practice problems very rarely arise. The operating system

uses this area for RS423 and tape output buffers but the area is also allocated for speech and sound use. Thus externally implemented systems performing these functions may utilise this memory according to the allocation below.

&900 to &9BF	envelope storage area (env.no's 5—16)
&9C0 to &9FF	speech buffer

Pages&Ato&C

These pages are reserved for exclusive use of the operating system as private workspace. The nature of the operating system use cannot be relied upon between different software versions and between different machines in the Acorn BBC range.

Page&D

This page is allocated in the following way:

&DOO to &D5F	NMI routine
&D60 to &D9E	reserved
&D9F to &DEF	paged ROM extended vectors
&DFO to &DFF	paged ROM workspace table

The NML routine is the code which is executed when a non-maskable interrupt is generated. This is entered at &DOO and should service the interrupt.

The paged ROM extended vectors provide an entry into paged ROM code regardless of which ROM is active as the call is made.
See section 10.3 for a description of extended vectors.

The paged ROM workspace table contains a single byte page address indicating the start of each ROM's private workspace (see section 10.3 for further details).

WARNING

Many games programmers have used page &D. These games will not work when a Plus 1 is fitted because it uses this space. DO NOT continually disconnect and re-connect the Plus 1 because this will damage both the Plus 1 and the Electron, A suitable program which disables the Plus 1 can be obtained from Acorn Computers Limited.

Page &EOO to the OSHWM

This memory is available for paged ROM workspace and for character definitions as part of a user defined font.

Each ROM is interrogated during a reset to determine its workspace requirements (see paged ROM service calls, section 10.1). This workspace extends from &EOO in page sized units until all the paged ROMs have made their claims.

The Acorn BBC range of machines allow the user to define the character patterns that are printed on the screen. The number of user defined characters which may be used depends on the explosion state of the font (see OSBYTE & 14). On the Electron and BBC microcomputer the memory required when exploding the font is allocated above the paged ROM workspace.

The user (or language) memory starts from the top of this workspace memory and the start address of this memory is called the operating system high water mark (OSHWM).

OSHWM to HIMEM

This is where a user might expect his program to live. Theoretically this memory has no fixed start address and no fixed end address which taken to extremes means that it may theoretically have no size. In practice, on the BBC microcomputer and the Electron, the region from &2800 to &3000 can be assumed to be within the OSHWM/HIMEM bounds.

The language environment may also place constraints on the amount of RAM available for a user's program and/or data.

No RAM should be accessed above HIMEM. This includes the screen memory and, on a second processor, the memory in which the language is stored.

Screen memory

This memory is not guaranteed to exist at any given place on Acorn BBC range machines, For example when a Tube is active a program may find itself on the second processor and thus any attempts to access what was the screen memory will have no effects on the screen image.

For more information about programming practices read chapter 1 on the Acorn design philosophy and programming rules.

Paged ROM memory: &8000 to &BFFF

This region in the memory map of non-Tube machines or I/O processors contains the currently 'paged' paged ROM. When the current filing system is in paged ROM and a filing system function used then the appropriate paged ROM is selected.

Operating system ROM memory: &COOO to &FFFF

The contents of the OS ROM are undefined except for the OS call entry points described in chapter x and the default vector table described in section 6.11.

Memory mapped 10: &FCOO to &FEFF

Hardware devices are addressed via these memory locations. Once again extreme care should be taken to address them in the correct manner using OSBYTEs &92 to &97 for reading and writing these addresses. See chapter X for more information about the memory mapped I/O.

(The OS ROM contains a list of credits in this region made inaccessible by the switch to memory mapped I/O.)

13 An Introduction to Hardware

BASIC is a very useful programming tool. It allows users to take advantage of the Electron's facilities without bothering about the details of how it is performed in hardware. Commands are provided to deal with output to the screen, input from the keyboard and cassette, plus all of the other hardware. The same applies to machine code to a large extent through the use of **OSBYTES, OSWORDS and other operating system commands.**
However, a much more detailed understanding of the hardware and how it can be controlled from machine code programs is very useful and allows certain features to be implemented which would have been impossible in BASIC.

The hardware section of this book satisfies the requirements of two types of people. Those who wish to use the hardware features already present on the computer, and those who wish to add their own hardware to the computer. All of the standard hardware features available on the Electron are therefore outlined in detail from a programmer's point of view. Wherever possible, it is better to use operating system routes for controlling the hardware. These are very powerful and will be referred to whenever relevant. In certain specialised cases, it is necessary to directly access hardware, but even in such cases, OSBYTES &92-&97 should be used. This will ensure that the software will still operate on machines fitted with a Tube processor. For those who wish to add their own hardware, full details on connecting circuits to the Electron's expansion port are provided.

The hardware on the Electron consists of a large quantity of integrated circuits , resistors , capacitors , transistors and various other electronic components. All of these are shown on the full circuit diagram in Appendix F. In order to help those who are not familiar with the general layout of a computer circuit and the devices attached to it, the rest of this introduction is devoted to analysing the hardware as a series of discrete blocks interconnected by a series of system buses.

Refer to figure 13.1 whilst reading the following outline of the hardware. There are two major blocks inside the Electron.

The first is the uncommitted logic array (usually referred to as the ULA), This is a very large chip which does most of the boring system tasks. It's life is devoted to copying data from the video memory to the video circuit, driving the cassette, producing sounds, keeping an eye on the keyboard plus other minor tasks.

The other major component is the computing centre of the system, called the 6502A central processing unit (CPU). This is the chip which executes all of the programs including BASIC. It is connected to the ULA, ROM and expansion bus. For clarity on the diagram, the connecting buses are all compressed into one which is represented by the double lines terminated with arrows at each major block.

A *bus* is simply a number of electrical links connected in parallel to several devices. Normally one of these devices is talking to another device on the bus. The communication protocols which enable this transfer of data to take place are set up by the control, address and data buses. In the case of the address bus, there are 16 separate lines which allow *65536* (216) different combinations of l's and 0's. The maximum amount of directly addressable memory on a 6502 is therefore *65536* bytes. The data bus consists of 8 lines, one for each bit of a byte. Any number between 0 and &FF (255) can be transferred across the data bus. Communication between the ULA, peripherals on the expansion bus, memory and the CPU occurs over the data bus. The CPU can either send out a byte or receive a byte. The data bus is therefore called a *bidirectional* bus because data flows in any one of two directions. The 6502 address bus is unidirectional because addresses can be provided but not received. The ULA sits back looking at the addresses from the 6502.

In order to control the direction of data flow on the data bus, a read or write signal is provided by the control bus. Hardware connected to the system can thereby determine whether it is being sent data or is meant to send data back to the CPU. The other major control bus functions are those of providing a clock, interrupts and resets. The clock signal keeps all of the chips

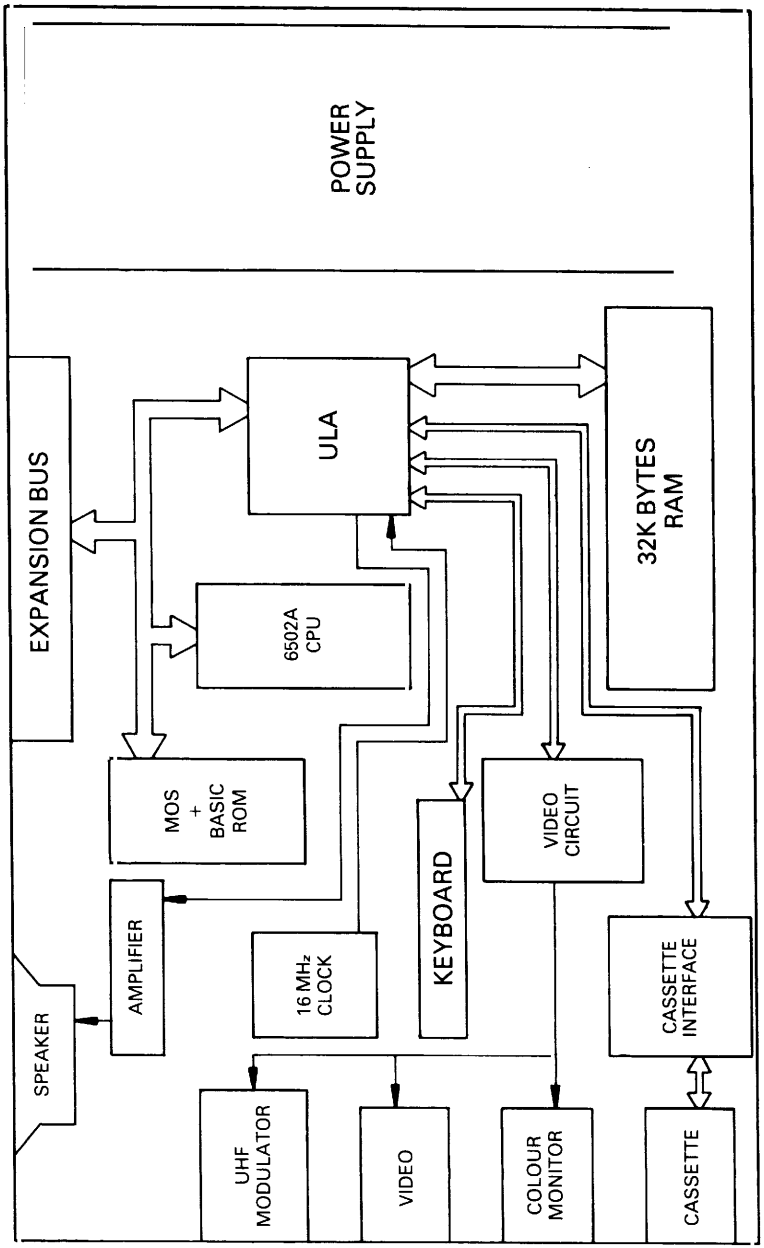


Figure 13.1 The system block diagram

running together at the same rate. The RESET line allows all hardware to be initialised to some predefined state after a reset. An interrupt is a signal sent from a peripheral to the 6502 requesting the 6502 to look at that peripheral. Two forms of interrupt are provided. One of these is the interrupt request (IRO) which the 6502 can ignore under software control. The other in the non-maskable interrupt (NMI) which can never be ignored. Refer to chapter 7 on interrupts for more information.

When power is first applied to the system, a reset is generated by the ULA to ensure that all devices start up in their reset states. The 6502 then starts to get instructions from the ROM. These instructions tell the 6502 what it should do next. A variety of different instructions exist on the 6502. The basic functions available are reading or writing data to memory or an input! output device and performing arithmetic and logical operations on the data. Once the MOS (machine operating system) program is entered, this piece of software gains full control of the system.

On an unexpanded Electron, the computer will continue operating under the MOS until it is switched off. Programs are entered into the memory from the keyboard or cassette port, then run. There is some scope for clever programming techniques using the standard hardware - they all involve some tampering with the various registers in the ULA, However, a lot more facilities can be provided by adding extra hardware onto the back *of* the Electron.

Since the Electron is the *little brother* of the BBC Micro, two forms of expansion are provided for. The first of these covers the addition of hardware which is supplied as standard on a BBC Micro. Within this category are included items like a printer port, analogue to digital converter (for joysticks) and paged ROMs. The second category includes items which would have to be added onto a BBC Micro. Products like the second processors and units which plug onto the *One Megahertz Bus* are in this category.

SHEILA and the ULA

On the BBC Micro, all of the resident hardware is mapped into page &FE of memory. This page is called Sheila. The Electron also has all of its internal hardware memory mapped into Sheila, but with one major difference to the BBC Micro. All memory mapped functions are contained within the ULA. These can be summarised as:

SHEILA	Address	Description
&FEXO		Interrupt status and control register
&FEX2		Video display start address (low byte)
&FEX3		Video display start address (high byte)
&FEX4		Cassette data register
&FEX5		Paged ROM control and interrupt control
&FEX6		Counter plus cassette control
&FEX7		Controls screen, sound, cassette and CAPS LED
&FEX8-XF		Pallette registers

Note that the ULA appears in every 16 byte block of page &FE. Writing to &FEO2 is therefore exactly the same as writing to &FEA2 or &FE32 etc.

14 Inside the Electron

The only hardware inside the Electron which can be accessed directly by the 6502 is the MOS ROM and the ULA, The RAM is read via the ULA, and *all* internal control functions are performed by the ULA.

As has already been mentioned in chapter 13, the ULA is addressed in page &FE (called Sheila). The rest of this chapter explains exactly what all of the registers within the ULA will do, and how they can be of use. Note that there are two ways of communicating with Sheila. OSBYTEs 150 and 151 will read and write to Sheila respectively. Alternatively, the memory mapped addresses can be POKEd directly from programs.

THE ULA AND ITS REGISTERS

SHEILA &FE00 - Interrupt status and control

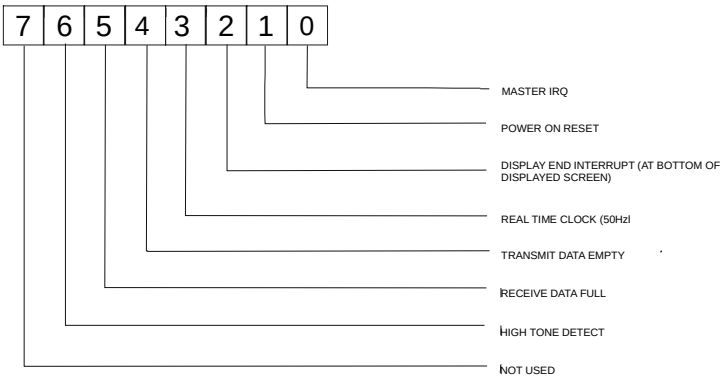


Figure 14.1 – IRQ status and control register

This register is concerned with the interrupts on the Electron. Interrupts are generated by pieces of hardware which require the 6502 to look at them urgently. A detailed discussion of interrupts can be found in chapter 7.

By writing a ‘1’ into the corresponding bits of this register, particular interrupts can be enabled. Writing ‘0’ into a particular bit will disable the related interrupt. Enabled interrupts can get the 6502 to look at them if they generate a suitable signal. Disabled devices will not be looked at even *if* they generate an interrupt.

Note that after an interrupt has occured, it will be necessary to *clear* the source of the interrupt, This can be done by writing to address &FE05.

SHEILA &FE02 and &FE03 - Screen start address control

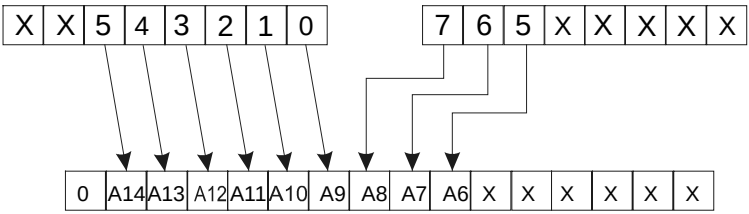


Figure 14.2 – The screen start address registers

These two registers together form the screen start address. This is the address in memory which will be mapped to the top lefthand corner of the displayed screen. Whenever a line is to be scrolled up or down, this register is incremented or decremented by the number of bytes in a line. As well as allowing vertical scrolling, a limited amount of horizontal scrolling is also possible. The start address can be changed in increments of 64 bytes of memory. In mode 0, 8 bytes are used per character. This means that a scroll in the minimum increment will move the whole screen 8 characters (64/8) left or right.

The following example demonstrates this feature. Once it has been typed in, the cursor keys can be used to move a block of text about over the mode 0 screen. Note that the actual screen start address has to be shifted right by one bit before it is POKEd into the ULA registers.

```
  10 REM HARDWARE SCROLL EXAMPLE IN MODE 0
  20 MODE 0
  30 OSBYTE=&FFF4
  40 START=&3000
  50 PRINT"THIS TEXT CAN SCROLL IN ANY DIRECTION USING
CURSOR— KEYS"
  60 REM SET KEYS AUTO REPEAT RATE
  70 *FX12,3
  80 REM SET CURSOR KEYS TO GIVE 136 etc.
  90 *FX4,1
  100 REPEAT
  110 A=INKEY(0)
  120 IF A=136 THEN PROCMOVE(64)
  130 IF A=137 THEN PROCMOVE(—64)
  140 IF A=138 THEN PROCMOVE(—640)
  150 IF A=139 THEN PROCMOVE(640)
  160 UNTIL FALSE
  170 DEF PROCMOVE(offset)
  180 START=START+offset
  190 REM IF ABOVE SCREEN TOP, SUBTRACT SCREEN LENGTH
  200 IF START>=&8000 THEN START=START—&5000
  210 REM IF BELOW SCREEN BASE, ADD SCREEN LENGTH
  220 IF START<=&3000 THEN START=START+&5000
  230 REM CALCULATE HIGH BYTE FOR ULA
  240 REM SHIFTED RIGHT BY ONE BIT
  250 H% = START DIV 512
  260 REM LOW BYTE SHIFTED RIGHT BY ONE BIT
  270 L% = (START MOD 512) DIV 2
  280 REM NOW PUT INTO ULA REGISTERS
  290 REM LOW BYTE TO &FEO2
  300 A%=151:X%=2:Y%=L%
  310 CALL OSBYTE
  320 REM HIGH BYTE TO &FEO3
  330 A%=151:X%=3:Y%=H%
  340 CALL OSBYTE
  350 ENDPROC
```

SHEILA &FE04 - Cassette data shift register

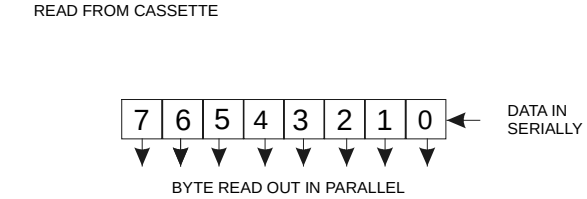


Figure 14.3a - Reading from the shift register

Data is input to the Electron from a cassette recorder, This data shifts into bit 0 of the serial shift register, then into bit 1 and so on until the whole 8 bits of a byte are in the ULA's receive data register. At this point, data can be read out and stored in memory somewhere.

There are several points which are worth remembering when the cassette is used. First of all, a *high tone* must have been recorded on the tape before any data is read into the Electron. This allows the circuitry to detect that data is about to be sent. The screen mode should have been set to between 4 and 6. If it is not, bits are sometimes lost because the 6502 cannot be interrupted whilst high resolution graphics are being displayed. Finally, the receive data full interrupt should be enabled. This will ensure that the 6S02 knows when a byte can be read. If the byte is not read within about 2ms, the data will be lost forever as bit 7 falls off the end of the register when the next bit comes in!

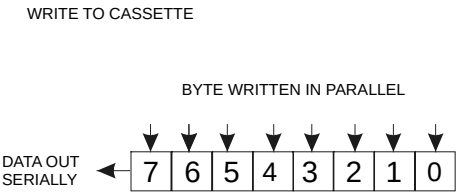


Figure 14.3b - Writing to the shift register

Writing to this register causes data to be output to the cassette (assuming that the cassette output mode has been set by writing to &FEO7). Bit 7 is written out first (so that it is the first in when the tape is played back). When the last bit has been written out, a *transmit data empty* interrupt is generated. This tells the 6502 that it can put the next byte to be sent into the register.

SHEILA &FEO5 - Interrupt clear and paging register

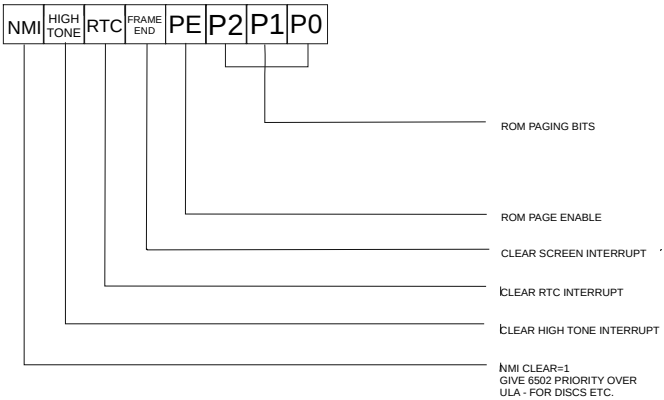


Figure 14.4 - The clear interrupt and paging register This register has two purposes, namely the clearing of interrupts and the selection of paged ROMs.

Interrupt clearing

Putting a ‘1’ into any of the bits 4-7 will cause the associated interrupt to be cleared. Interrupts should be cleared after they have been serviced, but before returning from the interrupt service routine.

Bits 4, 5 and 6 are associated with maskable interrupts. Bit 7 is associated with the Non-maskable interrupt, This type of interrupt is generated by very high priority devices like discs. An NMI automatically gives the 6502 precedence over the ULA, even if it is in the middle of displaying a screen. White snow may

therefore occur on the screen when discs are being accessed. Once the 6502 has dealt with the source of interrupt, it should clear it by writing a '1' to bit 7. This gives the screen memory back to the ULA.

Paging ROMs

The detailed mechanisms for decoding paged ROMs are covered in the next chapter, however, a simple summary is in order here.

There is the potential within the operating system to directly address up to 16 paged ROMs of 16K bytes each. However, four of the *slots* are effectively occupied by the keyboard and the BASIC ROM. The keyboard occupies positions 8 and 9 (both are equivalent). To read from the keyboard, the 14 address lines AO - A13 are used. Each of these is connected to one of the columns of the keyboard. If a particular address line is low, that line of the keyboard is selected on a read. The row data from the keyboard is then returned in the lower 4 bits read from the data bus. The BASIC ROM is selected by paging ROM number 10 or 11.

In order to select any of the other ROMs, a particular sequence must be followed, First of all, the ULA must be told that BASIC should be dc-selected. This is done with the page enable bit. One of the ROMs 12-15 will be selected in this way. Now that BASIC has gone, it is (if so desired) possible to page in one of the ROMs 0 to 7. This is simply performed by setting the page enable bit to 0 and selecting the required ROM with bits 0 to 2. You should refer to section 15.4 for a more detailed discussion.

SHEILA &FE06 - The counter

This write only register has several different functions, depending upon the particular mode of operation.

Reading from cassettes

X	0	0	0	0	0	0	0

Figure 14.5a - Cassette receive mode

When data is being read from a cassette, this timer is used to count from zero crossings. It therefore effectively determines the cassette baud rate. All bits should be set to 0 (except for bit 7 which doesn't matter). Cassette receive mode is set by bits 1 and 2 in &FEO7.

Making sounds

S7	S6	S5	S4	S3	S2	S1	S0

Figure 14.5b - Sound generation mode

Sound can only be generated when the cassette is not being used. The 8 bit integer written into this register determines the frequency of all generated sounds. If the value is '5' where '5' is between 0 and 255 in value, the generated sound frequency is given as:

Sound frequency = 1 MHz / [16 ***** (S + 1)]

To select sound mode, bits 1 and 2 of &FEO7 are used. Frequencies from 244Hz up to 62.5kHz can be generated, but you won't be able to hear the really high frequencies!

Writing to cassettes

X	X	X	X	X	X	X	X

Figure 14.5c - Writing to cassette

The states of the bits written to this register are ignored in this mode. The counter is used to control the received data baud rate, but cannot be changed. Bits 1 and 2 of &FEO7 should be used to select the cassette output mode.

SHEILA &FE07 - Miscellaneous control

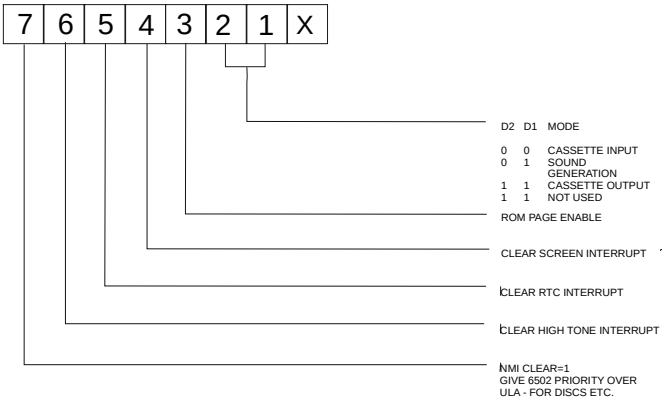


Figure 14.6 - control register

This general purpose control register provides a selection of different functions.

Communications mode, bit 1 and 2

Bits 1 and 2 control whether data is being written to a cassette recorder, read from a cassette recorder, or generating sounds. These three functions are mutually exclusive, so it is not possible to play cheery tunes whilst waiting for a long program to load.

Display mode selection, bits 3, 4 and *5*

There are seven display modes available on the Electron. These can be selected by writing a number between 0 and 6 into bits 5,4,3. Note that the other possible mode (7) is only available on the BBC Micro.

Cassette motor control, bit 6

Setting this bit to '1' will turn the cassette motor on. Setting it to '0' will turn the motor off. Motor control is effected by a small relay contact inside the Electron. It is possible to use this to switch small battery operated equipment on and off (for example a transistor radio).

CAPS LOCK LED control, bit 7

Setting this bit to a '1' turns on the CAPS LOCK LED on the side of the keyboard. A '0' turns it off again.

SHEILA &FEO8 to &FEOF - the colour palette

These addresses in the ULA define the mapping between the *logical* colours which are provided by programs and the *physical* colours which are displayed on the screen.

For example, in the two colour mode, *logical* colour 1 will actually produce a colour defined by &FEO8 bit 6 (blue), &FEO8 bit 2 (green) and &FEO9 bit 2 (red). The bits are *negative* logic, which means that a '1' in bit 6 of &FEO8 will ensure that *blue* is turned off for colour 1.

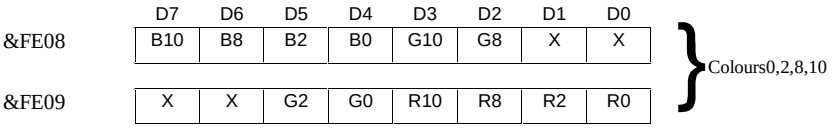
The cursor and flashing colours are entirely generated in software: This means that all of the logical to physical colour map must be changed to cause colours to flash.

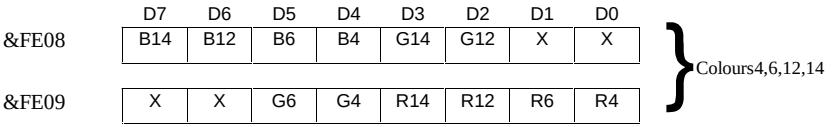
	D7	D6	D5	D4	D3	D2	D1	D0
&FE08	X	B1	X	B0	X	G1	X	X
&FE09	X	X	X	G0	X	R1	X	R0

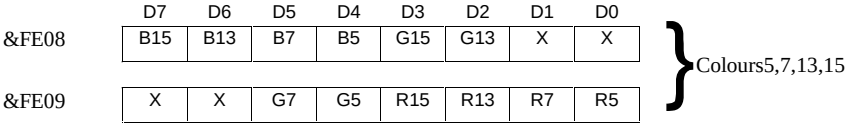
Figure 14.7a – 2 colour mode palette

	D7	D6	D5	D4	D3	D2	D1	D0
&FE08	B3	B2	B1	B0	G3	G2	X	X
&FE09	X	X	G1	G0	R3	R2	R1	R0

Figure 14.7b - 4 colour mode palette







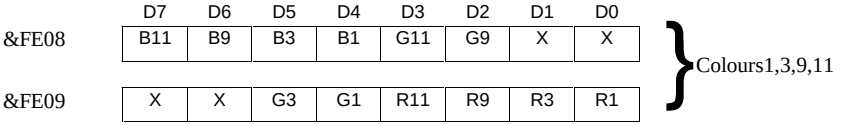


Figure 14.7c - 16 colour mode palette

15 Outside the Electron

15.1 Introduction to expanding the Electron

This chapter is intended for those who want to add their own bits of hardware onto the Electron. There are several reasons for doing this. The most common one is to allow the Electron to access facilities provided for the BBC Micro. All of the common interfaces such as discs, printer port, analogue to digital converter, speech chip, paged ROMs etc. can easily be added onto the Electron. If care is taken with the design, these products will operate in an almost identical manner to those on the BBC Micro. Several interface addons can already be purchased from Acorn.

If the only point in adding hardware onto the Electron were to make it totally BBC Micro compatible, there would have been little point in buying the Electron in the first place. In fact, the Electron has more potential for expansion than a BBC Micro. Why? Because all necessary system buses come out on the expansion connector. This ability to access all of the buses means that the devices which can be added onto the Electron are limited only by the imagination (and maximum allowable loading of the buses).

15.2 The Expansion Connector

All required signals from the Electron are present on this connector. In order to make use of them, a basic knowledge of interfacing to the 6502 will be required. Such a knowledge can be acquired by reading some of the popular electronics magazines and specialised books on interfacing. The aim in this book is to explain all of the details to those who have already read enough about microcomputer hardware in general, and now want to know about the Electron in particular.

Bottom				Top
18V AC	2		1	18VAC
AC RETURN	4		3	AC RETURN
—5V	6		5	—5V
0V	8		7	0VV
+5V	10		9	+5V
1 6M1-Iz	12		11	SOUND 0/P
PHI OUT	14		13	Divide 13_IN
!NMI	16		15	RST
R/!W	18		17	IRQ
D6	20		19	D7
D4	22		21	D5
D2	24		23	D3
DO	26		25	D1
NC	28		27	!RDY
SLOT	30		29	SLOT
A14	32		31	A15
A12	34		33	A13
AlO	36		35	A11
AO	38		37	A9
A2	40		39	A1
A4	42		41	A3
A6	44		43	A5
A8	46		45	A7
0V	48		47	0V
+5 V	50		49	+5V

Figure 15.1 _Expansion connector layout

18V AC (pins 1 ,2)

These lines are connected directly to the output from the Electron mains power adaptor.

AC return (pins 3,4)

Up to 6 watts of power may be drawn from this source (provided that none is drawn from the +SV line). Bear in mind that the AC will have to be rectified and smoothed before it can be used to drive any computer chips.

—*5V* pins (5,6)

This is a —5 volt supply from the Electron, from which a maximum of 2OmA can be drawn. It would often be used to power RS423 expansions.

0V (pins 7,8,47,48)

This is the signal and power ground on the Electron. All external circuits must have their 0 volt lines connected to this point.

+5V (pins 9,10,49,50)

This is a +5 volt power supply from the Electron. A maximum of 500mA can be drawn from it, but note that no power can be taken from the 18V AC line if this is done.

Sound o/p (pin 11)

Sound output from the Electron ULA. This signal

is 3 volts peak to peak fed via a 1K series resistor. 16

16MHz (pin 12)

This is the master 16 MHz clock from the Electron main oscillator. It can be used for clock generation on expansion modules, but see section 15.3.3 for a description of clock synchronisation.

16/13 MHz (pin 13)

This is 16 MHz divided by 13. It is normally used for baud rate generation, and will give approximately 1200Hz if divided by 1024.

PHI out (pin 14)

This is a nominally 2 MHz clock as connected to the 6502A. The low time is some 250ns. The high time varies depending upon the operation being performed. It is 250ns when reading ROMs, 750ns or 1250ns when accessing the 1MHz bus (depending upon the relative phase of the 2MHz clock) and can be up to 4Ous due to screen access in modes 0 to 3. The clock timing is covered in greater depth in section 15.3. Note that the NMI must be synchronised with PHI out. This is because the NMIs give the 6502 precedence over the ULA for the RAM. Incorrect data may be read from the RAM if the NMI is not latched on a negative going edge of PHI out.

RST (pin 15)

Active low reset signal. This is an OUTPUT ONLY for reseting expansion modules on power up, or when the BREAK key is pressed.

NMI (pin 16)

Non-maskable Interrupt (negative edge triggered). This open collector (wire-OR) line is the system NMI and can be asserted by an expansion module pulling it low. There is a 3K3 pull-up resistor inside the ULA. You must be very careful to avoid holding this line low after the interrupt has been serviced, because it will mask other interrupts whilst asserted. For more details about NMIs, you should refer to chapter 7.

IRQ (pin 17)

This is the active-low IRO (interrupt request). It is an open collector (wire-OR) line, so it can be asserted by any expansion module pulling it low. There is a 3K3 pull-up resistor within the ULA. Note that interrupts MUST NOT occur until the

software in the machine has initialised to a state at which it can deal with them. Power up and reset conditions should therefore disable all IROs, It is important to ensure that not too much of the interrupt service time is used up, otherwise some operations like the system clock may cease to function correctly.

R/W (pin 18)

This is the system read/write line from the 6502. It tells peripheral devices whether the 6502 is sending data to them, or is expecting data from them.

DO-D7 (pins 19 to 26)

This is the 8 bit wide bi-directional data bus. All data is transferred over this bus, the direction of data transfer being determined by the state of the read/write line.

RDY (pin 27)

This is the active low ready line from the 6502. It can be asserted by an expansion to slow down the processor when it is reading slow memory. This line is only operational on reads.

(pin 28)

No connection.

(pins 29,30)

Polarising key connector to ensure that boards cannot be plugged in the wrong way round.

AO-A15 (pins 31 to 46)

This is the system address bus. There are 16 lines in this bus which allow 216 (65536) different locations to be addressed.

15.3 Designing Circuits

It might at first appear to be very easy to add anything onto the Electron Expansion Bus. There is however one fairly major problem. The 6502A often changes speed to cope with the accessing of different devices. These fall into two main categories.

15.3.1 Accessing the ROM

When the ROM is being accessed, the 6502 runs at the maximum possible speed of 2MHz; PHI OUT is low for 250ns and then high for 2SOns.

15.3.2 Accessing the RAM and peripherals

When RAM or peripheral devices are accessed, the timing will be highly dependent on the display mode. This is because twice as much data has to be removed from the RAM to produce the display in modes 0—3 as in modes 4—6.

Modes 4—6

The processor will normally be running at 2MHz when it first needs to access RAM or peripherals like the 6522. It has to slow down to 1MHz first. This *slow down* either consists of a PHI OUT low time of 2SOns followed by a high time of 7SOns, or a low of 2SOns followed by a high of l2SOns. The particular type of transition which occurs will depend upon the relative phases of the 2MHz and 1MHz clocks, This is illustrated in figure 15.1. Both the 1MHz and 2MHz clocks are *internal* to the ULA, and are not available outside. They must be generated separately (see later in this section).

Modes 0—3

In these modes, the ULA must have access to the RAM for all the displayed part of a line (4Ous out of 64us in 256 lines out of 312). This doesn't matter provided that the CPU only wants to access peripherals and the ROM, which it is free to do in the normal way. However, if it tries to access RAM the the ULA will hold it's clock high for up to 4Ous. The overall effect is that the

processor can be effectively disabled for up to 40µs. The only way for the processor to obtain priority over the ULA is by an NMI being generated. This will automatically cause the ULA to release the 6502 (and the RAM), but inevitably creates *snow* on the screen.

15.3.3 Generating the 1MHz clock

Since the 1MHz and 2MHz signals only exist inside the ULA, it is necesary to regenerate them outside. Two clocks are provided on the expansion connector. A 16MHz one and a 16/13MHz one for baud rate generation. The former of these can be used to generate a 1MHz clock, This has to be synchronised to the processor clock if it is to be used with peripherals like the 6522 VIA. A simple division by 16 will not produce a suitable clock signal. The circuit in figure 15.2a will produce a suitable in phase signal. The timing for this is shown in figure 15.2b.

15.3.4 Long delays for interrupts

It is important to bear in mind how long the delays might be before a particular requested interrupt is serviced, This is determined by the longest period for which interrupts can be disabled.

In modes 0—3, this delay can be up to lOins in the very worst case. Such a long delay can cause problems with unbuffered circuits like the cassette serialiser/deserialiser. The only solution is to ensure that such devices are only used from modes 4—6 (even if it means forcing a particular mode before executing a routine).

The interrupt delay is only 4ms at worst in modes 4—6, so most actions which require a fast response can be executed in one of these modes. Note that NMIs can always be used as a last resort where necessary, but are normally reserved for disc and Econet accesses.

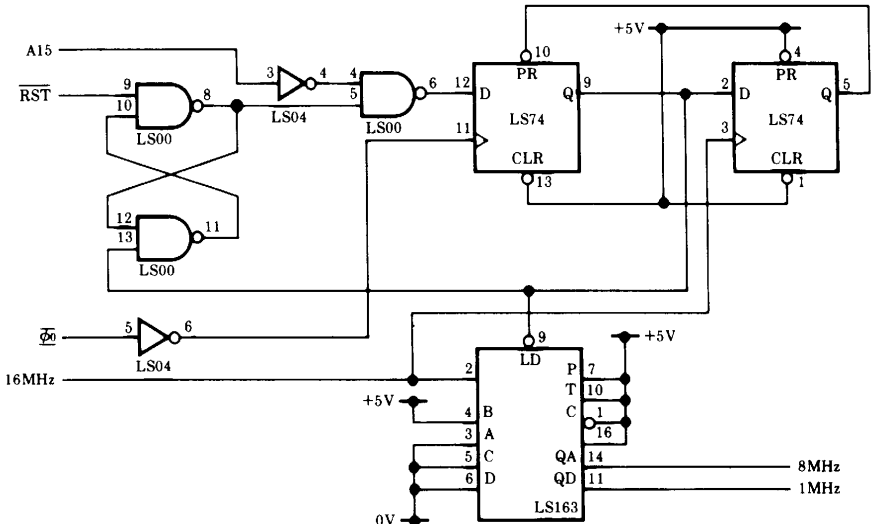


Figure 15.2a — A 16MHz to 1MHz synchronisation circuit

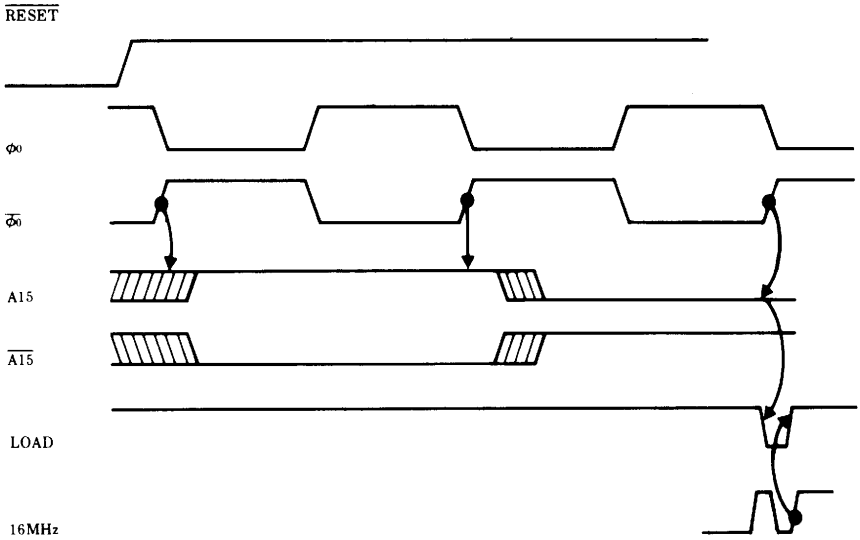


Figure 15.2b — the timing applied to figure 15.2a

15.4 Sideways ROMs

Sideways ROMs can be selected in place of BASIC. Languages like LISP, disc filing systems, utilities etc can all be plugged in. These sideways ROMs are covered from a software point of view in chapters 8 to 11.

From a hardware point of view, up to 16 sideways ROMs ae allowed. However, four of these are already allocated on the standard Electron. BASIC occupies two slots (ROMs 10 and 11 it appears the same in each). The *keyboard* occupies slots 8 and 9. The remaining 12 ROM slots are all available for expansion.

The ROM paging register is located in the ULA, and can be accessed by writing to location &FE05 (see section 14).

There are *two* distinct ways of accessing ROMs via this register. The first method accesses ROMs 12 to 15. This operation is very simply performed by writing the required ROM number into the low nibble of &FEO5. Hence:

	D7	D6	D5	D4	D3	D2	D1	D0
Write at &FE05	0	0	0	0	1	1	R1	R0

where R1 and R0 control which ROM is selected.

Suitable hardware must be included in the expansion unit to cope with this method of selecting ROMs. Selection of one of the ROMs 12 to 15 can be carried out by the following code. Be careful to ensure that the write to &F4 always occurs before the write to &FEO5, just in case an interrupt occurs in between.

```
LDA #ROMnumber
STA &F4
STA &FEO5
```

The second method for accessing ROMs will allow those numbered 0 to 7 to be selected. It is not possible to select these ROMs directly, because BASIC will still be paged in. The only way of paging BASIC and the keyboard out is to select one of the ROMs 12 to 15 first. This access causes the internal ROMs to page out. The correct ROM selection code can then be sent to the lower three bits of &FEO5.

	D7	D6	D5	D4	D3	D2	D1	D0
Write at &FE05	0	0	0	0	1	R2	R1	R0

where R2, R1 and R0 select the required ROM.

As with the other ROM slots, new hardware must be provided at address &FEO5 to select the relevant ROMs.

Code to select a ROM numbered 0 to 7 could be:

```
LDA     #&OC        \to deselect BASIC
STA     &F4         \one of ROM 12 to 15
STA     &FEO5       \must be selected
LDA     #ROMnumber          \Now select desired
STA     &F4         \Low order ROM
STA     &FEQ5
```

It is essential that the A register is stored to &F4 before &FEO5 in case an interrupt occurs in between.

When the machine is powered up, the sideways ROMs are polled in order from 15 down too. The first one which is found to be a language ROM (see the Paged ROM firmware section for specification) will start executing. Since BASIC is in slot 10/11, a ROM which is required to power-up before BASIC must be in one of the sockets 12 to *15.*

The ROMs 12 to 15 are allocated to high priority NMI devices or languages which are expected to power up before BASIC. The reason for putting high priority NMI servicing ROMs in these sockets is that a smaller delay is required to page them in than for ROMs 0 to 7.

The lower priority ROMs are all selected by performing two writes to the paging register. The first is to deselect BASIC, the second is to select the required ROM.

The Acorn Plus 1 expansion unit forces the priority of ROMs to be (from highest down):

ROMs 15 to 12
ROMs 7 to 0
BASIC

This implies that any language which is fitted to the Plus1 will automatically power up ahead of BASIC. ROM allocation has been defined by Acorn as follows:

ROM USE

0,1	Second external socket on expansion module (SK2)
2,3	First external socket on the expansion module (SK1)
4	Disc
5,6	USER applications
7	Modem interface ROM
8,9	Keyboard
10,11	BASIC
12	Expansion module operating system
13	High priority slot in expansion module
14	ECONET
15	Reserved

15.5 The One Megahertz Bus

Most 6502 compatible peripherals will generally be connected onto the 1MHz regenerated bus. This allows relatively slow devices to be accessed. On the BBC Micro, page &FC has been allocated especially for 1MHz devices, This page is called **FRED.** Generally, devices resident within FRED have relatively small memory requirements (mainly control and data registers).

Since Electron expansion should be compatible with BBC Micro expansion (so they can use the same expansion peripherals), the allocation of devices in FRED has been very well defined. The following list includes items which would normally be resident in Sheila on the BBC Micro, but which have to go on the 1MHz bus on an Electron.

&FC00 to &FC0F	Test hardware
&FC10 to &FC13	TELETEXT
&FC14 to &FC1F	PRESTEL
&FC20 to &FC27	IEEE 488 interface
&FC28 to &FC2F	ECONET
&FC30 to &FC3F	CAMBRIDGE RING interface
&FC40 to &FC47	WINCHESTER DISC interface
&FC48 to &FC5F	Reserved for Acorn expansions
&FC60 to &FC6F	*6850* ACIA
&FC70	A to D converter
&FC71	CENTRONICS parallel interface
&FC72	Status register BSY ADC FB2 FB1 X X X X Where BSY = printer busy ADC = A to D conversion end FB1 = Fire button 1 FB2 = Fire button 2 X = undefined
&FC73 to &FC7F	Reserved for Acorn expansions
&FC80 to &FC8F	Test hardware
&FC90 to &FC9F	Sound and speech
&FCA0 to &FCAF	Reserved for Acorn expansions
&FCB0 to &FCBF	6522 VIA/Real time clock
&FCC0 to &FCCF	Floppy disc controller
&FCD0 to &FCDF	USER applications
&FCE0 to &FCEF	The TUBE
&FCF0 to &FCFE	USER applications
&FCFF	Paging register for JIM

Note that page &FD in the Electron address space is used in conjunction with the paging register in FRED to provide an extra 64K of memory. This memory is accessed one page at a time. The particular page being accessed is selected by the value in FRED's paging register, and is referred to as the *extended page number*. Accessing memory via the 1MHz bus in this way will generally be about 20 times slower than accessing memory directly.

Appendix A — VDU Code Summary

This Appendix describes the functions performed by the whole of the character set when printed using VDU or PRINT CHR$. Note that several ones are labelled *expansion.* This means that they will only be effective if the associated expansion modules are connected.

Dec	hex	CTRL +	bytes	function
0	0	@	0	Does nothing
1	1	A	1	Send character to printer (expansion)
2	2	B	0	Enable printer (expansion)
3	3	C	0	Disable printer (expansion)
4	4	D	0	Write text at text cursor
5	*5*	E	0	Write text at graphics cursor
6	6	F	0	Enable VDU drivers
7	7	G	0	Make a short bleep (BEL)
8	8	H	0	Move cursor back one character
9	9	1	0	Move cursor forward one character
10	A	J	0	Move cursor down one line
11	B	K	0	Move cursor up one line
12	C	L	0	Clear text area
13	D	M	0	Carriage return
14	E	N	0	Pagedmodeon
15	F	0	0	Paged mode off
16	10	P	0	Clear graphics area
17	11	0	1	Define text colour
18	12	R	2	Define graphics colour
19	13	5	*5*	Define logical colour
20	14	T	0	Restore default logical colours
21	15	U	0	Disable VDU drivers/delete current line
22	16	V	1	Select screen MODE
23	17	W	9	Re-program display character
24	18	X	8	Define graphics window
25	19	Y	*5*	PLOT K,X,Y
26	lA	Z	0	Restore default windows
27	lB	[	0	Reserved
28	1C	,	4	Define text window

29	1D	—	4	Define graphics origin
30	lE		0	Home text cursor to top left of window
31	1F	/	2	MovetextcursortoX,y.
32—126				Complete set of ASCII characters
127	7F	DEL	0	Backspace and delete
128—223				Normally undefined (define using *FX20)
224—255				User defined characters

Appendix B - PLOT numbers

0 Move relative to last point
1 Draw relative to last point in current foreground colour
2 Draw relative to last point in logical inverse colour
3 Draw relative to last point in current background colour
4 Move absolute
5 Draw absolute in current foreground colour
6 Draw absolute in logical inverse colour
7 Draw absolute in current background colour

Higher PLOT numbers have other effects which are related to the effects given by the values above.

8-15 Last point in line omitted when 'inverted' plotting used

16-23 Using a dotted line

24-3 1 Dotted line, omitting last point

32-63 Reserved for Graphics Extension ROM

64-71 Single point plotting

72-79 Horizontal line filling

80-87 Plot and fill triangle

88-95 Horizontal line blanking (right only)

96-255 Reserved for future expansions

Horizontal line filling

These PLOT numbers start from the specified X,Y co-oridnates. The graphics cursor is then moved left until the first non-background pixel is encountered. The graphics cursor is then moved right until the first non-background coloured pixel is encountered on the right hand side. If the PLOT number is 73 or 77 then a line will be drawn between these two points in the current foreground colour. If the PLOT number is 72 or 76 then no line is drawn but the cursor movements are made (these may be read using OS WORD call with A=&D/13, see chapter 4).

Horizontal line blanking right

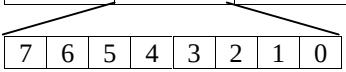
These PLOT numbers can be used to *undraw* an object on the screen. They have an the opposite effect to those of the horizontal line filling functions except that the graphics cursor is moved right only. PLOT numbers 91 and 95 will cause a line to be drawn from the specified co-ordinates to the nearest background coloured pixel to the right in the background colour. PLOT numbers 89 and 93 move the graphics cursor but do not cause the line to be blanked.

Appendix C - Screen mode layouts

MODE 0 Screen layout

Graphics 640x256
Colours 2
Text 80x32

&3000	&3008		&3278
&3001	&3009		&3279
&3002	&300A		&327A
&3003	&300B		&327B
&3004	&300C		&327C
&3005	&300D		&327D
&3006	&300E		&327E
&3007	&300F		&327F
&3280			
&3281			
&7B06			
&7B07			
&7D80	&7D88		&7FF8
&7D81	&7D89		&7FF9
&7D82	&7D8A		&7FFA
&7D83	&7D8B		&7FFB
&7D84	&7D8C		&7FFC
&7D85	&7D8D		&7FFD
&7D86	&7D8E		&7FFE
&7D87	&7D8F		&7FFF

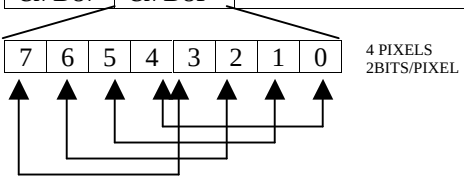


Note that the screen layout is only as shown after a CLS and will change as the screen is scrolled.

MODE 1 Screen layout

Graphics 320x256
Colours 4
Text 40x32

&3000	&3008		&3278
&3001	&3009		&3279
&3002	&300A		&327A
&3003	&300B		&327B
&3004	&300C		&327C
&3005	&300D		&327D
&3006	&300E		&327E
&3007	&300F		&327F
&3280			
&3281			
&7B06			
&7B07			
&7D80	&7D88		&7FF8
&7D81	&7D89		&7FF9
&7D82	&7D8A		&7FFA
&7D83	&7D8B		&7FFB
&7D84	&7D8C		&7FFC
&7D85	&7D8D		&7FFD
&7D86	&7D8E		&7FFE
&7D87	&7D8F		&7FFF

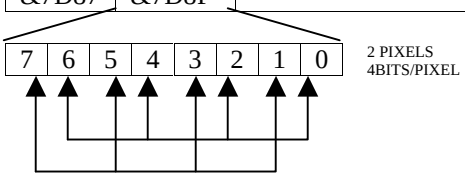


Note that the screen layout is only as shown after a `CLS` and will change as the screen is scrolled.

MODE 2 Screen layout

Graphics 160x256
Colours 16
Text 20x32

&3000	&3008		&3278
&3001	&3009		&3279
&3002	&300A		&327A
&3003	&300B		&327B
&3004	&300C		&327C
&3005	&300D		&327D
&3006	&300E		&327E
&3007	&300F		&327F
&3280			
&3281			
&7B06			
&7B07			
&7D80	&7D88		&7FF8
&7D81	&7D89		&7FF9
&7D82	&7D8A		&7FFA
&7D83	&7D8B		&7FFB
&7D84	&7D8C		&7FFC
&7D85	&7D8D		&7FFD
&7D86	&7D8E		&7FFE
&7D87	&7D8F		&7FFF

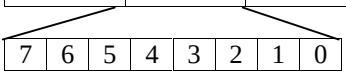


Note that the screen layout is only as shown after a `CLS` and will change as the screen is scrolled.

MODE 3 Screen layout

Graphics Not available
Colours 2
Text 80x25

&4000	&4008		&4278
&4001	&4009		&4279
&4002	&400A		&427A
&4003	&400B		&427B
&4004	&400C		&427C
&4005	&400D		&427D
&4006	&400E		&427E
&4007	&400F		&427F
BLANK	BLANK		BLANK
BLANK	BLANK		BLANK
&4280			
&4281			
&7980			
BLANK			
BLANK			
&7C00	&7C08		&7E38
&7C01	&7C09		&7E39
&7C02	&7C0A		&7E3A
&7C03	&7C0B		&7E3B
&7C04	&7C0C		&7E3C
&7C05	&7C0D		&7E3D
&7C06	&7C0E		&7E3E
&7C07	&7C0F		&7E3F
BLANK	BLANK		BLANK
BLANK	BLANK		BLANK

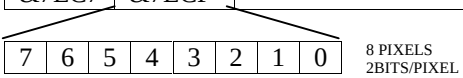


Note that the screen layout is only as shown after a C LS and will change as the screen is scrolled.

MODE 4 Screen layout

Graphics 320x256
Colours 2
Text 40x32

&5800	&5808		&5938
&5801	&5809		&5939
&5802	&580A		&593A
&5803	&580B		&593B
&5804	&580C		&593C
&5805	&580D		&593D
&5806	&580E		&593E
&5807	&580F		&593F
&5940			
&5941			
&7D86			
&7D87			
&7EC0	&7EC8		&7FF8
&7EC1	&7EC9		&7FF9
&7EC2	&7ECA		&7FFA
&7EC3	&7ECB		&7FFB
&7EC4	&7ECC		&7FFC
&7EC5	&7ECD		&7FFD
&7EC6	&7ECE		&7FFE
&7EC7	&7ECF		&7FFF

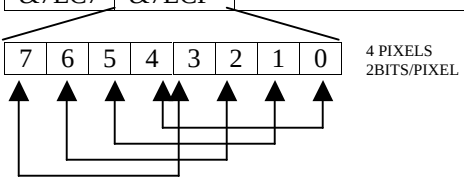


Note that the screen layout is only as shown after a `CLS` and will change as the screen is scrolled.

MODE *5* Screen layout

Graphics 160x256
Colours 4
Text 20x32

&5800	&5808		&5938
&5801	&5809		&5939
&5802	&580A		&593A
&5803	&580B		&593B
&5804	&580C		&593C
&5805	&580D		&593D
&5806	&580E		&593E
&5807	&580F		&593F
&5940			
&5941			
&7D86			
&7D87			
&7EC0	&7EC8		&7FF8
&7EC1	&7EC9		&7FF9
&7EC2	&7ECA		&7FFA
&7EC3	&7ECB		&7FFB
&7EC4	&7ECC		&7FFC
&7EC5	&7ECD		&7FFD
&7EC6	&7ECE		&7FFE
&7EC7	&7ECF		&7FFF

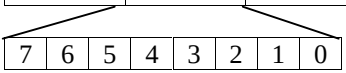


Note that the screen layout is only as shown after a C LS and will change as the screen is scrolled.

MODE 6 Screen layout

Graphics Not available
Colours 2
Text 40x25

&6000	&6008		&6138
&6001	&6009		&6139
&6002	&600A		&613A
&6003	&600B		&613B
&6004	&600C		&613C
&6005	&600D		&613D
&6006	&600E		&613E
&6007	&600F		&613F
BLANK	BLANK		BLANK
BLANK	BLANK		BLANK
&6140			
&7CC7			
BLANK			
BLANK			
&7F00	&7F08		&7F38
&7F01	&7F09		&7F39
&7F02	&7F0A		&7F3A
&7F03	&7F0B		&7F3B
&7F04	&7F0C		&7F3C
&7F05	&7F0D		&7F3D
&7F06	&7F0E		&7F3E
&7F07	&7F0F		&7F3F
BLANK	BLANK		BLANK
BLANK	BLANK		BLANK



Note that the screen layout is only as shown after a `CLS` and will change as the screen is scrolled.

Appendix D Operating System Calls and Vectors

Routine		**Vector**	**Function**	
	Addr	Name	Addr	Name
		USERV	200	The user vector
		BRKV	202	The BRK vector
		IRO1V	204	Primary interrupt vector
			IRQ2V	206 Unrecognised IRQ vector
OSCLI	FFF7	CLIV	Command line	interpreter
OSBYTE	FFF4	BYTEV	20A	*FX/OSBYTE call
OSWORD	FFF1	WORDV	20C	OS WORD call
OSWRCH	FFEE	WRCHV	20E	Write character
OSNEWL	FFE7	-	-	Write LF,CR to screen
OSASCI	FFE3	-	-	Write character, &OD=LF,CR
OSRDCH	FFEO			
OSFILE	FFDD	RDCHV	210	Read character
OSARGS	FFDA	FILEV	212	Load/save file
OSBGET	FFD7	ARGSV	214	Load/save file data
OSBPUT	FFD4	BGETV	216	Get byte from file
OSGBPB	FFD 1	BPUTV	218	Put byte in file
OSFIND	FFCE	GBPBV	21A	Multiple BPUT/BGET
		EVNTV	220	Event vector
		UPTV	222	User print routine
		NETV	224	Econet vector
		VDUV	226	Unrecognised VDU commands
		KEYV	228	Keyboard vector
		INSV	22A	Insert into buffer vector
		REMV	22C	Remove from buffer vector
		CNPV	22E	Count/purge buffer vector

		IND1V	230	Spare vector
		IND2V		232
		IND3V		234
NVRDCH	FFCB			Non-vectored read char.
NVWRCH	FFC8			Non-vectored write char.
GSREAD	FFC5			Read char. from string
GSINIT	FFC2			String input initialize
OSEVEN	FFBF			Generate an event
OSRDRM	FFB9			Read byte in paged ROM

Appendix E – Plus 1 ROM slot

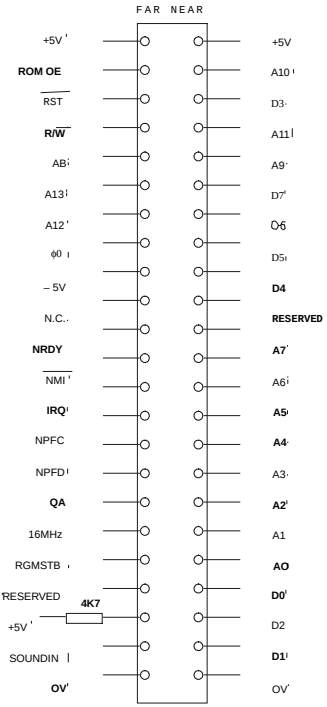
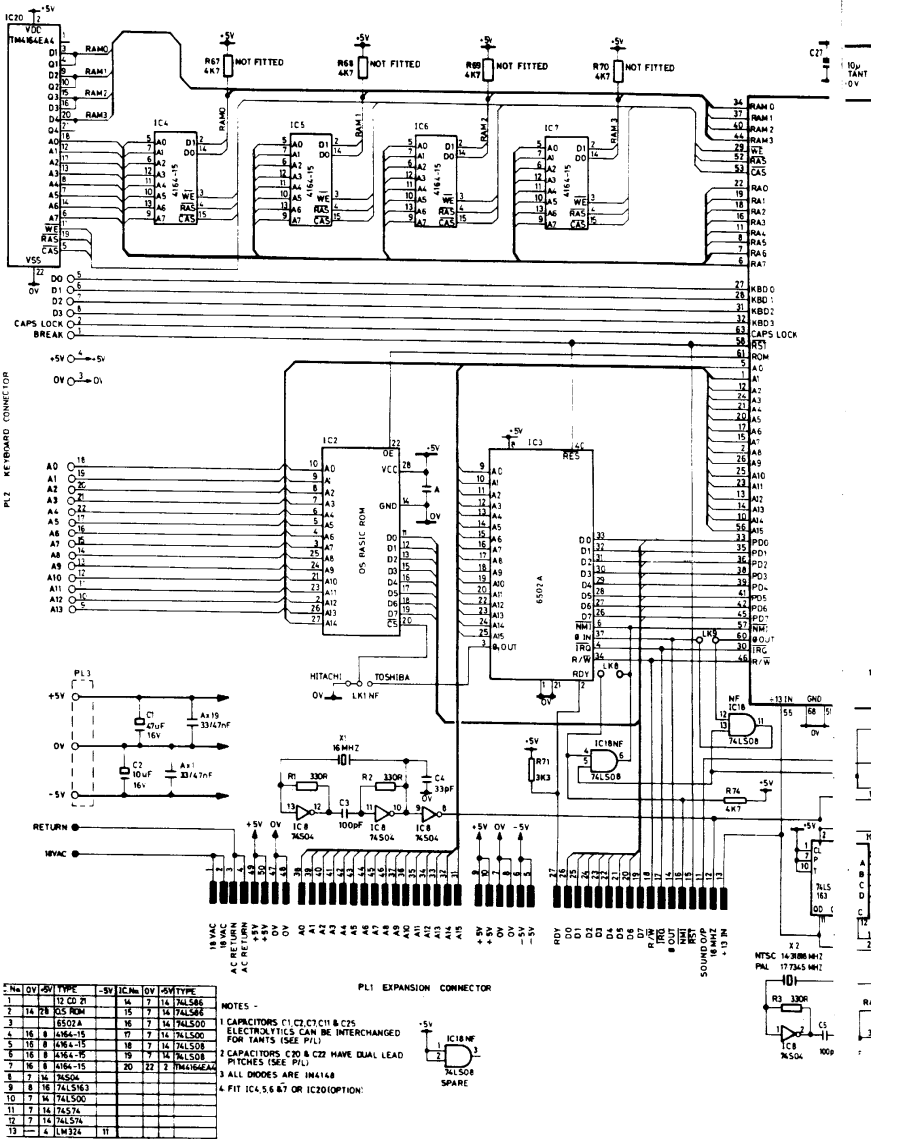


Figure E.1 — The Plus 1 ROM slot connector

Note that most of the standard BBC Micro 1MHz bus signals are available from this slot. However, some of the uses are marginally different to the BBC 1MHz bus. A full specification for producing suitable add-ons is available from Acorn Computers Limited.

Appendix F – Complete circuit diagram



IC No	0V	-5V	TYPE
1			12 CD 21
2	14	28	OS ROM
3			6502A
4	16	8	4164-15
5	16	8	4164-15
6	16	8	4164-15
7	16	8	4164-15
8	7	14	74S04
9	8	16	74LS163
10	7	14	74LS00
11	7	14	74S74
12	7	14	74LS74
13	—	4	LM324

IC No	0V	-5V	TYPE
14	7	14	74LS86
15	7	14	74LS86
16	7	14	74LS00
17	7	14	74LS00
18	7	14	74LS08
19	7	14	74LS08
20	22	2	TMM4164EA4

NOTES -

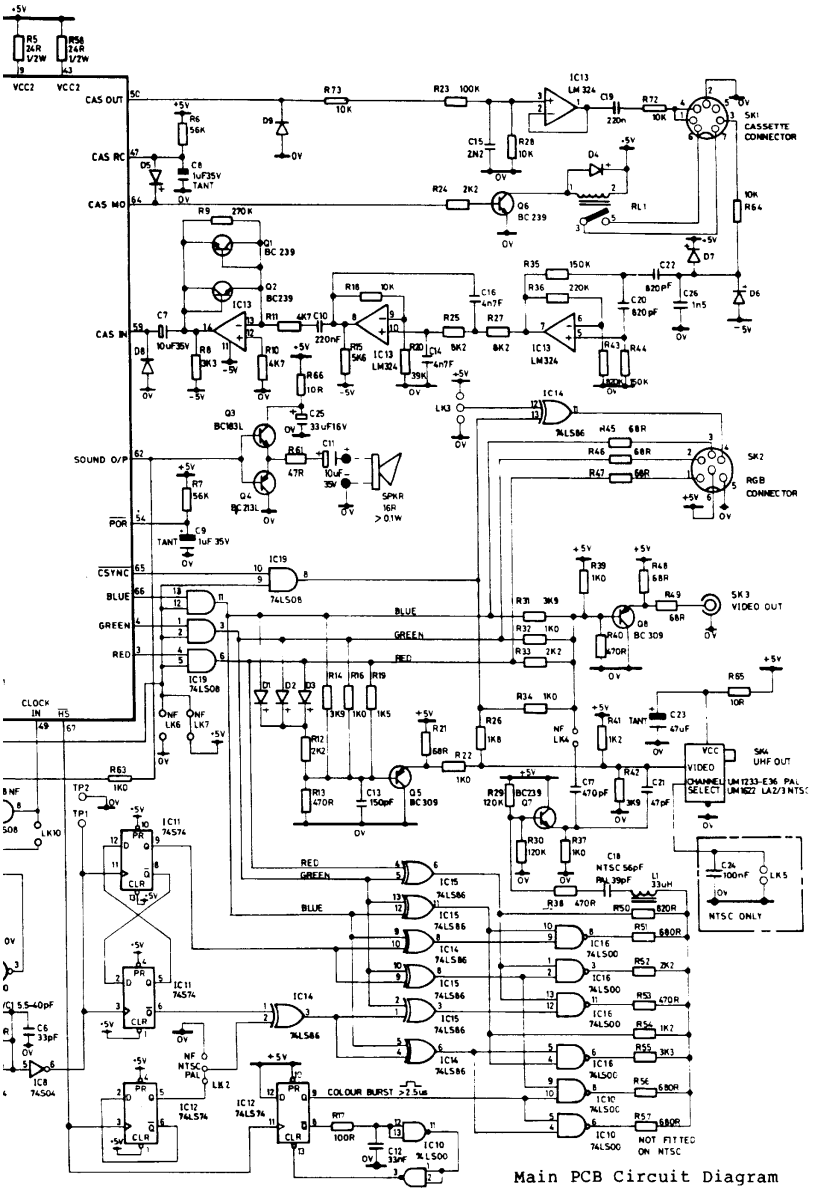
1 CAPACITORS C1,C2,C7,C11 & C25 ELECTROLYTICS CAN BE INTERCHANGED FOR TANTS (SEE P/L)

2 CAPACITORS C20 & C22 HAVE DUAL LEAD PITCHES (SEE P/L)

3 ALL DIODES ARE IN4148

4 FIT IC4,5,6 &7 OR IC20(OPTION)

IC18 NF 74LS08 SPARE



Main PCB Circuit Diagram

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Glossary

Address Bus – a set of 16 connections, each one of which can be set to logic 0 or logic 1. This allows the CPU to address &FFFF *(65536)* different memory locations.

Active low – signals which are *active low* are said to be valid when they are at logic level 0.

Analogue to digital converter (ADC) – this is a chip which can accept an analogue voltage at one of its inputs and provide a digital output of that voltage.

Asynchronous – two devices which are operating independently of one another are said to be operating asynchronously.

Baud Rate – used to define the speed at which a serial data link transfers data. One baud is equal to 1 bit of data transferred per second. The standard cassette baud rate of 1200 baud is therefore equal to 1200 bits per second.

Bidirectional – a communication line is bidirectional if data can be sent and received over it. The data bus lines are bidirectional.

Bit of memory – this is the fundamental unit of a computer's memory. It may only be in one of two possible states, usually represented by a 0 or 1.

Buffer – a software buffer is an area of memory set aside for data in the process of being transferred from one device or piece of software to another.

Byte of memory – 8 bits of memory. Data is normally transferred between devices one byte at a time over the data bus.

Chip – derived from the small piece of silicon wafer or chip which has all of the computer logic circuits etched into it. A chip is normally packaged in a black plastic case with small metal leads to connect it to the outside world.

Clock – it is necessary to provide some master timing reference to which all data transfers are tied. The clock provides this synchronisation. A 16MHz clock is applied to the ULA. From this, the clock timing for the *6502* CPU is derived. See chapter 15 for a discussion of the clock timing requirements.

CPU (Central processing unit) – the 6502A in the Electron, It is this chip which does all of the computing work associated with running programs.

Cycle – this is usually applied to the *6502* clock. A complete clock cycle is the period between a clock going high, low, then high again. See *clock.*

Data bus – a set of eight connections over which all data transactions between devices in the BBC microcomputer take place.

Field – a space allocated for some data in a register, or in a program listing, For example, in an Assembly language program, the first few spaces are allocated to the line number field, the next few spaces are allocated to the label field, and so on.

Handshaking – this type of communications protocol is used when data is being transferred between two asynchronous devices. Two handshaking lines are normally required. One of these is a *data ready* signal from the originating device to the receiving device, When the receiving device has accepted the data, it sends a *data taken* signal back to the originating device, which then knows that it can send the second lot of data and so on. This type of handshaking is used with the RS423 serial interface option.

High — sometimes used to designate logic '1'

Interrupt – this signal is produced by peripheral devices and is always directed to the *6502A* CPU. Upon receiving an interrupt, the *6502* will normally run a special interrupt routine program before continuing with the task in hand before it was interrupted.

Latch – a latch is used to retain information applied to it after the data has been removed, It is rather like a memory location except that the outputs from the bits within the latch are connected to some hardware.

LED (Light emitting diode) – acts like a diode by only allowing current to pass in one direction. Light is emitted whilst current is passed.

Low – sometimes used to designate logic '0'.

Machine code – the programs produced by the *6502* **BASIC** Assembler are machine code. A machine code program consists of a series of bytes in memory which the *6502* can execute directly.

Mnemonic – the name given to the text string which defines a particular *6502* operation in the BASIC assembler. LDA is a mnemonic which means *load accumulator.*

Opcode – the name given to the binary code of a *6502* instrucction, For example, &AD is the opcode which means *load accumulator.*

Open Collector – this is a characteristic of a transistor output line, It simply means that the collector pin of the transistor is not driving a resistor load, ie it is *open.*

Operand – a piece of data on which some operation is performed. Usually the operand will be a byte in the accumulator of the *6502,* or a byte in some memory location.

Page – a page of memory in the *6502* memory map is & 100 *(256)* bytes long. There are therefore *256* pages in the entire address space. 256 pages of *256* bytes each account for the *65536* bytes of addressable memory.

Parallel – parallel data transfers occur when data is sent along two or more lines at once. The system data bus for example has eight lines operating in parallel.

Peripheral – any device connected to the *6502* central processor unit, such as the Plus 1, Plus 3 interface etc., but not including the memory.

Poll – most of the hardware devices on the Electron expansion modules will generate interrupts to the *6502* CPU. If interrupts have been enabled, the CPU has to find out which device generated the interrupt. It does this by successively reading status bytes from each of the hardware devices which could have caused an interrupt. This successive reading of devices is called *polling.*

RAM (Random access memory) – the main memory in the Electron is RAM because it can be both written to and read from.

Refresh – all of the RAM in the Electron is dynamic memory. This means that it has to be refreshed every few milliseconds so that data is not lost. The refreshing function is performed by the ULA as it accesses memory regularly for video output.

Register – the *6502* and the Electron ULA contain registers. These are effectively one byte memory locations which do not necessarily reside in the main memory map. All software on the *6502* makes extensive use of the internal registers for programming. The bits in most peripheral registers define the operation of a particular piece of hardware, or tell the processor something about that peripheral's state.

Rollover – this is a function provided on the keyboard to cope with fast typists. Two keys can be pressed at once. The previous key with a finger being removed, and the next key with the finger hitting the key. The software in the operating system ensures that rollover normally operates correctly.

ROM (Read only memory) – as the name implies, ROM can only be read from and cannot be modified by being written to. The MOS and BASIC are contained in one large 32K byte ROM chip.

Serial – data transmitted along only one line is transmitted serially. Serial data transmission is normally slower than parallel data transmission, because only one bit instead of several bits are transferred at a time. Communication with the cassette interface is carried out serially.

Stack – a page of memory in the *6502* used for temporary storage of data. Data is pushed onto a stack in sequence, then removed by pulling the data off the stack. The last byte to be pushed is the first byte to be pulled *off* again. The stack is used to store return addresses from subroutines, Page &01 is used for the stack in the Electron.

ULA (Uncommitted logic array) – this large chip is responsible for most of the system control on the Electron. It contains a large number of logic gates. The connection between the gates is defined when the chip is manufactured.

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