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# **The BBC Micro Machine Code Portfolio**

**Bruce Smith**

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# Contents

|                                      |     |
|--------------------------------------|-----|
| Acknowledgements                     | vii |
| 1 Introduction                       | 1   |
| 2 Function Key Reader                | 10  |
| 3 Program Information                | 20  |
| 4 Program Formatters                 | 32  |
| 5 The Screen                         | 41  |
| 6 Softly, Softly                     | 53  |
| 7 Global Variable Search and Replace | 61  |
| 8 Time for Bed                       | 72  |
| 9 Error, Pack and Autorun            | 78  |
| 10 The Necessary Evil                | 88  |
| 11 Vision On                         | 108 |
| 12 Assembling Data and Lists         | 131 |
| 13 Communication                     | 165 |
| 14 Odd One Out                       | 183 |
| <i>Index</i>                         | 210 |

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Finally, to Richard Miles of Granada, a thank you for seeding the idea for the Portfolio in the first place.

Bruce Smith

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# Chapter One

## **Introduction**

*The BBC Micro Machine Code Portfolio* is aimed at providing the serious machine code programmer with an interesting and useful set of assembly language routines. In all, a selection of 75 programs from my own disk-based library are included, ranging from general purpose utility aids to BASIC and machine code programming to specific utilities that could form the basis of an interesting machine code compiler. Each of the assembler routines is provided as a uniquely line numbered procedure that can be \*EXECuted back into a program any time it is required. Although the programs are written making full use of BASIC II's EQU functions, a solution is provided towards the end of this chapter that will enable BASIC I users to implement these functions with the absolute minimum of fuss.

The Portfolio is not aimed at the beginner. Many of the routines assume a rudimentary knowledge of the manipulative techniques involved. For this reason, the descriptive commentary of, say, a multibyte addition program may be kept to the looping and data manipulation means used rather than the principles of the actual addition itself. This does not mean to say that the Portfolio is presented with experts in mind - far from it. My own knowledge of machine code programming was facilitated by continuous trial and error programming, and at that time no books of this sort were available to help me along the way. Enter the program and use it as described in the text; in using the program and experimenting with it the real knowledge will be gained.

The contents of each chapter have been grouped together for ease of use. Chapters 2 to 9 provide the programming utilities which can make the programmer's life a merry one. These include function key definition printers, program variable dumps, a global search and replace utility and a program compacter.

Chapter 10 provides the mathematically biased routines. Four multibyte routines handle addition, subtraction, multiplication and division. The remaining seven routines provide square root solutions and dual byte shifts.

Graphics are dealt with in Chapter 11, with just about every BASIC-type graphics command covered. This includes a useful routine using the



interpreter-based \*640 multiplication table to convert an X,Y screen coordinate into an absolute screen address. The graphics routines are particularly easy to group into a BASIC driven menu to provide a simple graphics compiler (SGC).

All programs require data manipulation at some time and Chapter 2 supplies eleven procedures to sort, add, and delete items from a variety of lists and arrays. Screen interaction is important in making programs user-friendly, and Chapter 13 provides the routines to enable this to be performed with ease. Finally, Chapter 14 has grouped a few miscellaneous procedures together providing timing delays, counters and interrupt polling.

The Appendix contains a number of the Portfolio programs in a new form - as bar code listings. Using the MEP bar code reader these may be read in directly from the pages of the book itself!

## **The correct procedure**

As mentioned, each of the assembler routines are implemented as PROCedures, with each having its own range of line numbers. The procedure contains all the necessary coding to make the routine a stand-alone one. Because a procedure must be called from a program, each program contains several lines of BASIC to call first the PROC to assemble the machine code it contains and then demonstrate the type of application possible. This serves two functions; first, it assures you that you have entered the program correctly and also shows you how it works! If you flick through a few of the programs you'll notice that the lines of the PROC are given high line numbers in steps of 1 while the assemble and test routines use low line numbers. This is quite deliberate as it keeps the two parts of the program clearly separated.

To build up a library of these programs to disk or tape, the PROCedure can be save to tape. As the low line numbers are only, in effect, test routines these can be deleted so that only the procedure remains; and it is this that should be saved. I prefer to save my PROCedures as ASCII files rather than programs as this allows them to be added easily to other programs. The \*SPOOL command is used to perform this. Choosing a suitable filename, the syntax is simply:

**\*SPOOL NAME**

If you are using the cassette filing system then you'll need to start the cassette running. If you are using disks then these will already be whirling around. So, now simply LIST the program. As the listing appears onto the screen it will also be written to the current filing

system. When the program has finished listing enter

**\*SPOOL**

once again to complete the transfer from memory to filing medium. You will probably have noticed that the filename used in the **\*SPOOL** command was not enclosed within the quotes normally associated with a **SAVE**. This is acceptable as the MOS does not expect them - though using them will have no adverse effect.

Once all programs have been treated in this way they are ready to be used in a greater scheme of things! One point - when building up a large library of procedures it is very important to catalogue them, in a book, on another disk or tape, or on the front of each tape or disk. This catalogue should depict the program's name, line numbers and function as this will be invaluable when it comes to using them at a later date.

Once a program has been saved as a spooled file it can be loaded back into memory using the MOS-based **\*EXEC** command. To load the previously spooled file you use

**\*EXEC NAME**

Again, the quotes around the filename are not obligatory. When the operating system encounters the file it treats each line of it as though it had been typed in at the keyboard and as the return character at the end of the line is reached the line is entered into memory. This is the main reason for using unique line numbers within procedures, as it enables several procedures to be **\*EXEC**uted into memory without fear of overwriting any program lines already there.

## **A demonstration**

To show the flexibility of the programs within the Portfolio and their use, study the following demonstration. Suppose a short graphics routine is required that will select a **MODE 4** screen and draw a dotted line from the coordinate 200,200 to 900,600. First, the three desired files to perform a **MODE**, **MOVE** and **PLOT** must be loaded in (these can be found in Chapter 13). Depending on the filenames you have chosen, this might take the form of executing the following commands one by one:

**\*EXEC mode**

**\*EXEC move**

**\*EXEC plot**

The resultant listing forms part of Program 1.1. Next, a BASIC primer needs to be written to call each PROC and pass the relevant information through the arguments of the procedural call. First, PROCmode:

20 PROCmode (4,&A96)

The PROCedure is called passing the mode number, 4 into the variable 'action' and the assembly address, &A99, into 'addr'. Next, the graphics cursor must be moved. The problem here is that we do not really want to have to calculate the new value to be assigned to 'addr' for the code assembly; instead we can simply use the program counter itself in the form of P%. Thus line 30 becomes

30 PROCmove (200,200,P%)

The move coordinates are 200,200 and the PROCmove code is assembled from P%. Finally PROCplot can be treated in the same way to give

40 PROCplot (21,900,600,P%)

where 21 is the plot code for an absolute dotted line, 900,600 the final coordinates and P% the assembly address. Now each PROCedure will assemble its code as a subroutine call. To implement the machine code, a short procedure must be written that will call each subroutine in turn, thus:

```
JSR mode  \set up MODE
JSR move  \move graphics cursor
JMP plot  \draw line and return
```

Program 1.1 lists the final program and, by way of proof of the output, Figure 1.1 lists the assembler listing produced when RUN.

When using this modular-cum-structured assembly approach, the use of the OPT command must be borne in mind. If the OPT command is omitted then the default value of 3 will be assumed by the assembler. In the case of the above example this was not too much of a problem, but there are occasions when it will be! For example, if assembly is performed on a conditional basis then it may be desirable to suppress it altogether using OPT 2 lest it corrupt some vital screen detail. Alternatively, a FOR . . . NEXT combination may be imperative to suppress errors during a first pass to assign forward branch labels. There is no simple way around this. A universal solution would be to include a

FOR pass=0 TO 2 STEP 2

line in all procedures. I prefer to add the OPT commands as required, but the choice is yours.

```

10 REM *** USING THE PORTFOLIO ***
20 PROCmode (4,&A00)
30 PROCmove (200,200,P%)
40 PROCplot (21,900,600,P%)
50 PROCassemble(P%)
60 CALL test
70 END
80 :
100 DEF PROCassemble (addr)
110 P%=addr
120 [
130 .test
140 JSR mode
150 JSR move
160 JMP plot
170 ]
180 ENDPROC
200 :
6000 DEF PROCmode (action,addr)
6001 P%=addr
6002 [
6003 .mode
6004 LDA #22
6005 JSR &FFEE
6006 LDA #action
6007 JSR &FFEE
6008 RTS
6009 ]
6010 ENDPROC
6100 DEF PROCmove(xpos,ypos,addr)
6101 P%=addr
6102 [
6103 .move
6104 LDA #25
6105 JSR &FFEE
6106 LDA #4
6107 JSR &FFEE
6108 LDA #xpos MOD 256
6109 JSR &FFEE
6110 LDA #xpos DIV 256
6111 JSR &FFEE
6112 LDA #ypos MOD 256
6113 JSR &FFEE
6114 LDA #ypos DIV 256
6115 JSR &FFEE
6116 RTS

```

```

6197 J
6198 ENDPROC
6220 DEF PROCplot(code,xcoord,ycoord,ad
dr)
6221 P%=addr
6222 [
6223 .plot
6224 LDA #25
6225 JSR &FFEE
6226 LDA #code
6227 JSR &FFEE
6228 LDA #xcoord MOD 256
6229 JSR &FFEE
6230 LDA #xcoord DIV 256
6231 JSR &FFEE
6232 LDA #ycoord MOD 256
6233 JSR &FFEE
6234 LDA #ycoord DIV256
6235 JSR &FFEE
6236 RTS
6237 J
6238 ENDPROC

```

*Program 1.1. Spooling procedures to form a graphics program*

```

>RUN
0A00
0A00 .mode
0A00 A9 16 LDA #22
0A02 20 EE FF JSR &FFEE
0A05 A9 04 LDA #action
0A07 20 EE FF JSR &FFEE
0A0A 60 RTS
0A0B
0A0B .move
0A0B A9 19 LDA #25
0A0D 20 EE FF JSR &FFEE
0A10 A9 04 LDA #4
0A12 20 EE FF JSR &FFEE
0A15 A9 C8 LDA #xpos MOD 256
0A17 20 EE FF JSR &FFEE
0A1A A9 00 LDA #xpos DIV 256
0A1C 20 EE FF JSR &FFEE
0A1F A9 C8 LDA #ypos MOD 256
0A21 20 EE FF JSR &FFEE
0A24 A9 00 LDA #ypos DIV 256
0A26 20 EE FF JSR &FFEE
0A29 60 RTS
0A2A
0A2A .plot
0A2A A9 19 LDA #25
0A2C 20 EE FF JSR &FFEE
0A2F A9 15 LDA #code

```

```

0A31 20 EE FF JSR &FFEE
0A34 A9 84 LDA #xcoord MOD 256
0A36 20 EE FF JSR &FFEE
0A39 A9 03 LDA #xcoord DIV 256
0A3B 20 EE FF JSR &FFEE
0A3E A9 58 LDA #ycoord MOD 256
0A40 20 EE FF JSR &FFEE
0A43 A9 02 LDA #ycoord DIV256
0A45 20 EE FF JSR &FFEE
0A48 60 RTS
0A49
0A49 .test
0A49 20 00 0A JSR mode
0A4C 20 0B 0A JSR move
0A4F 4C 2A 0A JMP plot

```

Fig. 1.1. Assembler listing produced by Program 1.1.

## The BASIC solution

BASIC II provides several enhancements over its predecessor BASIC I. The most useful of these are the EQU functions which are implemented as pseudo-opcodes. These functions and their operations are:

EQUB : assemble specified byte  
 EQUW : assemble specified word (2 bytes)  
 EQUd : assemble specified double word (4 bytes)  
 EQU\$ : assemble specified string as ASCII characters

Numerous programs in the Portfolio take advantage of these commands, which would therefore make them inoperable on Beebs with BASIC I. These commands can be simulated quite simply using the ability of the FN command.

Program 1.2 lists the function definitions plus a suitable demonstration. Taking each definition as it appears in the program, FNequs (lines 500 to 530) uses the program counter variable P% as the string argument for the ASCII character string passed into the function via 'strings'. Before exit, P% is incremented by the length of the string.

FNequb (lines 550 to 580) takes the value 'byte%' and simply pokes it into memory at P%. The program counter is incremented by one and completes. FNequw (lines 600 to 640) is an extension and provides two pokes at the position of P%. The high and low bytes are extracted from 'word' using the MOD and DIV operators. Finally, FNequd (lines 660 to 690) uses the word indirection operator to pling its four bytes into memory.

```

10 REM ** SIMULATING BASIC II EQU **
20 P%=&900
30 I
40 LDA #255
50 OPT FNequs("TEST",3)
60 LDX #0
70 OPT FNequb(6,3)
80 LDY #&33
90 OPT FNequw(&FFFF,3)
100 STX &70
110 OPT FNequd(&12345678,3)
120 LDX #&AA
130 RTS
140 I
150 END
160 :
500 DEF FNequs(string$,opt)
510 $P%=string$
520 P%=P%+LEN(string$)
530 =opt
540 :
550 DEF FNequb(byte%,opt)
560 ?P%=byte%
570 P%=P%+1
580 =opt
590 :
600 DEF FNequw(word%,opt)
610 ?P%=word% MOD 256
620 P%?1=word% DIV 256
630 P%=P%+2
640 =opt
650 :
660 DEF FNequd(double%,opt)
670 !P%=double%
680 P%=P%+4
690 =opt

```

*Program 1.2. Simulating the BASIC II EQU functions in BASIC I.*

The assembler text (lines 40 to 130) shows how each procedure should be called. The second parameter in each of the OPT FN calls (3 throughout) simply refers to the OPT selection and this should be seeded as required by the program. To end with, Figure 1.2 shows the assembler listing provided when running this program, while the hex dump in Figure 1.3 shows that each FN has indeed performed the required task.

```

>RUN
0900
0900 A9 FF    LDA #255
0906         OPT FNequs("TEST",3)

```

```

0906 A2 00    LDX #0
0909          OPT FNequb(6,3)
0909 A0 33    LDY #&33
090D          OPT FNeqlw(&FFFF,3)
090D 86 70    STX &70
0913          OPT FNequd(&12345678,3)
0913 A2 AA    LDX #&AA
0915 60      RTS

```

*Fig. 1.2.* Assembler listing produced by Program 1.2

```

900 A9
901 FF
902 54
903 45
904 53
905 54
906 A2
907 0
908 6
909 A0
90A 33
90B FF
90C FF
90D 86
90E 70
90F 78
910 56
911 34
912 12
913 A2
914 AA
915 60

```

*Fig. 1.3.* A hex dump of the code assembled by Program 1.2, showing that the functions have worked.





## Chapter Two

# Function Key Reader

Virtually all the toolbox type of commercial ROM packages around these days include a facility for printing any resident function key definitions. Many, though, are incomplete and only deal with keys 0 through to 10, neglecting keys 11 to 15. Writing a custom-built routine to handle printing definitions present in all sixteen function keys is a relatively easy task providing a working knowledge of the function key buffer is to hand. Two programs are presented here; the first is reprinted from the April 1984 edition of Acorn User while the second is an improved version. The two differ in that the former, Program 2.1, is not capable of printing multistatement single key definitions whereas the latter, Program 2.2, is. The advantage in using the former is the saving in memory overheads as it requires only half the memory space required by the latter.

| Key | Pointer Byte |
|-----|--------------|
| 0   | &B00         |
| 1   | &B01         |
| 2   | &B02         |
| 3   | &B03         |
| 4   | &B04         |
| 5   | &B05         |
| 6   | &B06         |
| 7   | &B07         |
| 8   | &B08         |
| 9   | &B09         |
| 10  | &B0A         |
| 11  | &B0B         |
| 12  | &B0C         |
| 13  | &B0D         |
| 14  | &B0E         |
| 15  | &B0F         |

*Fig. 2.1.* Function key associated bytes.

The function key buffer is located in page &B of block zero RAM occupying the bytes &B99 to &BFF inclusive. With the exception of the first seventeen bytes, all of this is used to hold the key definitions in ASCII format; commands are not tokenised. These first seventeen bytes, &B99 to &B 10, are the key pointer bytes and Figure 2.1 details the bytes associated with the individual keys. Monitoring each of these bytes as key definitions are entered, modified and deleted gives an insight into their purpose. Figure 2.2 is a hex dump of the start of the buffer after a hard break, either when you have switched on or the CTRL-BREAK sequence is carried out. At this stage the buffer contains nothing but &10 in every byte.

```

0B00 10 10 10 10 10 10 10 10 .....
0B08 10 10 10 10 10 10 10 10 .....
0B10 10 10 10 10 10 10 10 10 .....
0B18 10 10 10 10 10 10 10 10 .....
0B20 10 10 10 10 10 10 10 10 .....
0B28 10 10 10 10 10 10 10 10 .....
0B30 10 10 10 10 10 10 10 10 .....
0B38 10 10 10 10 10 10 10 10 .....

```

Fig 2.2. Key buffer after switch-on.

Figure 2.3 depicts the same area of the key buffer after a short definition has been entered into f0 thus:

\*KEY 0 CLS IM

```

0B00 10 14 14 14 14 14 14 14 .....
0B08 14 14 14 14 14 14 14 14 .....
0B10 14 43 4C 53 0D 10 10 10 .CLS....
0B18 10 10 10 10 10 10 10 10 .....
0B20 10 10 10 10 10 10 10 10 .....
0B28 10 10 10 10 10 10 10 10 .....
0B30 10 10 10 10 10 10 10 10 .....
0B38 10 10 10 10 10 10 10 10 .....

```

Fig 2.3. Key buffer after executing \*KEY0 CLSIM.

The dump shows that the ASCII string CLS is present but that the return sequence 'IM' has been replaced with the more conventional ASCII return character &0D. It is also obvious from the dump that the key pointer bytes have altered. The first byte at &B00 is, we know from Figure 2.1, associated with \*KEY9, and this byte still contains &10 or 16 decimal. Counting sixteen bytes from this location we arrive at the

first character in the \*KEY 0 definition. The remaining key pointer bytes now all contain &14 or 20 decimal; counting 20 bytes from the \*KEY 0 pointer brings us to the last byte; of the \*KEY 0 definition, the carriage return character at &B14.

Figure 2.4 shows the buffer after a further key has been defined, thus:

\*KEY 9 AUTOIM

```

0B00 10 19 19 19 19 19 19 19 .....
0B08 19 14 19 19 19 19 19 19 .....
0B10 19 43 4C 53 0D 41 55 54 .CLS.AUT
0B18 4F 0D 10 10 10 10 10 10 O.....
0B20 10 10 10 10 10 10 10 10 .....
0B28 10 10 10 10 10 10 10 10 .....
0B30 10 10 10 10 10 10 10 10 .....
0B38 10 10 10 10 10 10 10 10 .....

```

Fig. 2.4. Key buffer after executing \*KEY9 AUTOIM.

The ASCII characters of the new definition are entered into the buffer immediately after the last definition. The key pointer byte for \*KEY 9 at &B09 still contains & 14 while the \*KEY9 byte remains at &10. All the other key pointer bytes have been updated to hold &19 or 25 decimal. Starting from &B00 and counting 25 bytes brings us to &B19, the last byte defined in the buffer.

It is worth looking at what happens in the buffer if a function key is redefined. Figure 2.5 shows the effect of placing a longer definition into \*KEY 0 than was already present, thus:

\*KEY 0 VDU 7IM

What has happened now is that the previous \*KEY0 definition has been deleted, the remaining definition(s) shuffled up to the front of the buffer and the new \*KEY0 definition added onto the end. Each of the key pointer bytes have been adjusted to point to the correct location.

```

0B00 15 1B 1B 1B 1B 1B 1B 1B .....
0B08 1B 10 1B 1B 1B 1B 1B 1B .....
0B10 1B 41 55 54 4F 0D 56 44 .AUTO.VD
0B18 55 20 37 0D 10 10 10 10 U 7.....
0B20 10 10 10 10 10 10 10 10 .....
0B28 10 10 10 10 10 10 10 10 .....
0B30 10 10 10 10 10 10 10 10 .....
0B38 10 10 10 10 10 10 10 10 .....

```

Fig. 2.5. Key buffer after redefining f0 as \*KEY0 VDU 7IM

\*KEY 9 was defined as AUTO and the pointer byte at &B09 now holds &10 giving the offset from &B00 to the start of the definition. \*KEY 0 which is now tacked onto the end of the \*KEY 9 definition has had its pointer offset reset to &15 or 21 decimal. The remaining pointer bytes have also been adjusted to all give the correct offset to the last used byte in the buffer, &1B or 27 decimal, which when added to &B00 gives &B1B.

The key pointer area contains an extra 'general' byte at &B10 that we have not yet mentioned. This byte is, in fact, the TOP pointer in the buffer and always holds the byte offset into the buffer of the last used location. The MOS uses this byte to test if a \*KEY definition is present when a function key has been defined. If the key pointer byte and the TOP pointer byte are the same, the MOS inserts the definition directly after the last definition (as pointed to by the pointer and TOP bytes). If, on the other hand, the pointer byte and TOP byte are different, the MOS knows that a definition is already present for the function key just defined and that it must do some reshuffling of the bytes in the buffer.

## Program 2.1

Program 2.1 is the first of the function key definition printer programs. Called PROCkeys1, it occupies 63 lines between 1000 and 1063. All processor registers are used and the object code occupies 126 bytes anywhere in memory as specified by the variable 'addr'.

```

10 REM *** FUNCTION KEY PRINTER ***
20 REM *(C) Bruce Smith & Acorn User*
30 oswrch=&FFEE
40 osasci=&FFE3
50 PROCkeys1 (&C00)
60 *KEY0 CALL &C00|M
70 END
80 :
1000 DEF PROCkeys1(addr)
1001 LOCAL key, pointer
1002 key=&B00
1003 pointer=&B10
1004 FOR pass=0 TO 3 STEP3
1005 P%=addr
1006 COPT pass
1007 LDX #0
1008 .main_loop

```

```

1009             TXA
1010             ASL A
1011             TAX
1012             JSR print_word_key
1013             LDA number_table,X
1014             JSR oswrch
1015             LDA number_table+1,X
1016             JSR oswrch
1017             TXA
1018             LSR A
1019             TAX
1020             LDA #820
1021             JSR oswrch
1022             LDA key,X
1023             CMP pointer
1024             BNE over
1025             JMP update
1026 .over
1027             TAY
1028             INY
1029 .next_character
1030             LDA key,Y
1031             CMP #13
1032             BEQ carriage_return
1033             JSR oswrch
1034             INY
1035             BNE next_character
1036 .carriage_return
1037             LDA #ASC "|"
1038             JSR oswrch
1039             LDA #ASC "M"
1040             JSR oswrch
1041 .update
1042             LDA #13
1043             JSR osascii
1044             INX
1045             CPX #16
1046             BNE main_loop
1047             RTS
1048 .print_word_key
1049             LDY #6
1050 .next_letter
1051             LDA spell_key,Y
1052             JSR oswrch
1053             DEY
1054             BNE next_letter
1055             RTS
1056 .number_table
1057             EQU$ " 0 1 2 3 4 5 6 7 "
1058             EQU$ "8 9101112131415"
1059 .spell_key
1060             EQU$ " YEK* "
1061 ]

```

```
1062 NEXT
1063 ENDPROC
```

*Program 2.1. PROCkeys1 - a simple function key lister*

Converting the hard facts of Function Key Buffer operation into some suitable machine code is relatively easy and the main areas of coding are straightforward. From this we can see the main routines of the code which, in everyday terms, are as follows:

- (a) Print the string '\*KEY' followed by the current key number (therefore we need a key counter!).
- (b) Obtain the key pointer and if the same as the TOP pointer move onto the next function key.
- (c) Else increment key pointer and print the definition string until the RETURN character is found.
- (d) Print IM and do a RETURN.
- (e) Increment the function key counter.
- (f) Repeat the whole process until all sixteen keys have been printed.

The X register is used to keep a count of the current key being investigated so initially this is set to zero (line 1007). The register is also used as an index into the key number look-up table (lines 1056 to 1058) where each of the ASCII codes {key number occupies two bytes. To ensure that the correct offset is located, the key count must be multiplied by two using an arithmetic shift left (lines 1009 to 1011). The word '\*KEY' and the current key number are printed using the subroutine calls of lines 1012 to 1016.

A definition present test is performed in line 1022 and 1023 and a branch over executed (line 1024) if one is found. A simple index, extract and print routine is used to print the definition string (lines 1036 to 1040) before the key count in the index register is updated (lines 1041 to 1047).

## **Program 2.2**

Program 2.2 is, in essence, the same as Program 2.1 but extra coding has been incorporated into the listing to test for multiple definitions and control codes. The procedure is called PROCkeys2 and assumes line numbers 1070 to 1189 inclusive. The source code generates 246 bytes of hex assembled at 'addr'.

```

10 REM *FUNCTION KEY DEFINITIONS V2*
20 PROCkeys2(&A00)
30 *KEY0 CALL&A00|M
40 END
50 :
1070 DEF PROCkeys2 (addr)
1071 FOR pass=0 TO 3 STEP3
1072 P%=addr
1073 [
1074 OPT pass
1075 .entry
1076             LDA #0
1077             STA key
1078             STA offset
1079 .mainloop
1080             JSR &FFE7
1081             JSR printwordkey
1082             LDX key
1083             LDA numbtable,X
1084             INX
1085             JSR &FFEE
1086             LDA numbtable,X
1087             JSR &FFEE
1088             INX
1089             STX key
1090             LDA #32
1091             JSR &FFEE
1092             LDX offset
1093             LDA &B00,X
1094             STA keystart
1095             INC keystart
1096             LDA &B10
1097             STA endpointer
1098             LDX #&F
1099 .keyend
1100             LDA &B00,X
1101             CMP endpointer
1102             BCS nexttry
1103             CMP keystart
1104             BCC nexttry
1105             STA endpointer
1106 .nexttry
1107             DEX
1108             BPL keyend
1109             LDA endpointer
1110             CMP keystart
1111             BCC nextkey
1112             LDX keystart
1113 .printdef
1114             LDA &B00,X
1115             CMP #128
1116             BCC asciichr
1117             PHA

```



```

1118          LDA #ASC"|"
1119          JSR &FFEE
1120          LDA #ASC"!|"
1121          JSR &FFEE
1122          PLA
1123          AND #&7F
1124 .asciichr
1125          CMP #32
1126          BCS notcontrol
1127          PHA
1128          LDA #ASC"|"
1129          JSR &FFEE
1130          PLA
1131          CLC
1132          ADC #64
1133          JSR &FFEE
1134          JMP nextcharacter
1135 .notcontrol
1136          CMP #127
1137          BNE over
1138          LDA #ASC"|"
1139          JSR &FFEE
1140          LDA #ASC"?|
1141          JSR &FFEE
1142          JMP nextcharacter
1143 .over
1144          CMP#124
1145          BNE not
1146          LDA #ASC"|"
1147          JSR &FFEE
1148          JSR &FFEE
1149          JMP nextcharacter
1150 .not
1151          JSR &FFEE
1152 .nextcharacter
1153          CPX endpointer
1154          BEQ nextkey
1155          INX
1156          JMP printdef
1157 .nextkey
1158          INC offset
1159          LDA offset
1160          CMP #16
1161          BNE notfinished
1162          JSR &FFE7
1163          RTS
1164 .notfinished
1165          JMP mainloop
1166          .printwordkey
1167          LDY #6
1168          .nextletter
1169          LDA spellkey,Y

```

```

1170          JSR &FFEE
1171          DEY
1172          BNE nextletter
1173          RTS
1174 .numbertable
1175          EQU$ " 0 1 2 3 4 5 6 7 "
1176          EQU$ "8 9101112131415"
1177 .spellkey
1178          EQU$ " YEK* "
1179 .key
1180          EQU$ 0
1181 .keystart
1182          EQU$ 0
1183 .endpointer
1184          EQU$ 0
1185 .offset
1186          EQU$ 0
1187 ]
1188 NEXT
1189 ENDPROC

```

*Program 2.2. PROCkeys2 - the complete function key lister.*

The definition printing routine (line 1113) begins by testing the definition for a character code greater than 128 (entered previously with the '!' sequence). If one is present this sequence is printed; either way, control progresses to line 1124 where a control character (less than &32) is tested for. If a control character is found, the '!' character is printed followed by the ASCII code of the control character representation, obtained by adding &40 to it. Thus CTRL-L is printed as '!L'.

The end\_pointer bytes are used to keep track of the length of the entered key definition as previously calculated by the key\_end coding (lines 1099 to 1112), and the print\_def loop continues until the entire function key definition is printed. The main\_loop is executed sixteen times to print all the function key definitions. The final output of this program is shown in Figure 2.6.

```

*KEY 0 CALL&A00|M
*KEY 1 CLS|M
*KEY 2 *GREPL|M
*KEY 3 LIST|M
*KEY 4 *ASSFORM|M
*KEY 5 *INSPECT
*KEY 6 *BASFORM|M
*KEY 7 FORN=&70 TO &7F:P.?N:N.|M
*KEY 8 *EXMON|M
*KEY 9 *BASIC|M
*KEY 10 OLD|MLIST|M

```

```

*KEY 11
*KEY 12
*KEY 13
*KEY 14
*KEY 15

```

*Fig. 2.6. Typical output of Program 2.2.*

## **Program fact sheets**

### *Function key printers*

#### *Program 2.1*

|                        |                |
|------------------------|----------------|
| Proc title             | : PROCkeys1    |
| Line numbers           | : 1000 to 1063 |
| Variables required     | : addr         |
| Length                 | : 126 bytes    |
| Zero page requirements | : none         |
| Registers changed      | : A, X, Y      |

#### *Program 2.2*

|                        |                |
|------------------------|----------------|
| Procedure title        | : PROCkeys2    |
| Line numbers           | : 1070 to 1189 |
| Variables required     | : addr         |
| Length                 | : 246 bytes    |
| Zero page requirements | : none         |
| Registers changed      | : A, X, Y      |

## Chapter Three

# Program Information

Two programming utilities are provided in this chapter. Program 3.1 lists the status of the various BASIC pseudo-variables in addition to displaying the length of the program currently under development and the number of bytes remaining available for use. To complement this, Program 3.2 when called will list every variable currently defined within a BASIC program (except the resident integer variables A% to Z%), and this includes assembler labels. This is particularly useful in long programs when it is difficult to keep a mental track of the variable names you have already chosen and thus avoids the infuriating situation that can occur when you use the same variable name twice and wonder why the program will just not work as it should!

```
10 REM *** PROGRAM INFORMATION ***
20 himem=HIMEM
30 himem=himem-8200
40 HIMEM=himem
50 PROCinfo (&70,HIMEM)
60 *KEY0 CALL HIMEM|M
70 END
80 :
1200 DEF PROCinfo (current,addr)
1201 FOR pass=0 TO 3 STEP3
1202 P%=addr
1203 [
1204 OPT pass
1205 LDX #title MOD 256
1206 LDY #title DIV 256
1207 JSR print_message
1208 .do_page
1209 LDX #message1 MOD 256
1210 LDY #message1 DIV 256
1211 JSR print_message
1212 LDA &18
1213 JSR hex_out
1214 LDA #0
1215 JSR hex_out
1216 JSR &FFE7
1217 .do_top
1218 LDX #message4 MOD 256
```

```

1219          LDY #message4 DIV 256
1220          JSR print_message
1221          LDA &13
1222          JSR hex_out
1223          LDA &12
1224          JSR hex_out
1225          JSR &FFE7
1226 .do_himem
1227          JSR &FFE7
1228          LDX #message2 MOD 256
1229          LDY #message2 DIV 256
1230          JSR print_message
1231          LDA &7
1232          JSR hex_out
1233          LDA &6
1234          JSR hex_out
1235          JSR &FFE7
1236 .do_lomem
1237          LDX #message3 MOD 256
1238          LDY #message3 DIV 256
1239          JSR print_message
1240          LDA &1
1241          JSR hex_out
1242          LDA &0
1243          JSR hex_out
1244          JSR &FFE7
1245          JSR &FFE7
1246 .do_size
1247          LDX #message5 MOD 256
1248          LDY #message5 DIV 256
1249          JSR print_message
1250          SEC
1251          LDA &13
1252          SBC &18
1253          JSR hex_out
1254          LDA &12
1255          JSR hex_out
1256          LDX #bytes MOD 256
1257          LDY #bytes DIV 256
1258          JSR print_message
1259 .do_next_free
1260          LDX #message6 MOD 256
1261          LDY #message6 DIV 256
1262          JSR print_message
1263          LDA &3
1264          JSR hex_out
1265          LDA &2
1266          JSR hex_out
1267          JSR &FFE7
1268          JSR &FFE7
1269 .memory_left
1270          LDX #message7 MOD 256

```

```

1271          LDY #message7 DIV 256
1272          JSR print_message
1273          SEC
1274          LDA &6
1275          SBC &2
1276          STA store
1277          LDA &7
1278          SBC &3
1279          JSR hex_out
1280          LDA store
1281          JSR hex_out
1282          LDX #bytes MOD256
1283          LDY #bytes DIV 256
1284          JSR print_message
1285          RTS
1286 .print_message
1287          STX current
1288          STY current+1
1289          LDY #0
1290 .loop
1291          LDA (current),Y
1292          BMI all_done
1293          JSR &FFFE3
1294          INY
1295          BNE loop
1296 .all_done
1297          RTS
1298 .hex_out
1299          PHA
1300          LSR A
1301          LSR A
1302          LSR A
1303          LSR A
1304          SED
1305          CLC
1306          ADC #&90
1307          ADC #&40
1308          CLD
1309          JSR &FFFE
1310          PLA
1311          AND #15
1312          SED
1313          CLC
1314          ADC #&90
1315          ADC #&40
1316          CLD
1317          JMP &FFFE
1318 .title EQUB 12
1319          EQU$ " Program"
1320          EQU$ " Information Service"
1321          EQU$ &0D0D0D0D
1322          EQU$ 255
1323 .message1

```

```

1324          EQU$"PAGE : &"
1325          EQU$ 255
1326 .message2
1327          EQU$"HIMEM : &"
1328          EQU$ 255
1329 .message3
1330          EQU$"LOMEM : &"
1331          EQU$ 255
1332 .message4
1333          EQU$"TOP : &"
1334          EQU$ 255
1335 .message5
1336          EQU$"Program Size=&"
1337          EQU$ 255
1338 .message6
1339          EQU$"Next Free Location=&"
1340          EQU$ 255
1341 .message7
1342          EQU$"Memory Remaining=&"
1343          EQU$ 255
1344 .bytes
1345          EQU$ " bytes"
1346          EQU$ &0D0D
1347          EQU$ 255
1348 .store
1349          EQU$ 0
1350          ]
1351          NEXT
1352          ENDPROC

```

*Program 3.1. PROCinfo - provides details on system pseudo-variables.*

## Program status

PROCinfo is the assembler procedure to generate the source code for the info program. I have given the name 'info' to the procedure simply because it is more representative to the program's function. I would suggest, however, that it is saved to tape or disk with the filename STATUS. This is because INFO is generally recognised as a disk filing system command and therefore the command \*INFO could not be used to load and run the program from disk whereas \*STATUS would be acceptable. When executed, the program prints the hexadecimal values of the following:

```

PAGE
HIMEM
LOMEM

```

TOP  
 Program size  
 Next free location  
 Memory remaining

All the information required to calculate each of these values can be found in zero page. Figure 3.1 lists the byte allocation for the first couple of dozen locations.

The assembler is quite straightforward and is split into easy-to-handle segments. The screen information title is first printed onto the screen using the `print_message` subroutine (lines 1286 to 1297). The address of the string to be printed is transferred to the subroutine via the index registers. On return, the relevant data is extracted from zero page and printed in hexadecimal format using a fairly standard hex to ASCII print routine, `'hex_out'` (lines 1298 and 1317).

---

|           |                             |
|-----------|-----------------------------|
| &00 - &01 | : LOMEM                     |
| &02 - &03 | : VARTOP (top of variables) |
| &04 - &05 | : Basic Stack Pointer       |
| &06 - &07 | : HIMEM                     |
| &08 - &09 | : ERL                       |
| &0A       | : Text pointer index        |
| &9B - &9C | : Text pointer              |
| &0D - &11 | : RND seed                  |
| &12 - &13 | : TOP                       |
| &16 - &17 | : Error vector              |
| &18       | : PAGE byte                 |

---

*Fig. 3.1. Assignment of first 24 zero page bytes.*

The values of PAGE, TOP, HIMEM, LOMEM and the next free location can be obtained directly from the BASIC workspace. The other values must be calculated, which generally involves a simple two-byte subtraction. Program size is calculated by subtracting TOP from PAGE and the amount of memory remaining by subtracting the top of variables (termed VARTOP by me!) from HIMEM. The actual value of VARTOP is not displayed by the program but could be simply added if so required.

The `'hex_out'` routine works four bits at a time. Taking the high nibble first (as this is the first printed working left to right) and moving this into the low nibble, the conversion is performed using decimal addition with the decimal flag set with SED. The decimal addition of &90 converts the binary values 0 to 9 into the range &90 to &99 with the carry flag set.



The addition of a further &40 converts these values to the range &30 to &39 with the carry set, which corresponds to the correct ASCII codes for the values 0 to 9. If the original nibble held &A to &F, adding &90 gives values in the range &0 to &5 (remember we are working with decimal addition). Addition of a further &40 with the carry set gives a final result in the range &41 to &46, the ASCII codes for A to F. The low nibble is treated in the same manner to produce the second digit before the decimal flag is cleared. Using STATUS is straightforward: just perform a CALL to the assembly address. The BASIC primer generates the 372 bytes of code above a lowered HIMEM and can be called using function key 0. Figure 3.2 shows a typical output of the machine code.

---

```

      Program Information Service

PAGE   : &1C00
TOP    : &2559

HIMEM  : &7A00
LOMEM  : &2559

Program Size=&0959 bytes

Next Free Location=&26C7

Memory Remaining=&5339 bytes

```

---

*Fig. 3.2. Typical of output produced by Program 3.2.*

### **Variable lister**

PROCvars generates a useful variable lister that occupies a compact 103 bytes of memory, the cassette / RS 423 buffer in the demonstration. Five bytes of workspace are required in addition, and two bytes of these must be in zero page to facilitate indirect addressing.

```

10 REM *** LIST ALL PROGRAM VARIABLES
***
20 PROCvars(&70,&71,&73,&A00)
30 *KEY 1 CALL&A00|M
40 END
50 :
1400 DEF PROCvars(asc,varpointer,varstr
ing,addr)
1401 FOR pass=0 TO 3 STEP 3
1402 P%=addr

```

```

1403 [ OPT pass
1404         .variables
1405         LDA #12
1406         JSR &FFEE
1407         LDA #14
1408         JSR &FFEE
1409         LDA #65
1410         STA asc
1411         LDA #82
1412         STA varpointer
1413         LDA #4
1414         STA varpointer+1
1415 .loop
1416         LDY #1
1417         LDA (varpointer),Y
1418         BEQ update
1419         STA varstring+1
1420         LDY #0
1421         LDA (varpointer),Y
1422         STA varstring
1423 .next_var
1424         LDA #13
1425         JSR &FFE3
1426         LDA asc
1427         JSR &FFE3
1428         LDY #2
1429 .print_loop
1430         LDA ( varstring),Y
1431         BEQ end_print
1432         JSR&FFE3
1433         INY
1434         JMP print_loop
1435 .end_print
1436         LDY #1
1437         LDA ( varstring),Y
1438         BEQ update
1439         TAX
1440         DEY
1441         LDA (varstring),Y
1442         STA varstring
1443         STX varstring+1
1444         JMP next_var
1445 .update
1446         LDA #2
1447         CLC
1448         ADC varpointer
1449         CMP #8F6
1450         BEQ finished
1451         STA varpointer
1452         INC asc
1453         JMP loop
1454 .finished
1455         LDA #13

```

```
1456      JSR &FFE3
1457      LDA #15
1458      JSR &FFE3
1459      RTS
1460      ]
1461      NEXT
1462      ENDPROC
```

*Program 3.2. PROCvars - lists all program variables.*

An understanding of variable storage is essential to follow the program's operation. In addition to the resident integer variables there are basically two other types of variable. One of these variables is postfixed with a % sign to signify that it is also an integer, while a variable without the % defines that it is a floating point variable. When a program is run, the BASIC interpreter extracts each variable from the program and places it in a fixed format above the main program and below TOP. The format is as follows:

- (a) A two-byte address which points to the next variable starting with the same letter. If none are present these bytes contain zero.
- (b) The variable name in ASCII format excluding the first letter of the variable, e.g. START is stored as TART.
- (c) A zero byte to mark the end of the variable name.
- (d) The binary representation of the value assigned to that variable. This is stored in four bytes for an integer variable and five bytes for a floating point variable.

We can see from item (a) that it is quite easy to move from one variable to another, starting with the same letter, simply by extracting the address pointer from each variable 'definition' in turn. However, we need to know exactly where the first variable is located and Acorn have provided, by design, a variable pointer table on Page 4 in block zero RAM. Figure 3.3 details the locations holding the pointers for the characters A to Z and a to z. If both locations for a particular character contain zero then no variable beginning with that letter is present. 28  
The BBC Micro Machine Code Portfolio

| Character | LSB address | MSB address |
|-----------|-------------|-------------|
| A         | &482        | &483        |
| B         | &484        | &485        |
| C         | &486        | &487        |
| D         | &488        | &489        |

|   |      |      |
|---|------|------|
| E | &48A | &48B |
| F | &48C | &48D |
| G | &48E | &48F |
| H | &490 | &491 |
| I | &492 | &493 |
| J | &494 | &495 |
| K | &496 | &497 |
| L | &498 | &499 |
| M | &49A | &49B |
| N | &49C | &49D |
| O | &49E | &49F |
| P | &4A9 | &4A1 |
| Q | &4A2 | &4A3 |
| R | &4A4 | &4A5 |
| S | &4A6 | &4A7 |
| T | &4A8 | &4A9 |
| U | &4AA | &4AB |
| V | &4AC | &4AD |
| W | &4AE | &4AF |
| X | &4B9 | &4B1 |
| Y | &4B2 | &4B3 |
| Z | &4B4 | &4B5 |
| a | &4C2 | &4C3 |
| b | &4C4 | &4C5 |
| c | &4C6 | &4C7 |
| d | &4C8 | &4C9 |
| e | &4CA | &4CB |
| f | &4CC | &4CD |
| g | &4CE | &4CF |
| h | &4D0 | &4D1 |
| i | &4D2 | &4D3 |
| j | &4D4 | &4D5 |
| k | &4D6 | &4D7 |
| l | &4D8 | &4D9 |
| m | &4DA | &4DB |
| n | &4DC | &4DD |
| o | &4DE | &4DF |
| p | &4E9 | &4E1 |
| q | &4E2 | &4E3 |
| r | &4E4 | &4E5 |
| s | &4E6 | &4E7 |
| t | &4E8 | &4E9 |
| u | &4EA | &4EB |
| v | &4EC | &4ED |

|   |      |      |
|---|------|------|
| w | &4EE | &4EF |
| x | &4F0 | &4F1 |
| y | &4F2 | &4F3 |
| z | &4F4 | &4F5 |

---

*Fig. 3.3. Variable start pointers*

## Program lowdown

Figure 3.4 flowcharts the program's operation. The first ten lines of assembler clear the screen, place it into paged mode, save the ASCII code for A in 'asc' and seed the variable pointer table start address, &482, into a zero page vector.

The main program loop is entered at line 1415 and commences by extracting the most significant byte from the pointer table. For a variable to be present, this byte must be non-zero as no variables can be placed in zero page. If it is zero a branch to update is performed, otherwise the low byte address is accessed and seeded into a second vector, pointer.

Lines 1423 to 1427 print a carriage return followed by the first character of the variable saved in asc. Using post-indexed indirect addressing, the `print_loop` (lines 1429 to 1434) extract each variable character from the program workspace, printing each until the zero terminating byte is encountered.

The linking address from the beginning of the variable definition is then sought. If this is zero a branch to update is performed, otherwise the link address is placed into the pointer vector and the next variable name printed.

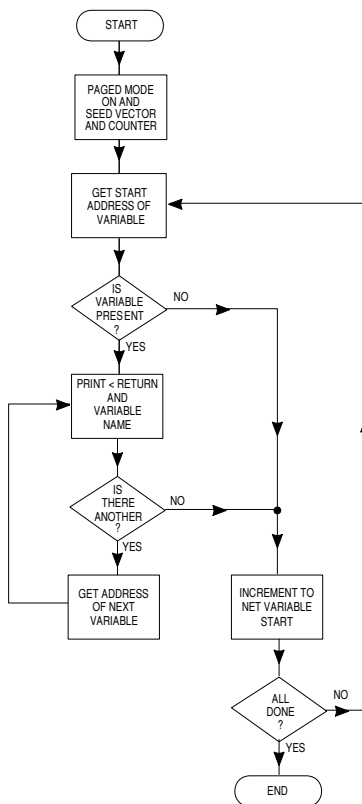


Fig. 3.4. PROCvars flowchart.

The update routine (lines 1445 to 1453) first increments the `var_pointer` vector by two to move onto the next character associated bytes, and increments the character value, `asc`, by one. The program terminates when the last location in the variable pointer table is reached (line 1449 and 1450). Finally, Figure 3.5 illustrates a typical output of the program, listing the variables in the program itself!

```

asc
addr
end_print
finished
loop
next_var
pass

```

```

print_loop
update
varpointer
varstring
variables

```

*Fig. 3.5. Typical output produced by Program 3.3.*

## **Program fact sheets**

### *Program 3.1*

|                        |                                |
|------------------------|--------------------------------|
| Procedure title        | : PROCinfo                     |
| Line numbers           | : 1200 to 1352                 |
| Variables required     | : current,addr                 |
| Length                 | : 372 bytes                    |
| Zero page requirements | : 2 bytes (anywhere in memory) |
| Registers changed      | : A, X, Y                      |

### *Program 3.2*

|                        |                                 |
|------------------------|---------------------------------|
| Procedure title        | : PROCvars                      |
| Line numbers           | : 1400 to 1462                  |
| Length                 | : 103 bytes                     |
| Zero page requirements | : 5 bytes, four forming vectors |
| Registers changed      | : A, X, Y                       |

## Chapter Four

# Program Formatters

BASIC's LISTO command allows a limited amount of control in producing formatted listings, inserting spaces to indent loops and structures as required. The two programs presented in this chapter provide an extended formatting option for either BASIC or assembler programs; indeed, the Assembler Formatter was used to produce the clear listing within this book, inserting ten spaces between line number and mnemonic but leaving labels un-indented and clearly separated from the listing.

```
10 REM * A Basic Formatted Listing *
20 FOR loop=0 TO 100
30 PRINT loop : NEXT loop
40 INPUT "A number" N%
50 IF N%=10 PRINT "Correct" ELSE PRINT
"wrong"
60 REPEAT : INPUT "Code" C$
70 FOR wait=0 TO 1000 : NEXT wait
80 UNTIL C$="END"
```

>LIST

```
10 REM * A Basic Formatted Listing *
20 FOR loop=0 TO 100
30   PRINT loop
   : NEXT loop
40 INPUT "A number" N%
50 IF N%=10 PRINT "Correct"
   ELSE PRINT "wrong"
60 REPEAT
   : INPUT "Code" C$
70   FOR wait=0 TO 1000
   : NEXT wait
80   UNTIL C$="END"
```

*Fig. 4.1. A BASIC listing with and without the BASIC formatter*

The BASIC formatter splits multistatement lines by issuing a carriage return each time it encounters a colon. It also splits IF . . THEN . . ELSE structures in addition to indenting them along with



REPEAT . . . UNTIL and FOR. . .NEXT loops. Figure 4. 1 shows the type of listing the BASIC Formatter is capable of. Now for the programs!

### The BASIC Formatter (Program 4.1)

The basic\_format procedure assembles its machine code into Page 9 of block zero RAM. This area has a number of uses (in addition to housing our machine code) and is more normally associated with ENVELOPES 5-16, the speech buffer, cassette and RS 423 buffer. The routine has two entry points - &900 and &928 in this case - and function keys I and 2 have been programmed to call these locations. These two entries simply turn the formatter on and off respectively.

The 'on' entry point (line 1485) first prints the formatter on message before storing the current value of LISTO, found at &1F, in a byte above the program. Its maximum value of 7 is then inserted. The WRCHV vector contents are extracted and saved and the WRCHV pointed to the \*format' entry point at line 1521. The 'off' entry, line 1506, simply reverses these procedures. Line 1518 could be changed if required to make the formatter clear the LISTO option each time it is switched off by replacing it with

LDA #0

```

10 REM *** LISTING FORMATTER ***
20 PROCbasic_format(&900)
30 *KEY0 CALL &900|M
40 *KEY1 CALL &928|M
50 END
60 :
1480 DEF PROCbasic_format(addr)
1481 interpreter=&E0A4
1482 FOR pass=0 TO 3 STEP3
1483 P%=addr
1484 COPT pass
1485 .on
1486             LDY #&00
1487 .next_character
1488             LDA message,X
1489             JSR &FFE3
1490             INX
1491             CMP#13
1492             BNE next_character
1493             LDA &1F

```

```

1494          STA list0
1495          LDX #&07
1496          STX &1F
1497          LDA &20E
1498          STA address
1499          LDA &20F
1500          STA address+1
1501          LDA #format MOD 256
1502          STA &20E
1503          LDA #format DIV 256
1504          STA &20F
1505          RTS
1506 .off
1507          LDX #&00
1508 .next_character
1509          LDA message2,X
1510          JSR &FFE3
1511          INX
1512          CMP #13
1513          BNE next_character
1514          LDA address
1515          STA &20E
1516          LDA address+1
1517          STA &20F
1518          LDA list0
1519          STA &1F
1520          RTS
1521 .format
1522          PHA
1523          CMP #ASC(":")
1524          BNE no_colon
1525          JSR output
1526          LDA #&00
1527          STA byte
1528          STA byte+1
1529          BEQ not_else
1530 .no_colon
1531          LDA #&01
1532          CMP &1E
1533          BNE not_same
1534          LDA #&00
1535          STA byte+2
1536          STA byte+3
1537          STA byte+4
1538 .not_same
1539          CPY #&00
1540          BEQ carry_on
1541 .not_else
1542          PLA
1543          JMP interpreter
1544 .carry_on
1545          LDA &37
1546          CMP #&E7

```

```

1547          BNE not_if
1548          INC byte+2
1549 .not_if
1550          CMP #&8B
1551          BNE not_else
1552          INC byte+3
1553          JSR output
1554          JSR interpreter
1555          JMP not_else
1556 .output
1557          LDA #&0A
1558          JSR interpreter
1559          LDA #&0D
1560          JSR interpreter
1561          CLC
1562          LDA &3B
1563          ADC &3C
1564          ADC byte+2
1565          TAX
1566          INX
1567          LDA #&20
1568          JSR interpreter
1569          JSR interpreter
1570          JSR interpreter
1571 .more_spaces
1572          JSR interpreter
1573          JSR interpreter
1574          DEX
1575          BNE more_spaces
1576          RTS
1577 .message
1578          EQU$ " Formatter on!"
1579          EQU$ 7
1580          EQU$ 13
1581 .message2
1582          EQU$ " Formatter off!"
1583          EQU$ 7
1584          EQU$ 13
1585 .byte
1586          EQU$ "
1587 .address
1588          EQU$ "
1589 .list EQU$ 0
1590      ]
1591      NEXT pass
1592      ENDPROC

```

*Program 4.1.* PROCbasic\_format - neatly formats a BASIC listing.

On entry into 'format' ,through the reset WRCHV the accumulator contains the character to be written. This is tested to see if it is a colon. If this test fails a branch to 'no\_colon' is performed. Assuming a colon is present, the 'output' routine at line 1556 is called to perform a line feed and carriage return and a series of spaces printed. The output routine uses a direct jump into the MOS to do the printing. This is necessary as we have intercepted the normal WRCHV address.

Incidentally, disassembling from this address, &E9A4, provides an interesting insight into how the Beeb programs the CRTC to display characters. As a machine code programmer you must be in possession of a suitable disassembler, so have a look! But I digress, so back to the program description. On return from the output call (line 1526) the 'byte' locations, which act as counters, are cleared and a forced branch to 'not\_else' is performed, which prints the character to the screen (line 1541).

Routing around the rest of the code takes place if any of the indenting loop commands already mentioned are identified by intercepting the count value held at &1E and used by LISTO. Special treatment of the IF statement is required to ensure that any subsequent ELSE is generated both on a new line and further indented - this is because ELSE is normally ignored by LISTO. These two commands are identified by their token values before the 'interpreter' call hands them over to the BASIC detokenising routine for expansion. The codes and the entry points are as follows:

```
IF      (= &E7) entry at line 1546
ELSE   (= &8B) entry at line 1550
```

The byte at &37 is used by the BASIC interpreter to hold the current command token (line 1545).

## **The Assembler Formatter (Program 4.2)**

This utility is probably the one I use most of all along with the global search and replace utility presented in Chapter 7. I find that the neatest way to present assembler listings is in the manner used throughout this book; the mnemonics are indented and clearly and follow through. The most obvious way to perform this task is simply to tap in spaces as required at the keyboard as the program is entered, but this is boring, time-consuming and extremely wasteful of memory which can be of a premium in the hi-res graphics modes. Thus, Program 4.2 was conceived.

```

10 REM *** ASSEMBLER FORMATTER ***
20 PROCass_format (&C00)
30 *KEY0 CALL &C00|M
40 *KEY1 CALL &C29|M
50 END
60 :
1600 DEF PROCass_format (addr)
1601   osunch=?%20E+(?%20F*256)
1602   FOR pass=0 TO 3 STEP 3
1603     P%=addr
1604     [
1605         OPT pass
1606     .on
1607         LDX #0
1608     .nextchr
1609         LDA message,X
1610         JSR &FFE3
1611         INX
1612         CMP #13
1613         BNE nextchr
1614         LDA#0
1615         STA byte +1
1616         LDA &20E
1617         STA byte+2
1618         LDA &20F
1619         STA byte+3
1620         LDA #assembler MOD 256
1621         STA &20E
1622         LDA #assembler DIV 256
1623         STA &20F
1624         RTS
1625     .off
1626         LDX #0
1627     .nextchr
1628         LDA message2,X
1629         JSR &FFE3
1630         INX
1631         CMP #13
1632         BNE nextchr
1633         LDA byte+2
1634         STA &20E
1635         LDA byte+3
1636         STA &20F
1637         RTS
1638     .assembler
1639         STA byte
1640         PHP
1641         TXA
1642         PHA
1643         LDA byte+1
1644         BNE testshut

```

```

1645          LDA byte
1646          CMP #ASC("[")
1647          BNE return
1648          STA byte+1
1649 .return
1650          LDA byte
1651          JSR oswrch
1652          PLA
1653          TAX
1654          PLP
1655          LDA byte
1656          RTS
1657 .testshut
1658          LDA byte
1659          CMP #93
1660          BNE testcr
1661          LDA #0
1662          STA byte+1
1663          BEQ return
1664 .testcr
1665          CMP #13
1666          BNE testlabel
1667          LDA #0
1668          STA byte+4
1669          BEQ return
1670 .testlabel
1671          CMP #ASC(".")
1672          BEQ signal
1673          CMP #ASC(":")
1674          BCC return
1675          LDA byte+4
1676          BNE return
1677          LDX #10
1678          LDA #32
1679 .spaces
1680          JSR oswrch
1681          DEX
1682          BNE spaces
1683          LDA #1
1684 .signal
1685          STA byte+4
1686          JMP return
1687 .message
1688          EQU$"Assembler "
1689          EQU$"Formatter On!"
1690          EQUW &0D07
1691 .message2
1692          EQU$"Assembler "
1693          EQU$"Formatter Off!"
1694          EQUW &0D07
1695 .byte
1696          EQU$ " "
1697          ]

```

```

1698             NEXT
1699             ENDPROC

```

*Program 4.3. PROCass\_format - makes an assembler listing more readable.*

Like its BASIC predecessor, the Assembler Formatter has two entry points to turn the utility on and off. The 'on' entry point is at line 1606 which outputs the 'Assembler Formatter On' message before saving and redirecting the contents of the WRCHV to the 'assembler' entry point at line 1638. The 'off' routine, entered at line 1625 performs the reverse operation.

When the formatter is on, all output produced by the Beeb is channelled through the 'assembler' routine via WRCHV. After preserving the program status (lines 1639 to 1642) the accumulator's contents are tested to see if they contain the '[' code to indicate the start of assembler (line 1646). If this test succeeds, the code is stored at 'byte+1'. As you may have noticed, the code immediately before this tested this particular location to see if it were non-zero which would denote an already open assembler listing. This test routine would therefore be jumped over to the test\_shut routine (line 1657). This section of code first tests to see if the close bracket, end of assembler mark, has been found in which case the 'byte' values are reset and the normal oswrch output pursued.

If a carriage return is not present (lines 1664 to 1669) the 'test\_label' routine is invoked. If the label start character, a full-stop, is present the fact is signalled in 'byte-4' and the routine completed; a delimiting colon is treated in a similar manner. If neither of these characters is encountered, the X register is loaded with the number of padding spaces to be printed (line 1677). I chose to use ten though you can adjust this to your own taste. The 'spaces' loop is entered and exited on completion of printing the ten spaces. Mnemonics will subsequently be printed from this ten spaces in position, while labels are printed as usual.

## **Program fact sheets**

### *Program 4.1*

|                        |                    |
|------------------------|--------------------|
| Procedure title        | : PROCbasic_format |
| Variables required     | : addr             |
| Line numbers           | : 1480 to 1592     |
| Length                 | : 227 bytes        |
| Zero page requirements | : none             |
| Registers changed      | : none             |

*Program 4.2*

|                        |                  |
|------------------------|------------------|
| Procedure title        | : PROCass_format |
| Variables required     | : addr           |
| Line numbers           | : 1600 to 1699   |
| Length                 | : 214 bytes      |
| Zero page requirements | : none           |





## Chapter Five

# The Screen

If you are interested in the graphics capabilities of the BBC Micro there will no doubt be occasions when you wish to save the graphics design you have created so that it can be recalled at a later date. Programs 5.1 and 5.2 will facilitate this using the OSFILE call to perform these tasks rapidly in machine code. The third program in this chapter, Program 5.3, provides a printer screen dump program that will work on the Epson, Star and compatible printers.

### Save Screen Memory (Program 5.1)

The OSFILE routine is entered in the MOS at &FFDD. Like the majority of the operating system calls it expects to be pointed in the direction of a parameter block via an address held within the index registers. The parameter block needs to contain all the information required by the call to operate. Figure 5.1 details the OSFILE parameter block.

---

|                |  |
|----------------|--|
| XY+0 to XY+1   | : Filename address. Filename must be terminated by RETURN. |
| XY+2 to XY+5   | : File load address, stored low byte first.                |
| XY+6 to XY+9   | : Run address of file, stored low byte first.              |
| XY+10 to XY+13 | : Data start address to be saved.                          |
| XY+14 to XY+17 | : Data end address.  |

---

*Fig. 5.1. The OSFILE parameter block.*

The OSFILE call can perform up to eight different tasks depending upon the value in the accumulator when the call is effected and these are detailed in Figure 5.2. The call code we are interested in here is with the accumulator holding 0.

---

|     |  |
|-----|--|
| 0   | : Save block of memory as detailed in parameter block.     |
| 1   | : Write information in parameter block to catalogue entry. |
| 2   | : Write load address only for existing file.               |
| 3   | : Write the run address only for an existing file.         |
| 4   | : Write file attributes only for an existing file.         |
| 5   | : Read a file's catalogue information to parameter block.  |
| 6   | : Delete file named in parameter block.                    |
| 255 | : Load the file detailed in the parameter block.           |

---

*Fig. 5.2. The OSFILE call codes.*

Program 5.1 is relatively straightforward, but the amount of screen memory to be saved will vary depending on the currently selected screen mode. For example, MODEs 0, 1 and 2 utilise a full 20K from &3000 while MODEs 4 and 5 require 10K from &5800, and the amazingly versatile MODE 7 needs just a meagre 1K from &7C00.

```

10 REM *** SAVE SCREEN MEMORY ***
20 PROCsavescreen (&C00)
30 inc=5
40 X=640 : Y=512
50 MODE 4
60 FOR loop=1 TO 50
70 MOVE X,Y
80 DRAW X+inc,Y
90 DRAW X+inc,Y+inc
100 DRAW X,Y+inc
110 DRAW X,Y
120 X=X-20 : Y=Y-20
130 inc=inc+40
140 NEXT
150 CALL &C00
160 END
170 :
1700 DEF PROCsavescreen (addr)
1701 FOR pass=0 TO 3 STEP 3
1702 P%=addr
1703 [
1704 OPT pass
1705 .save_screen
1706         LDA #135
1707         JSR &FFF4
1708         TYA
1709         BEQ dump1
1710         CMP#3
1711         BCC dump1
1712         CMP#4
1713         BEQ dump2

```

```

1714          CMP#5
1715          BEQ dump2
1716          CMP #7
1717          BEQ teletext
1718 .error
1719          LDY #0
1720 .loop
1721          LDA message,Y
1722          BEQ finished
1723          JSR &FFE3
1724          INY
1725          BNE loop
1726 .finished
1727          RTS
1728 .dump1
1729          LDA #&30
1730          STA paramblk+3
1731          STA paramblk+7
1732          STA paramblk+&0B
1733          LDA #0
1734          JMP osfile
1735 .dump2
1736          LDA #&58
1737          STA paramblk+3
1738          STA paramblk+7
1739          STA paramblk+&0B
1740          LDA#0
1741          JMP osfile
1742 .teletext
1743          LDA #&7C
1744          STA paramblk+3
1745          STA paramblk+7
1746          STA paramblk+&0B
1747          LDA #0
1748          JMP osfile
1749 .osfile
1750          LDX #paramblk MOD 256
1751          LDY #paramblk DIV 256
1752          JMP &FFDD
1753 .filename
1754          EQU$"SSAVED"
1755          EQU$ 13
1756 .paramblk
1757          EQU$ filename MOD 256
1758          EQU$ filename DIV 256
1759          EQU$&3000
1760          EQU$ 0
1761          EQU$&3000
1762          EQU$&7FFF
1763 .message
1764          EQU$ 7
1765          EQU$ "Not a graphics Mode"
```

```

1766             EQUB 13
1767             EQUB 0
1768             J
1769             NEXT
1770             ENDPROC

```

*Program 5.1. PROCsavescreen - saves the screen memory to tape or disk*

The program acts 'intelligently' in this respect by obtaining the current screen mode from the Y register after an \*FX135 call (lines 1706 to 1708). If, after the comparison of line 1710, the carry is clear a MODE of less than 3 is indicated and the branch to 'dump1' performed. If a mode value of 4 or 5 is determined, 'dump2' is sought while a branch to 'teletext' is executed if 7 is returned. Note that the 'error' loop is entered if the screen is in MODE 3 or MODE 6; this prints out the 'Not a graphics Mode' message from line 1765 and the routine is exited.

Each of these sections of code simply seed the first page number of the current graphics MODE into the correct places within the parameter block. If the graphics MODE was MODE 1 then the branch to 'dump1' would seed the value &30 into the three bytes at paramblk+3, paramblk+7 and paramblk+0B, prior to loading the accumulator with 0 and jumping to 'osfile' at line 1749. Here the address of 'paramblk' is loaded into the index registers and a JMP to OSFILE at &FFDD performed.

The parameter block is located at the top of the calling machine code, lines 1756 to 1762 and the EQU functions used to prime the static contents. The filename is stored at 'filename' (line 1753) and I have chosen to use SSAVED, but this can be changed to suit your own needs, of course.

The BASIC test routine simply draws a succession of squares in MODE 4 before using the machine code to save the screen's contents.

The following program, Program 5.2, can be used to reload screen memory.

## **Load Screen Memory (Program 5.2)**

The load screen memory program is essentially the same program as its saving counterpart. The main difference is that the accumulator is loaded with 255 to indicate a load operation to the MOS.

```

10 REM *** LOAD SCREEN MEMORY ***
20 PROCloadscreen (&C00)
30 MODE4
40 CALL &C00

```

```

50 END
60 :
1800 DEF PROCloadscreen (addr)
1801 FOR pass=0 TO 3 STEP 3
1802 P%=addr
1803 [
1804 OPT pass
1805 .load_screen
1806         LDA #135
1807         JSR &FFF4
1808         TYA
1809         BEQ dump1
1810         CMP#3
1811         BCC dump1
1812         CMP#4
1813         BEQ dump2
1814         CMP#5
1815         BEQ dump2
1816         CMP #7
1817         BEQ teletext
1818 .error
1819         LDY #0
1820 .loop
1821         LDA message,Y
1822         BEQ finished
1823         JSR &FFE3
1824         INY
1825         BNE loop
1826 .finished
1827         RTS
1828 .dump1
1829         LDA #830
1830         STA paramblk+3
1831         STA paramblk+7
1832         STA paramblk+80B
1833         LDA #255
1834         JMP osfile
1835 .dump2
1836         LDA #858
1837         STA paramblk+3
1838         STA paramblk+7
1839         STA paramblk+80B
1840         LDA #255
1841         JMP osfile
1842 .teletext
1843         LDA #87C
1844         STA paramblk+3
1845         STA paramblk+7
1846         STA paramblk+80B
1847         LDA #255
1848         JMP osfile
1849 .osfile

```

```

1850          LDX #paramblk MOD 256
1851          LDY #paramblk DIV 256
1852          JMP &FFDD
1853 .filename
1854          EQU$SSAVED"
1855          EQU$ 13
1856 .paramblk
1857          EQU$ filename MOD 256
1858          EQU$ filename DIV 256
1859          EQU$&3000
1860          EQU$ 0
1861          EQU$&3000
1862          EQU$&7FFF
1863 .message
1864          EQU$ 7
1865          EQU$ "Not a graphics Mode"
1866          EQU$ 13
1867          EQU$ 0
1868          ]
1869          NEXT
1870          ENDPROC

```

*Program 5.2. PROCloadscreen - loads a saved graphics screen back into screen memory.*

## Printer Screen Dumper

If you own or have aspirations to own a printer then you will certainly wish to be able to dump the contents of screen to the printer at some time to obtain that all important hard copy, be it a graphics masterpiece or just a copy of a some neatly formatted data. Program 5.3 was designed specifically for use with 'bit-mapped' printers such as the Epson and Star ranges. The program is a stand-alone version and includes a short graphics program at the start which will be dumped correctly if you have a suitable printer attached.

```

10 REM *** PRINTER SCREEN DUMPER ***
20 REM *** EPSON FX and STAR ***
30 MODE 5
40 X=640 : Y=512
50 increment=5
60 FOR loop=1 TO 50
70 MOVE X,Y
80 DRAW X+increment,Y
90 DRAW X+increment,Y+increment
100 DRAW X,Y+increment
110 DRAW X,Y
120 X=X-20 : Y=Y-20
130 increment=increment+40

```

```

140 NEXT
150 PROCscreen_dump(&70,&71,&72,&73,&7
5,&76,&2E00)
160 CALL screen_dump
170 END
180 :
1900 DEFPROCscreen_dump(xlo,xhi,ylo,yhi
,byte,bits,addr)
1901 FOR pass=0 TO 2 STEP 2
1902 P%=addr
1903 [ OPT pass
1904 .screen_dump
1905         LDA #2
1906         JSR &FFEE
1907         LDA #1
1908         JSR &FFEE
1909         LDA #27
1910         JSR &FFEE
1911         LDA #1
1912         JSR &FFEE
1913         LDA #65
1914         JSR &FFEE
1915         LDA #1
1916         JSR &FFEE
1917         LDA #8
1918         JSR &FFEE
1919         LDA #1
1920         JSR &FFEE
1921         LDA #10
1922         JSR &FFEE
1923         LDA# &FF
1924         STA ylo
1925         LDA# &3
1926         STA yhi
1927 .next_row
1928         LDA #&0
1929         STA xlo
1930         LDA# &0
1931         STA xhi
1932         JSR duel_density
1933         LDA# &1
1934         JSR &FFEE
1935         LDA# &D
1936         JSR &FFEE
1937         SEC
1938         LDA ylo
1939         SBC# 32
1940         STA ylo
1941         BCS check_finish
1942         DEC yhi
1943 .check_finish
1944         LDA yhi

```



```

1945          CMP# &FF
1946          BNE next_row
1947          LDA ylo
1948          CMP# &FF
1949          BNE next_row
1950          LDA #1
1951          JSR &FFEE
1952          LDA #12
1953          JSR &FFEE
1954          LDA #1
1955          JSR &FFEE
1956          LDA #27
1957          JSR &FFEE
1958          LDA #1
1959          JSR &FFEE
1960          LDA #64
1961          JSR &FFEE
1962          LDA #3
1963          JSR &FFEE
1964          RTS
1965 .duel_density
1966          LDA# &1
1967          JSR &FFEE
1968          LDA #27
1969          JSR &FFEE
1970          LDA #1
1971          JSR &FFEE
1972          LDA #76
1973          JSR &FFEE
1974          LDA #1
1975          JSR &FFEE
1977          JSR &FFEE
1978          LDA #1
1979          JSR &FFEE
1980          LDA #2
1981          JSR &FFEE
1982 .next_byte
1983          LDA #0
1984          STA bits
1985          LDA #128
1986          STA byte
1987 .read_pixel
1988          LDA #9
1989          LDX #x10
1990          LDY #0
1991          JSR &FFF1
1992          LDA x10+4
1993          AND #&FF
1994          BEQ step4
1995          LDA byte
1996          ORA bits
1997          STA bits
1998 .step4

```

```

1999          SEC
2000          LDA ylo
2001          SBC #4
2002          STA ylo
2003          BCS rotate
2004          DEC yhi
2005 .rotate
2006          CLC
2007          ROR byte
2008          BCC read_pixel
2009 .print_pattern
2010          LDA #1
2011          JSR &FFEE
2012          LDA bits
2013          JSR &FFEE
2014          CLC
2015          LDA ylo
2016          ADC #32
2017          STA ylo
2018          BCC over
2019          INC yhi
2020 .over
2021          CLC
2022          LDA xlo
2023          ADC #2
2024          STA xlo
2025          BCC leap_frog
2026          INC xhi
2027 .leap_frog
2028          LDA xhi
2029          CMP #5
2030          BNE do_again
2031          RTS
2032 .do_again
2033          JMP next_byte
2034          ]
2035          NEXT pass
2036          ENDPROC

```

*Program 5.3. PROCscreen\_dump - outputs the graphics screen to a connected printer.*

The machine code of the program assembles just below the memory required by either of the 20K screen modes. It would be a good idea to obtain a second source coding that will sit just below the MODE 4 and 5 memory, thus making the 'unused' screen memory available for use by the program. A suitable value for 'addr' in this instance would be &5600.

The major part of any graphics-printer dump program is spent preparing the pixel - in other words, converting it from its screen form into a form that the printer can handle and translate into selecting which

of its eight dot-matrix pins it fires. (Yes, I know there are nine but we only use eight!) The steps required to perform this conversion process are summarised below:

- (a) Read a pixel off the screen.
- (b) Adjust the byte using suitable rotates.
- (c) Check a counter to see if byte is complete.
- (d) Adjust the value of Y and X as needed to allow for resolution changes.
- (e) Send the byte to the printer in the form of a VDU1 command.

Looking at the assembler program shows that the first section of code from line 1904 to 1926 is responsible for issuing a series of VDU1 codes to the printer using OSWRCH. In BASIC terms the following is performed:

```
VDU 2, 1, 27, 1, 65, 1, 8, 1, 10
```

The VDU 2 is used to enable the printer while the intermediate codes set the line spacing to 8/72 inches. The final VDU 10 performs a line feed. Much of the code comprises these VDU 1 codes and they could be more efficiently incorporated into a look-up table if required. I have persevered with the long-winded method mainly for reasons of clarity. Lines 1922 to 1932 initialise the variables ylo, yhi and xlo, xhi. The pair ylo,yhi are loaded with &3FF which in decimal is 1023 and shows itself to be the maximum on-screen value of the Y axis. The xlo,xhi combination are set to zero. The 'dual\_density' subroutine is responsible for putting the printer in graphics geaf and performs a BASIC VDU 1, 27, 1, 76, 1, 128, 2 selecting 640 dots per line in bit image mode.

Before printing, the current screen pixel details must be read from the screen. This is readily performed with OSWORD and the accumulator holding 9 (lines 1987 to 1992). The parameter block requires five bytes set out as follows using the declared variables:

```
xlo    - low byte X coordinate
xhi    - high byte X coordinate
ylo    - low byte Y coordinate
yhi    - high byte Y coordinate
xlo+4  - result after OSWORD call
```

As can be seen, we have neatly used the program variables to form the parameter block of the call, a saving in coding and space when it works!

The byte to be sent to the printer is formed by rotating it through the carry flag position into the accumulator (lines 2003 to 2013) and

printing it via OSWRCH. The rest of the general housekeeping is performed in lines up to 2033 and the whole process repeated until the 'check\_finish' (line 1943) routine indicates a completed picture. The final succession of VDU 1 calls issue a form feed, place the printer into its more standard printing mode and disable it. Figure 5.3 shows a dump produced by the program on my own printer.

One final point: always ensure that the graphics origin is set to its normal default position prior to calling the dump. This is best done by inserting a VDU 29,0;0; at the onset of the program. As it stands, the program looks at every screen coordinate; if any of these have been moved off the screen due to a redefined graphics origin then the pixel read routine will return -1 or &FF, which will cause awful black bars and lines to be printed as part of your dump in the offscreen areas.

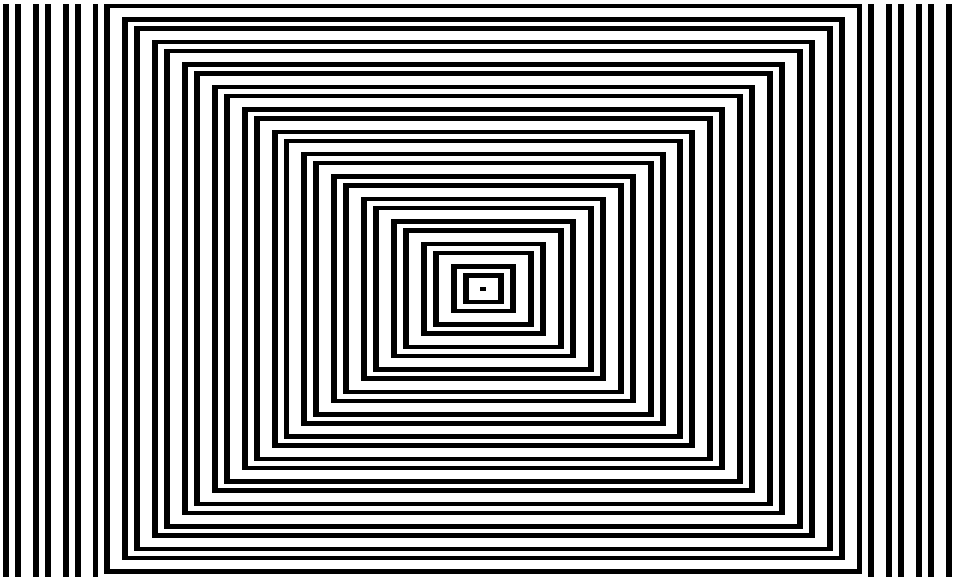


Fig. 5.3. Screen dump produced by Program 5.3.

## **Program fact sheets**

### *Program 5.1*

|                        |                  |
|------------------------|------------------|
| Procedure title        | : PROCsavescreen |
| Variables required     | : addr           |
| Line numbers           | : 1700 to 1770   |
| Length                 | : 140 bytes      |
| Zero page requirements | : none           |
| Registers changed      | : A, X, Y        |

### *Program 5.2*

|                        |                  |
|------------------------|------------------|
| Procedure title        | : PROCloadscreen |
| Variables required     | : addr           |
| Line numbers           | : 1800 to 1870   |
| Zero page requirements | : none           |
| Registers changed      | : A,X,Y          |

### *Program 5.3*

|                        |  |
|------------------------|--|
| Procedure title        | : PROCscreen_dump                      |
| Variables required     | : xlo, xhi, ylo, yhi, byte, bits, addr |
| Line numbers           | : 1900 to 2036                         |
| Program length         | : 260 bytes                            |
| Zero page requirements | : 7 bytes                              |
| Registers changed      | : A,X,Y                                |

## Chapter Six

# Softly, Softly

The Beeb allows the user to define characters using the VDU 23 command. This is followed by eight byte-sized numbers which represent the bit patterns of the eight bytes that form the character.

```
*** SOFT CHR CHARACTER DEFINITIONS ***
224: 32,165, 12,169,224,133,114,169,
225: 12,133,113,169, 0,133,112,133,
226: 115,208, 12,165,116,208, 12,165,
227: 115,208, 12,165,116,208, 8, 32,
228: 227, 12,208,240, 76,239, 12,165,
229: 114, 32, 89, 12,169, 58, 32,238,
230: 255,169, 32, 32,238,255,160, 0,
231: 117,112, 32, 89, 12,169, 44, 32,
232: 238,255,200,192, 8,208,241, 32,
233: 227, 12,169, 0,133,115,133,116,
234: 168,169, 13, 32,227,255, 76, 20,
235: 12,162, 0,134,117,201,100,144,
236: 8,233,100,232,134,117, 76, 93,
237: 12, 32,129, 12,162, 0,201, 10,
238: 144, 6,233, 10,232, 76,110, 12,
239: 32,129, 12, 24,105, 48, 76,238,
240: 255, 72,138,105, 48,201, 48,208,
241: 6,166,117,208, 2,169, 32, 32,
242: 238,255,104, 96,160, 7,177,112,
243: 24,101,115,133,115,144, 2,230,
244: 116,136, 16,242, 96,162, 0,189,
245: 180, 12, 48, 7, 32,238,255,232,
246: 76,167, 12, 96, 10, 13, 10, 13,
247: 42, 42, 42, 32, 83, 79, 70, 84,
248: 32, 67, 72, 82, 32, 67, 72, 65,
249: 82, 65, 67, 84, 69, 82, 32, 68,
250: 69, 70, 73, 78, 73, 84, 73, 79,
251: 78, 83, 32, 42, 42, 42, 10, 13,
252: 10, 13,255, 24,165,112,105, 8,
253: 133,112,230,114,240, 1, 96, 32,
254: 231,255,104,104, 96, 0, 0, 0,
```

*Fig. 6.1. A typical output produced by PROCvduchrs.*

Primarily these definable characters, 224 to 255, are used to create new characters whether they be fancy stylised alphanumeric characters or, more commonly, games characters. Program 6.1 provides a routine that will display the full definitions of any of these characters that have been defined. Figure 6.1 shows the output produced by the program.

User-definable characters are stored in the soft character definition area on page &C between &C00 to &CFF. Machine code programmers will know this area better as an assembly area for their code! As mentioned, eight bytes are associated with each character; thus, character VDU224 is allocated the eight bytes &C90 to &C07 inclusive; VDU 255 the bytes &C08 to &C0F, and on up to VDU 255 which is allocated the bytes &CF8 to &CFF. The first byte in each definition (the top-most one) is placed in the first byte of the corresponding memory location and so on - as Figure 6.2 illustrates.

|            |  |  |  |  |  |  |  |
|------------|--|--|--|--|--|--|--|
| &C00 = &18 |  |  |  |  |  |  |  |
| &C01 = &3C |  |  |  |  |  |  |  |
| &C02 = &5A |  |  |  |  |  |  |  |
| &C03 = &66 |  |  |  |  |  |  |  |
| &C04 = &3C |  |  |  |  |  |  |  |
| &C05 = &18 |  |  |  |  |  |  |  |
| &C06 = &24 |  |  |  |  |  |  |  |
| &C07 = &42 |  |  |  |  |  |  |  |

Fig. 6.2. The byte definition storage of user-defined character 224.

As Figure 6.1 showed, the program does not print out the contents of every character - merely the characters that are or seem to be defined. This is quite simple to determine. On a power-up or reset, the MOS clears this area of memory with zero, so all the program needs to do is to add up the bytes corresponding to each VDU character. If the result is zero, no definition is present and the next character is sought. If, on the other hand, the result is non-zero then a definition is assumed and the contents printed. I say 'assumed' because it might not be a proper definition - it may, of course, be machine code! Also, the last 5 characters in the buffer, VDU 250 to VDU 255, seem to be susceptible to having garbage placed into them by the MOS.

Figure 6.3 flowcharts the program's operation. The definition test just discussed is performed by the 'test\_for\_definition' routine (lines 2135 to 2147 in Program 6.1). The result of the summing is placed in Softly, Softly55 the 'addition' then a branch to 'print\_definition' is executed (lines 2067 to 2070).

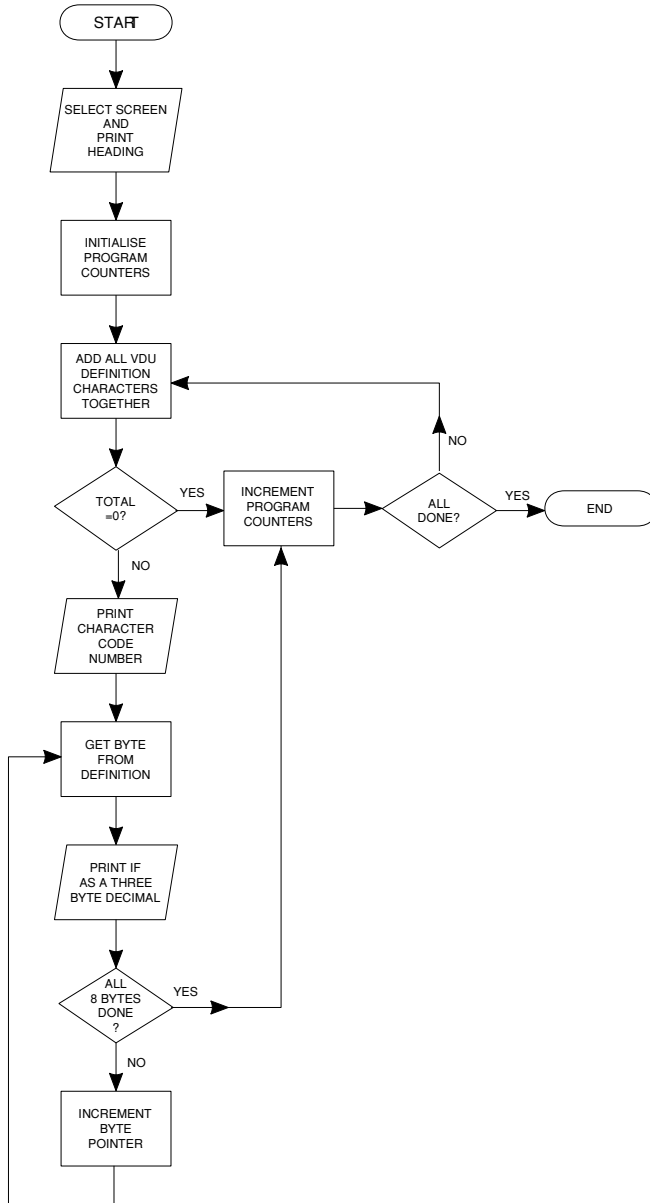


Fig. 6.3. The PROCvduchr flowchart.



The 'print\_definition' loop (lines 2074 to 2097 in Program 6.1) begins by printing the VDU number of the current character followed by a colon. Each byte is then extracted in turn and printed to the screen in decimal form followed by a comma. After the last definition byte is printed a new line is printed and the next VDU character is sought. The 'update routine' (lines 2166 to 2173), as its name implies, increments all program counters and determines when every VDU character has been processed.

```

10 REM * SOFT CHR VDU'S VERSION V2 *
20 REM *(c) Bruce Smith/Acorn User *
30 PROCvdhchr(&70,&72,&73,&75,&4000)
40 *KEY0 CALL &4000|M
50 END
60 :
2050 DEF PROCvdhchr(soft_base, vdu_chara
cter, addition_bytes, flag, addr)
2051 FOR pass=0 TO 3 STEP3
2052 P%=&4000
2053 [ OPT pass
2054 .start
2055             JSR set_up_screen
2056             LDA #224
2057             STA vdu_character
2058             LDA #&C
2059             STA soft_base+1
2060             LDA #0
2061             STA soft_base
2062             STA addition_bytes
2063             STA addition_bytes+1
2064             TAY
2065 .main_loop
2066             JSR test_for_definition
2067             LDA addition_bytes
2068             BNE print_definition
2069             LDA addition_bytes+1
2070             BNE print_definition
2071             JSR update
2072             BNE main_loop
2073             JMP exit
2074 .print_definition
2075             LDA vdu_character
2076             JSR binary_decimal_print
2077             LDA #ASC": "
2078             JSR &FFEE
2079             LDA #ASC" "
2080             JSR &FFEE
2081             LDY #0
2082 .loop
2083             LDA (&70),Y
2084             JSR binary_decimal_print

```

```

2085          LDA #ASC","
2086          JSR &FFEE
2087          INY
2088          CPY #8
2089          BNE loop
2090          JSR update
2091          LDA#0
2092          STA addition_bytes
2093          STA addition_bytes+1
2094          TAY
2095          LDA #13
2096          JSR &FFE3
2097          JMP main_loop
2098 .binary_decimal_print
2099          LDX #0
2100          STX flag
2101 .hundreds
2102          CMP#100
2103          BCC no_hundreds
2104          SBC #100
2105          INX
2106          STX flag
2107          JMP hundreds
2108 .no_hundreds
2109          JSR print_decimal
2110          LDX #0
2111 .tens
2112          CMP #10
2113          BCC no_tens
2114          SBC #10
2115          INX
2116          JMP tens
2117 .no_tens
2118          JSR print_decimal
2119          CLC
2120          ADC #ASC"0"
2121          JMP &FFEE
2122 .print_decimal
2123          PHA
2124          TXA
2125          ADC #ASC"0"
2126          CMP #ASC"0"
2127          BNE no_zero
2128          LDX flag
2129          BNE no_zero
2130          LDA #32
2131 .no_zero
2132          JSR &FFEE
2133          PLA
2134          RTS
2135 .test_for_definition
2136          LDY#7

```

```

2137 .check_loop
2138         LDA (&70),Y
2139         CLC
2140         ADC addition_bytes
2141         STA addition_bytes
2142         BCC no_carry
2143         INC addition_bytes+1
2144 .no_carry
2145         DEY
2146         BPL check_loop
2147         RTS
2148 .set_up_screen
2149         LDX #0
2150 .next_character
2151         LDA table,X
2152         BMI done
2153         JSR &FFEE
2154         INX
2155         JMP next_character
2156 .done
2157         RTS
2158 .table
2159         EQUB 22
2160         EQUB 6
2161         EQU $0D0A0D0A
2162         EQU "*** SOFT CHR"
2163         EQU " CHARACTER "
2164         EQU "DEFINITIONS ***"
2165         EQU $0D0A0D0A
2166         EQUB 255
2167 .update
2168         CLC
2169         LDA soft_base
2170         ADC#8
2171         STA soft_base
2172         INC vdu_character
2173         BEQ exit
2174         RTS
2175 .exit
2176         JSR &FFE7
2177         PLA
2178         PLA
2179         RTS
2180         ]
2181         NEXT pass
2182         ENDPROC

```

*Program 6.1. PROCvduchr - lists the soft character definitions.*

The program incorporates a useful decimal printing routine between lines 2098 and 2134. This itself would be useful to have as a separate procedure. Character base conversion can seem difficult, but like most

things in life it is quite simple to do when you know how! As it stands, the routine will convert an eight-bit binary number held in the accumulator into a three-digit decimal ASCII number, or more correctly a string of three ASCII characters. Thus, if the accumulator held 11110001 (&F1) the ASCII string "241" would be printed.

To perform this, it is first necessary to calculate how many hundreds, tens and units there are in the byte. All that is required to do this is to subtract 100 or 10 from the byte and increment a hundreds or tens count each time the subtraction leaves a remainder. Using the byte &E1 mentioned above this would work as follows. First, the hundreds:

|      |                         |
|------|-------------------------|
| 241  |                         |
| -100 |                         |
| ---- |                         |
| 141  | hundreds count=1        |
| 141  |                         |
| -100 |                         |
| ---- |                         |
| 41   | hundreds count=2        |
| 41   |                         |
| -100 |                         |
| ---- |                         |
| -59  | This result is negative |

The final hundreds count is therefore 2. This can be converted into its ASCII code simply by adding ASC"0" and printing it.

Next, the tens count, and the value we use to start with is the remainder from the hundreds count.

|      |                |
|------|----------------|
| -10  |                |
| ---- |                |
| 31   | tens count = 1 |
| 31   |                |
| -10  |                |
| ---- |                |
| 21   | tens count = 2 |
| 21   |                |
| -10  |                |
| ---- |                |
| 11   | tens count = 3 |
| 11   |                |
| -10  |                |
| ---- |                |
| 1    | tens count = 4 |

The final tens count is therefore 4, and adding ASCII"0" to this will derive the ASCII code for 4 which can be printed. Finally, the units count is left as the remainder, 1 in this case. Again, ASCII"0" needs to be added to this to get the character's ASCII code so that it can be printed.

### **Program fact sheet**

#### *Program 6.1*

|                        |   |
|------------------------|---|
| Procedure title        | : PROCvduchr  |
| Variables Required     | : soft_base, vdu_character, addition_bytes,<br>flag, addr |
| Line numbers           | : 2050 to 2181  |
| Length                 | : 246 bytes   |
| Zero page requirements | : 6 bytes   |
| Registers changed      | : A, X, Y   |

## Chapter Seven

# Global Variable Search and Replace

GREPL is the longest program in this book, a massive 582 bytes when assembled, but it is invaluable. Using it allows variable names within a program to be replaced throughout simply and easily. This eradicates the need to work through the program replacing them 'by hand', thus allowing new, more meaningful, names to be assigned or, if memory is tight, shorter names to be inserted.

### Program description

Because of the long nature of the program, I have chosen to present the program details in a line-by-line block format which if used in conjunction with the flowchart of Figure 7.1 and the description of variable storage in Chapter 3 should make its understanding much easier.

Line 2195: Clear occurrence counter.

Lines 2196 to 2198: Print 'variable' prompt.

Lines 2199 to 2202: Input variable name to be replaced into buffer, pointed to by the Index registers and save the strings length in 'olen'.

Lines 2203 to 2205: Print 'Replace with' prompt.

Lines 2206 to 2208: Input new variable name and store it in buffer pointed to by the Index registers.

Lines 2210 to 2213: Calculate difference in variable name lengths and save result.

Lines 2214 to 2217: Read current setting of OSHWM.

Lines 2222 to 2221: Clear registers and get first byte from program.

Lines 2222 to 2227: If byte is ASCII return, check for the TOP marker &FF.

Lines 2228 to 2230: If TOP found perform OSNEWL and exit via 'report'.

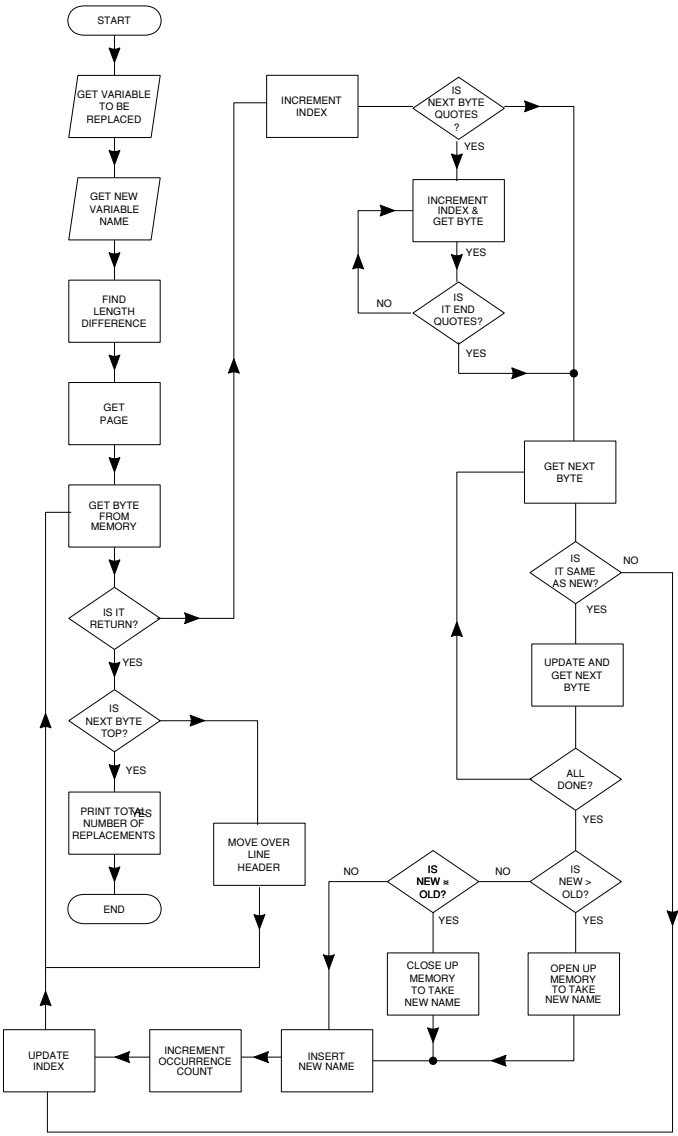


Fig. 7.1. Flowchart for PROCgrepl.

```

10 REM ***GLOBAL REPLACE - GREPL***
20 himem=HIMEM
30 himem=himem-&300
40 HIMEM=himem
50 PROCgrepl (&70,&72,&74,&76,&77,&78
, himem)
60 *KEY0 CALL HIMEM|M
70 END
80 :
2190 DEF PROCgrepl (current,last,link,o
len,nlen,result,himem)
2191 FOR pass=0 TO 3 STEP 3
2192 P%=HIMEM
2193 COPT pass
2194 .Global_replace
2195     LDA #0 :STA number
2196     LDX #old_prompt MOD 256
2197     LDY #old_prompt DIV 256
2198     JSR print_string
2199     LDX #old_name_store MOD 256
2200     LDY #old_name_store DIV 256
2201     JSR input_string
2202     STA olen
2203     LDX #new_prompt MOD 256
2204     LDY #new_prompt DIV 256
2205     JSR print_string
2206     LDX #new_name_store MOD 256
2207     LDY #new_name_store DIV 256
2208     JSR input_string
2209 .do_again
2210     SEC
2211     STA nlen
2212     SBC olen
2213     STA result
2214     LDA #&83
2215     JSR &FFF4
2216     STX current
2217     STY current+1
2218 .main_loop
2219     LDX #0
2220     TXA :TAY
2221     LDA (current),Y
2222     CMP #13
2223     BNE not_return
2224     INY
2225     LDA (current),Y
2226     CMP #&FF
2227     BNE over
2228     JSR &FFE7
2229     LDA number
2230     JMP report
2231     RTS

```



```

2232 .over
2233         CLC
2234         LDA current
2235         ADC #3
2236         STA link
2237         LDA current+1
2238         ADC #0
2239         STA link+1
2240         LDY #4
2241         BNE update4
2242 .not_return
2243         CMP #&22
2244         BNE validity_test
2245 .end_quotes
2246         INY
2247         LDA (current),Y
2248         CMP #&22
2249         BEQ update3
2250         CMP #13
2251         BNE end_quotes
2252         BEQ update4
2253 .validity_test
2254         CMP #ASC"&"
2255         BEQ hexadecimal
2256         JSR check_variable
2257         BCC match_names
2258 .hexadecimal
2259         INY
2260         LDA (current),Y
2261         JMP validity_test
2262
2263 .match_names
2264         CPY olen
2265         BNE update2
2266         DEY
2267 .next_chr
2268         LDA (current),Y
2269         CMP old_name_store,Y
2270         BNE move_on
2271         DEY
2272         BPL next_chr
2273         BMI insert_new
2274 .move_on
2275         LDY olen
2276 .update2
2277         TYA
2278         BNE update4
2279 .update3
2280         INY
2281 .update4
2282         JSR memory_update
2283         DEY
2284         BNE update4

```

```

2285             BEQ main_loop
2286 .insert_new
2287             INC number
2288             LDA current
2289             STA last
2290             LDA current+1
2291             STA last+1
2292             LDY #0
2293             CLC
2294             LDA result
2295             ADC <link>,Y
2296             CMP #238
2297             BCC leap_frog
2298             JMP bad_string
2299 .leap_frog
2300             LDX #2
2301             STA <link>,Y
2302             LDA result
2303             BEQ overwrite
2304             BMI shuffle_down
2305 .back
2306             JMP memory_update
2307             LDA <last>,Y
2308             CMP #&FF
2309             BNE back
2310             LDX #0
2311             LDY result
2312 .shuffle_up
2313             LDA <last,X>
2314             STA <last>,Y
2315             LDA last
2316             BNE low_last
2317             DEC last+1
2318 .low_last
2319             DEC last
2320             LDA last
2321             CMP current
2322             BNE shuffle_up
2323             LDA last+1
2324             CMP current+1
2325             BNE shuffle_up
2326 .overwrite
2327             LDY #0
2328 .inset_loop
2329             LDA new_name_store,Y
2330             STA <current>,Y
2331             INY :CPY nlen
2332             BNE inset_loop
2333             LDX #0
2334             BEQ update2
2335 .shuffle_down
2336             LDA result

```

```

2337             EOR  #&FF
2338             TAY
2339             INY
2340 .next_down
2341             LDA  (last),Y
2342             STA  (last-2,X)
2343             JSR  memory_update
2344             CMP  #&FF
2345             BNE  next_down
2346             BEQ  overwrite
2347 .memory_update
2348             INC  current,X
2349             BNE  skip_high
2350             INC  current+1,X
2351 .skip_high
2352             RTS
2353 .check_variable
2354             CMP  #ASC"z"+1
2355             BCS  less_than
2356             CMP  #ASC"_"
2357             BCS  greater_than
2358             CMP  #ASC"Z"+1
2359             BCS  less_than
2360             CMP  #ASC"A"
2361             BCS  greater_than
2362             CMP  #ASC"$"
2363             BEQ  greater_than
2364             CPY  #0
2365             BEQ  less_than
2366             CMP  #ASC"9"+1
2367             BCS  less_than
2368             CMP  #ASC"0"
2369             BCS  greater_than
2370             CMP  #ASC"%"
2371             BEQ  greater_than
2372 .less_than
2373             CLC
2374 .greater_than
2375             RTS
2376 .print_string
2377             STX  current
2378             STY  current+1
2379             LDY  #0
2380 .print_string2
2381             LDA  (current),Y
2382             BMI  no_more
2383             JSR  &FFE3
2384             INY
2385             BNE  print_string2
2386 .no_more
2387             RTS
2388 .input_string
2389             STX  last

```

```

2390          STY last+1
2391 .input_loop2
2392          LDY #0
2393 .get_character
2394          JSR &FFE0
2395          CMP #&1B
2396          BEQ escape
2397          CMP #13
2398          BEQ string_end
2399          CMP #&7F
2400          BEQ rub_out
2401          JSR check_variable
2402          BCC get_character
2403          STA (last),Y
2404          JSR &FFE3
2405 .input_loop3
2406          INY
2407          CPY #21
2408          BEQ too_big
2409          BNE get_character
2410 .string_end
2411          TYA
2412          BEQ get_character
2413          JSR &FFE7
2414          TYA
2415          RTS
2416 .rub_out
2417          DEY
2418          BMI input_loop3
2419          JSR &FFE3
2420          JMP get_character
2421 .too_big
2422          LDX #error1 MOD 256
2423          LDY #error1 DIV 256
2424          JSR print_string
2425          PLA :PLA :RTS
2426 .escape
2427          LDA #&7E
2428          JSR &FFF4
2429          PLA :PLA :RTS
2430 .report
2431          LDX #0
2432          SEC
2433 .decimal_loop
2434          SBC #10
2435          BMI no_jump
2436          INX
2437          JMP decimal_loop
2438 .no_jump
2439          DEX
2440          CLC
2441          ADC #58

```

```

2442          PHA
2443          TXA
2444          ADC #48
2445          CMP #ASC"0"
2446          BEQ no_print
2447          JSR &FFEE
2448 .no_print
2449          PLA
2450          JSR &FFEE
2451          LDX #done MOD 256
2452          LDY #done DIV 256
2453          JMP print_string
2454 .bad_string
2455          LDX #error2 MOD 256
2456          LDY #error2 DIV 256
2457          JSR print_string
2458          LDX #20
2459 .swap_pointers
2460          LDA old_name_store,X
2461          PHA
2462          LDA new_name_store,X
2463          STA old_name_store,X
2464          PLA
2465          STA new_name_store,X
2466          DEX
2467          BPL swap_pointers
2468          LDA olen
2469          PHA
2470          LDA nlen
2471          STA olen
2472          PLA :PLA :PLA
2473          RTS
2474 .old_name_store
2475          EQU$ " "
2476 .new_name_store
2477          EQU$ " "
2478 .old_prompt
2479          EQU$ 13
2480          EQU$ "Variable : "
2481          EQU$ 255
2482 .new_prompt
2483          EQU$ 13
2484          EQU$ "Replace with : "
2485          EQU$ 255
2486 .error1
2487          EQU$ 13
2488          EQU$ "Err1"
2489          EQU$ &FF07
2490 .error2
2491          EQU$ 13
2492          EQU$ "Err2"
2493          EQU$ &FF07
2494 .done

```

```

2495             EQUUS" occurrence(s) replaced"
2496             EQUW &FF0D
2497 .number      EQUW 0
2498             J :NEXT pass
2499             ENDPROC

```

*Program 7.1. PROCgrepl - a global search and replace facility*

Lines 2233 to 2241: Otherwise move on past new line header bytes and force branch to 'update4'.

Lines 2243 to 2244: Test for quotes and branch if not there.

Lines 2245 to 2249: Locate the end pair of quotes.

Lines 2250 to 2252: If ASCII return found first, branch to 'update4'.

Lines 2254 to 2255: If a hexadecimal value is indicated, branch.

Lines 2256 to 2261: Check for a valid variable character.

Lines 2263 to 2272: Compare old variable name with the string pointed to in the program by 'current'. Exit on first unlike character.

Line 2273: If negative strings compared force a branch to 'insert\_new'.

Lines 2274 to 2285: String not found so update all pointers and redo from 'main\_loop'.

Lines 2286 to 2291: Increment occurrence pointer and update pointers.

Lines 2292 to 2298: Add new line length to the 'jink' byte. If link byte is greater than permissible value then perform 'bad\_string' error. Else go to 'leap\_frog'.

Lines 2299 to 2304: Calculate if space occupied by variable needs to be altered, if so, move distal portion of program up or down memory as required.

Lines 2305 to 2325: Open up the program at the variable name to make way for a longer variable name.

Lines 2326 to 2334: Write new variable name over the old variable name.

Lines 2335 to 2346: Close up variable space by desired amount to ensure that new shorter variable name fits correctly, then overwrite it.

Lines 2347 to 2352: Update current position in program vector.

Lines 2353 to 2375: Check that 'current' contents being investigated is a legal variable value.

Lines 2376 to 2387: Print the ASCII character string pointed to by the address held in the Index registers. Printing is terminated on encountering a negative byte, typically &FF.

Lines 2388 to 2415: Input an ASCII character string up to 20 characters long and store it in the buffer pointed to by the index registers.

Lines 2416 to 2420: Perform DELETE

Lines 2421 to 2425: Execute 'Too big' error.

Lines 2426 to 2429: Handle ESCAPE.

Lines 2430 to 2453: Print number of occurrences after first converting it into an ASCII-based decimal number.

Lines 2454 to 2457: Print bad string error message.

Lines 2458 to 2473: Reset pointers to former values and exit to BASIC.

Lines 2474 to 2497: ASCII string storage area.

## **Using GREPL**

Because of its large size, a hole must be created within the Beeb's memory map to insert GREPL, because the normal page size areas are not big enough. The program makes a niche by lowering HIMEM by three pages and placing it above the new value, programming function key 0 with the correct call address.

To use GREPL press f0 and answer to the prompts as they appear. The new variable name may be up to 20 characters long; variables greater than this are not accepted. Once the replace name is entered the program goes about its business and the number of occurrences/ replacements are indicated on completion.

## **Program fact sheet**

### *Program 7.1*

|                        |   |
|------------------------|---|
| Procedure title        | : PROCgrepl   |
| Variables required     | : current, last, link, olen, nlen, result,<br>himem |
| Line numbers           | : 2190 to 2499                                      |
| Length                 | : 582 bytes   |
| Zero page requirements | : 9 bytes   |
| Registers changed      | : A, X, Y   |

## Chapter Eight

# Time for Bed

Next to Saturday night's Match of the Day, the home computer must be the most frequent centrepiece of the friendly matrimonial dispute. Even four years on, my wife will often appear in the early hours of the morning to 'pull the plug out' of my latest sojourn into the land of ROM and RAM. It is certain that most hobbyists world-wide have suffered their mate's wrath in the small hours of the night at some time. It is difficult to explain to the non-committed that, once in front of the keyboard, time is meaningless.

This program was born at the specific request of my wife. It's a background clock that sits ticking its digits away at the top right-hand corner of the screen while the Beeb goes about its more important tasks, stopping once every second to create the tick or tock to push the second-hand a fraction further into the night!

The clock is based on the use of events or, more correctly, the redirection of events. The BBC Micro is built up around events, so much so that all the time it is switched on and being used it actually stops what it is doing every ten milliseconds to catch up on any outstanding house-keeping chores it needs to be. These chores take many guises and range from reading any pressed keys into the keyboard buffer to sampling some of the ADC channels. Due to the design of the BBC Micro it is possible to intercept these events as they take place and interpret them as we wish, and this concept forms the basis of the digital clock display.

There are several ways in which an event can be made to occur and these are listed in Figure 8.1. The one that we are particularly interested in is event 5 which occurs when the interval timer crosses zero. The interval timer is a 5-byte clock that is incremented one hundred times every second. When the timer is incremented so that it resets to zero, i.e. goes from &FFFFFFF to &0, the event is initiated. When the event occurs, the operating system is directed through the event vector, EVNTV at &220, so that by redirecting this vector to our own event handler the appropriate action can be taken. The basic component in our clock is, of course, the second, so the interval timer must be made to time-out every second. Being an upcounting device, the interval timer must be loaded with -100 centiseconds. This write interval timer



operation is performed using an OSWORD 4 call. As with all OSWORD calls the index registers hold the address of the parameter block which contains the 5-byte value to be written. In Program 8.1, the parameter block is located at 'clock' lines 2606 to 2608.

| Event | Cause                               |
|-------|-------------------------------------|
| 0     | Output buffer empty                 |
| 1     | Input buffer full                   |
| 2     | Character for input buffer entering |
| 3     | ADC conversion finished             |
| 4     | Vertical sync start                 |
| 5     | Interval timer crossing zero        |
| 6     | ESCAPE detected                     |
| 7     | RS 423 error                        |
| 8     | Econet event detected               |
| 9     | User event detected                 |

*Fig. 8.1.* Details of operating system events

```

10 REM *** Continuous display clock *
**
20 REM *** redirects EVENTV vector *
**
30 *FX13,5
40 CLS
50 PRINTCHR$141;" The Mute Clock!"
60 PRINTCHR$141;" The Mute Clock!"
..
70 INPUT"Hour : "H%
80 INPUT"Minute : "M%
90 INPUT"Seconds : "S%
100 PROCtime(H%,M%,S%,&A00)
110 PRINT''
120 PRINT"You have set the time for:"
130 PRINT" ";H%";":";M%";":";S%''
140 PRINT"Press key to start clock"
150 key=GET
160 CALL &A00
170 END
180 :
2500 DEF PROCtime(gethrs,getmins,getsec
s,addr)
2501 FOR pass=0 TO 2 STEP 2
2502 P%=addr
2503 [ OPT pass
2504 JMP setup

```

```

2505 .tick_clock
2506         PHP
2507         PHA
2508         TXA:PHA
2509         TYA
2510         PHA
2511         LDA#4
2512         LDY#clock DIV 256
2513         LDX#clock MOD 256
2514         JSR &FFF1
2515         INC seconds
2516         LDA seconds
2517         CMP#60
2518         BNE over
2519         LDA#0
2520         STA seconds
2521         INC minutes
2522         LDA minutes
2523         CMP#60
2524         BNE over
2525         LDA#0
2526         STA minutes
2527         INC hours
2528         LDA hours
2529         CMP#24
2530         BNE over
2531         LDA#0
2532         STA hours
2533 .over
2534         LDA hours
2535         LDY#72
2536         JSR display
2537         LDA#ASC":"
2538         STA HIMEM,Y
2539         INY
2540         LDA minutes
2541         JSR display
2542         LDA #ASC":"
2543         STA HIMEM,Y
2544         INY
2545         LDA seconds
2546         JSR display
2547         PLA
2548         TAY
2549         PLA
2550         TAX
2551         PLA
2552         PLP
2553         RTS
2554 .display
2555         LDX#0
2556         SEC
2557 .loop

```

```

2558          SBC#10
2559          BMI no_jump
2560          INX
2561          JMP loop
2562 .no_jump
2563          DEX
2564          CLC
2565          ADC#58
2566          PHA
2567          TXA
2568          ADC#48
2569          STA HIMEM,Y
2570          INY
2571          PLA
2572          STA HIMEM,Y
2573          INY
2574          RTS
2575
2576 .setup
2577          LDA #gethrs
2578          LDX #getmins
2579          LDY #getsecs
2580          STA hours
2581          STX minutes
2582          STY seconds
2583          LDA#22
2584          JSR &FFEE
2585          LDA#7
2586          JSR &FFEE
2587          LDA#28
2588          JSR &FFEE
2589          LDA#0
2590          JSR &FFEE
2591          LDA#24
2592          JSR &FFEE
2593          LDA#39
2594          JSR &FFEE
2595          LDA#2
2596          JSR &FFEE
2597          LDA#tick_clock MOD 256
2598          STA&220
2599          LDA#tick_clock DIV 256
2600          STA &221
2601          JSR tick_clock
2602          LDA#14
2603          LDX#5
2604          JSR &FFF4
2605          RTS
2606 .clock
2607          EQUd &FFFFFF9C
2608          EQUb &FF
2609 .hours EQUb 0

```

```

2610 .minutes EQUB 0
2611 .seconds EQUB 0
2612      J
2613      NEXT
2614      ENDPROC

```

*Program 8.1. PROCtime - a background digital clock*

The initial program call to 'setup' (line 2504) does a number of things. First, it loads the hours, minutes and seconds values previously input into their respective counters (lines 2577 to 2582). A MODE 7 screen is then selected and a text window defined to ensure that the digital clock cannot be scrolled off the screen. Lines 2597 to 2600 reset the EVNTV vector to point to the 'tick\_tock' routine at line 2505. The final lines (lines 2602 and 2603) perform an \*FX14,5 which balances the previous \*FX13,5 (line 30). These two calls disable and enable the interval timer crossing zero event.

The rest of the program's operation is straightforward. Each time the event occurs 'tick\_tock' is entered and the interval timer reset to count a further second (lines 2511 to 2514). Note that on entry to the routine all processor registers are preserved. This is very important, otherwise the processor would probably crash when it returned to take up the task it was undertaking before the event occurred. Lines 2515 to 2532 simply update the seconds, minutes and hours counters as required. The code between lines 2534 to 2546 stores the latest clock value at the top left-hand corner of the screen. The display subroutine (line 2554) called by the program performs a simple hex to decimal ASCII conversion by continually subtracting 10 from the value to be displayed.

Finally, the processor registers are restored (lines 2547 to 2552) before control is transferred back to the interrupted program.

## **Program fact sheet**

### *Program 8.1*

|                        |                                  |
|------------------------|----------------------------------|
| Procedure title        | : PROCtime                       |
| Variables required     | : gethrs, getmins, getsecs, addr |
| Line numbers           | : 2500 to 2614                   |
| Zero page requirements | : none                           |
| Registers changed      | : none                           |



## Chapter Nine

# Error, Pack and Autorun

### Error Lister (Program 9.1)

This utility can be of great help at the initial run-time debugging stage of a program. Normally, if an error occurs, one of the Beeb's terse error messages is issued and you are left to list the line referenced - often scratching your head wondering just where the problem is. The most infuriating part of debugging is when you make what amounts to a fundamental mistake to which you remain blind, no matter how many times you run and list the erroneous line. I speak from frequent experience!

One way around the error problem is to incorporate an error handling procedure in your program, starting the program off with a line such as:

```
10 ON ERROR GOTO 5000
```

At line 5000, the error message and line can be printed out. The problem still remains that the erroneous line is not listed, nor is the source of the error listed.

Program 9.1 solves both these problems. After being set up and installed, errors occurring at run-time will be treated in the normal manner except that the line containing the error will be listed starting at the point of the error, thus highlighting the mistake. For example, the program line

```
10 PRINT"HELLO" : STUPID ERROR : VDU 7
```

would normally result in the error:

Mistake at line 10

at run-time. With the new error lister inserted, the response would be

## STUPID ERROR : VDU 7

Mistake at line 10

```

10 REM *** ERROR LISTER ***
20 PROCerror (&C00)
30 *KEY0 CALL &C00|M
40 *KEY1 CALL &C24|M
50 END
60 :
2620 DEF PROCerror (addr)
2621 FOR pass=0 TO 3 STEP3
2622 brku=?&202+(?&203*256)
2623 P%=addr
2624 [
2625 OPT pass
2626 .SETUP
2627         LDX #0
2628 .next_chr
2629         LDA message,X
2630         JSR &FFE3
2631         INX
2632         CMP #13
2633         BNE next_chr
2634         LDA &202
2635         STA address
2636         LDA &203
2637         STA address+1
2638         LDA #entry MOD 256
2639         STA &202
2640         LDA #entry DIV 256
2641         STA &203
2642         RTS
2643 .restore
2644         LDX #0
2645 .next_chr
2646         LDA message2,X
2647         JSR &FFE3
2648         INX
2649         CMP#13
2650         BNE next_chr
2651         LDA address
2652         STA &202
2653         LDA address+1
2654         STA &203
2655         RTS
2656 .entry
2657         BIT &FF
2658         BMI was_esc
2659         CLC
2660         LDA &1B
2661         ADC &39
2662         TAX

```

```

2663             LDY #0
2664             JSR &FFE7
2665 .next_error
2666             LDA (&19),Y
2667             CMP #13
2668             BEQ was_esc
2669             CMP #32
2670             BCC garbage
2671             CMP #&80
2672             BCS garbage
2673             JSR &FFEE
2674 .garbage
2675             INY
2676             DEX
2677             BNE next_error
2678 .was_esc
2679             JMP brkv
2680 .message
2681             EQU$ " Error Lister On!"
2682             EQU$ 7
2683             EQU$ 13
2684 .message2
2685             EQU$ " Error Lister Off!"
2686             EQU$ 7
2687             EQU$ 13
2688 .address
2689             EQU$ " "
2690             ]
2691             NEXT
2692             ENDPROC

```

*Program 9.1. PROCerror - lists the program line in which an error occurred.*

The section of line which created the mistake has been listed in addition to the normal error message.

The assembled program occupies just 141 bytes and is completely self-contained so that it can be tucked out of the way during debugging. As with other programs of this type in the Portfolio, there are two entry points - to switch the lister on (entry at line 2626) and off (entry at line 2643). The 'setup' section of code saves the normal contents of BRKV at &202 and revector it to point to 'entry' at line 2656.

When the interpreter causes the program to abort via BRKV the new wedge coding is executed. It begins first at line 2657 by testing bit 7 of location &FF. If this bit is set then the abortion was due to the ESCAPE key being pressed and so the normal 'brkv' is jumped to. Assuming that ESC was not pressed, the length of the current expression being evaluated by the interpreter, and the one that caused the error to occur, is calculated. The bytes at &1B and &39 are summed (lines 2659 to 2662) and the result moved into the X register Location &1B contains the



current offset for the expression evaluation pointer while &39 contains the actual length of the expression.

The address of the current expression is held in the vector at &19 which is known as the expression evaluation base pointer, and each byte is in turn accessed and printed to the screen (line 2666). If a carriage return is encountered, the end of the line has been reached and the program jumps to the normal 'brkv' for the printing of the error message (lines 2667 and 2668). The comparisons of lines 2669 and 2671 ensure that no garbage gets printed to the screen, should the program crash have caused any to have been poked into the program inadvertently.

## **A compact Pack (Program 9.2)**

'Pack' is basically a simple program compacter that, when called, removes all traces of spaces and REM statements from it, leaving behind just the minimal program. There are two advantages in doing this. First, the program becomes smaller, and in the case of some programs much smaller. Second, by virtue of being smaller, they run and execute much faster; even a single space slows a program down a fraction, so a hundred spaces will slow a program down that much more! The saving in memory can make the difference between a program running in a high resolution mode and the dreaded 'Bad Mode' message being reported.

Pack searches through a program in the current text space and looks for spaces and REM statements and the messages that follow them. Of course, the program doesn't wipe the spaces and REMs out; rather, it just shifts the top end of the program down a byte or bytes to write over the offending space or REM.

Program 9.2 begins by placing the current value of PAGE into two zero page vectors (lines 2705 to 2710). These are used to keep position in the current program and point to the same, packed position, in the new program. A special byte is also cleared: this is the 'rem\_flag' and is used to indicate if a REM statement is currently being processed. The heavy work of the program is performed by the subroutine, 'transfer' at lines 2784 to 2789. This moves a byte from its current position in the program undergoing packing to the final version. Postindexed addressing is used throughout. After the subroutine call, the byte just moved is tested for TOP, by comparing it with &FF (line 2716) in which case the pack is complete. Note that at the start of each line an extra two transfers are required to move the line number down (lines 2718 and 2719).

```

10 REM *** SPACE & REM REMOVER ***
20 PROCpack (&70,&72,&C00)
30 END
40 :
2700 DEF PROCpack (current,new_position
,addr)
2701 FOR pass=0 TO 3 STEP3
2702 P%=addr
2703         [
2704             OPT pass
2705             LDA #0
2706             STA new_position
2707             STA current
2708             LDA &18
2709             STA new_position+1
2710             STA current+1
2711 .outer
2712             LDA #0
2713             STA rem_flag
2714             LDY #1
2715             JSR transfer
2716             CMP #&FF
2717             BEQ all_done
2718             JSR transfer
2719             JSR transfer
2720 .inner
2721             LDA (current),Y
2722             BIT rem_flag
2723             BPL flag_clear
2724             CMP #13
2725             BNE space
2726             JSR transfer
2727             BEQ end_of_line
2728 .flag_clear
2729             CMP #ASC" "
2730             BEQ space
2731             CMP #&F4
2732             BNE not_rem
2733             DEY
2734             LDA #&FF
2735             STA rem_flag
2736             BNE space
2737 .not_rem
2738             JSR transfer
2739             BEQ end_of_line
2740             CMP #&22
2741             BEQ inside_quote
2742             BNE inner
2743 .space
2744             INC current
2745             BNE inner
2746             INC current+1
2747             BNE inner

```

```

2748 .end_of_line
2749         DEY
2750         TYA
2751         PHA
2752         CPY #3
2753         BEQ clear
2754         LDY #3
2755         STA (new_position),Y
2756         CLC
2757         ADC new_position
2758         STA new_position
2759         BCC clear
2760         INC new_position+1
2761 .clear
2762         PLA
2763         CLC
2764         ADC current
2765         STA current
2766         BCC outer
2767         INC current+1
2768         BNE outer
2769 .inside_quote
2770         JSR transfer
2771         BEQ end_of_line
2772         CMP #&22
2773         BNE inside_quote
2774         BEQ inner
2775 .all_done
2776         LDA new_position
2777         CLC
2778         ADC #2
2779         STA &12
2780         LDA new_position+1
2781         ADC #0
2782         STA &13
2783         RTS
2784 .transfer
2785         LDA (current),Y
2786         STA (new_position),Y
2787         INY
2788         CMP #13
2789         RTS
2790 .rem_flag
2791         EQU$ " "
2792         ]
2793         NEXT
2794         ENDPROC

```

*Program 9.2. PROCpack - a space and REM remover.*

The space and REM tests are performed in lines 2729 and 2731 respectively and the corresponding branch made accordingly. If a space is detected, the 'current' vector is incremented, no change is made to the 'new\_position' vector and the space is not transferred. Thus, effectively the space gets lost as illustrated in Figure 9.1. The REM test looks for the token for REM which is &F4. If the token is found &FF is placed in the 'rem\_flag' to indicate this - so that the program knows it is within a REM statement and is, in fact, 'deleting' items from the line rather than transferring them. A branch to 'space' (line 2736) increments the 'current' vector before a branch to 'inner' is forced.

Fig. 9.1. Overwriting bytes to compact a program.

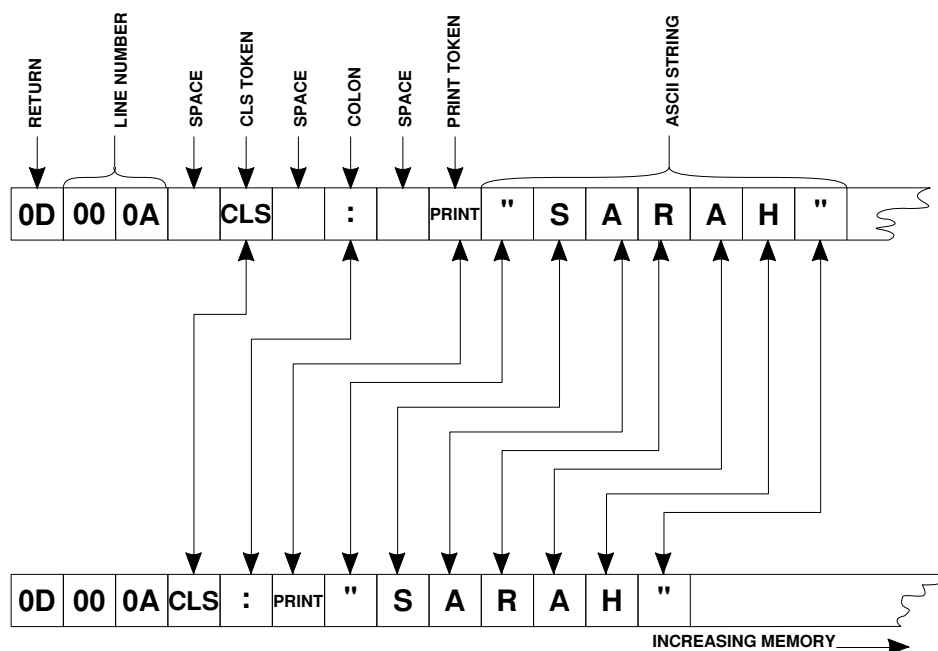


Figure 9.1. Overwriting bytes to compact a program

The relevant instruction here is in line 2722, where the 'rem\_flag' is tested with BIT. If the flag is clear, the following branch is executed, otherwise the 'current' vector is incremented via 'space'. This entire process continues until the end of line return character is encountered (line 2724). The 'end\_of\_line' routine (line 2748) rapidly transfers the three-byte line header, as comparing this would be an utter waste of processor time.

Occasionally, spaces are required by programs. The most obvious occasion is within ASCII strings where they are used for formatting text. The 'inside\_quote' coding ensures that any spaces occurring within the boundary of quotes are not removed. This section is entered via line 2741.

### Autorun (Program 9.3)

This program is interesting in that once run you cannot stop it from automatically running the program at PAGE. No matter what combination of keys you try, be it ESCAPE, BREAK or even CTRL-BREAK the program runs! In fact, the only way to be rid of it is to turn off the power to the Beeb, so this makes it an easy way to protect your own programs from the hackers.

```

      0 REM!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
!!!!!!!!!!!!!!!!!!!!!!
      10 PROCautorun
      20 END
      30 :
2800 DEF PROCautorun
2801 *FX247,76
2802 *FX248,6
2803 A%=249
2804 Y%=0
2805 X%=PAGE DIV 256
2806 CALL &FFF4
2807 P%=PAGE+6
2808 [
2809         LDA #138
2810         LDX #0
2811         LDY #ASC("O")
2812         JSR &FFF4
2813         LDY #ASC("L")
2814         JSR &FFF4
2815         LDY #ASC("D")
2816         JSR &FFF4
2817         LDY #14
2818         DEY

```

```

2819          JSR &FFF4
2820          LDY #ASC("R")
2821          JSR &FFF4
2822          LDY #ASC("U")
2823          JSR &FFF4
2824          LDY #ASC("N")
2825          JSR &FFF4
2826          LDY #14
2827          DEY
2828          JSR &FFF4
2829          RTS
2830 ]
2831 ENDPROC

```

*Program 9.3.* PROCautorun - will automatically run a program no matter what!

The assembler is quite straightforward: an \*FX 138 call is used to place the string "OLD<RETURN> RUN<RETURN>" into the keyboard buffer. It is not possible, however, to use this call to poke a return character, ASCII 13, into the buffer. To get round this, the Y register is loaded with 14 and then decremented (lines 2817 and 2826). The machine code is assembled in a rather strange place - in fact, it overwrites the 50 exclamation marks after the REM statement in line 0. As you can see, P% is set to PAGE+6 in line 2807. If you run the program then list it you will see that the !s are replaced by gobbledygook; this is just the interpreter trying to de-tokenise the machine code. These will have no effect when the program is run as they are away from the program, hiding behind the REM statement. The magic part of the program comes in lines 2801 to 2806. Here the BREAK intercept codes controlled by \*FX247, \*FX248 and \*FX249 are rewritten to print the BRK handler to the code now stored at PAGE+6, so whenever any sort of BREAK is performed the interpreter comes here and OLDs and re-RUNs the program. Once the program has been run, only line 0 need remain; the others can be deleted as required.

## **Program fact sheets**

### *Program 9.1*

|                        |                |
|------------------------|----------------|
| Procedure title        | : PROCerror    |
| Variables required     | : addr         |
| Line numbers           | : 2620 to 2692 |
| Length                 | : 141 bytes    |
| Zero page requirements | : none         |
| Registers changed      | : A, X, Y      |

*Program 9.2*

|                        |                |
|------------------------|----------------|
| Procedure title        | : PROCpack     |
| Variables required     | : addr         |
| Line numbers           | : 2700 to 2794 |
| Length                 | : 149 bytes    |
| Zero page requirements | : 4 bytes      |
| Registers changed      | : A, X, Y      |

*Program 9.3*

|                        |                             |
|------------------------|-----------------------------|
| Procedure title        | : PROCautorun               |
| Variables required     | : addr                      |
| Line numbers           | : 2800 to 2831              |
| Length                 | : 53 bytes (inside program) |
| Zero page requirements | : none                      |
| Registers changed      | : A, X, Y                   |

## Chapter Ten

# The Necessary Evil

Machine code programs of any length will often be required to manipulate numbers. Addition, subtraction, multiplication, division are all necessary evils in the computer world of data and figure manipulation. This chapter presents routines that should be versatile enough to cover most applications though often, by definition, they will be wasteful of memory and processor time. For example, rather than providing a procedure that will handle the multiplication of two eight-bit numbers a multi-byte multiplication procedure is provided. There is no reason, however, why you - the programmer - could not add a single-byte procedure to this Portfolio.

The programs provided in this chapter are as follows:

- Program 10.1* : Multi-byte addition.
- Program 10.2* : Multi-byte subtraction.
- Program 10.3* : Multi-byte multiplication.
- Program 10.4* : Multi-byte division.
- Program 10.5* : Single-byte square root.
- Program 10.6* : Double-byte square root.
- Program 10.7* : Double-byte ASL.
- Program 10.8* : Double-byte LSR.
- Program 10.9* : Double-byte ROR.
- Program 10.10* : Double-byte ROL.
- Program 10.11* : Multi-byte ASL.

### **Multi-byte addition (Program 10.1)**

Program 10.1 uses the post-indexed indirect address capabilities of the Beeb's 6502 to sum two sets of bytes stored anywhere in the Beeb's memory map, depositing the result over the first number. The start address of the two number sets is stored in the vectors 'first' and 'second'. These variables must therefore be assigned to addresses in zero page. A further variable, count, is required and this should contain the number of



bytes to be summed which is transferred into the X register to act as the bytes to add counter.

The program is simply an addition routine controlled by a loop counter. After seeding the index registers (lines 5005 to 5008) the carry flag is initially cleared. The 'first' byte is sourced and added to the 'second' byte with the result being stored at 'first' (lines 5009 to 5012). The index registers are adjusted and the loop reiterated until X becomes zero (lines 5013 to 5015).

Since the index registers are only capable of holding a maximum value of 255 the number of bytes to add together is limited to this value.

```

10 REM *** MULTI-BYTE ADDITION ***
20 PROCmulti_add(&70,&71,&73,&C00)
30 @%=0
40 ?&70=4
50 !&71=&4000
60 !&73=&4100
70 !&4000=123456
80 !&4100=123456
90 PRINT'''.123456+123456=";
100 CALL mbadd
110 PRINT!&4000
120 END
130 :
5000 DEF PROCmulti_add(count,first,second,addr)
5001 FOR PASS=0 TO 3 STEP 3
5002 P%=addr
5003 [
5004 OPT PASS
5005 .mbadd
5006         LDX count
5007         LDY #0
5008         CLC
5009 .next_byte
5010         LDA (first),Y
5011         ADC (second),Y
5012         STA (first),Y
5013         INY
5014         DEX
5015         BNE next_byte
5016 RTS
5017 ]
5018 NEXT
5019 ENDPROC

```

*Program 10.1. PROCmulti\_add - adds two multi-byte numbers together*

**Multi-byte Subtraction (Program 10.2)**

Program 10.2 operates identically to the last one. The only difference is that the SBC and the SEC instructions are substituted for their addition counterparts. It is important to remember that the 'second' value is subtracted from the 'first'.

```

10 REM *** MULTI-BYTE SUBTRACTION ***
20 PROCmulti_sub(&70,&71,&73,&C00)
30 @%=0
40 ?&70=4
50 !&71=&4000
60 !&73=&4100
70 !&4000=123456
80 !&4100=3456
90 PRINT ' ',123456-3456='';
100 CALL mbsub
110 PRINT !&4000
120 END
130 :
5030 DEF PROCmulti_sub(count,first,seco
nd,addr)
5031 FOR PASS=0 TO 3 STEP 3
5032 P%=addr
5033 [
5034 OPT PASS
5035 .mbsub
5036             LDX count
5037             LDY #0
5038             SEC
5039 .next_byte
5040             LDA (first),Y
5041             SBC (second),Y
5042             STA (first),Y
5043             INY
5044             DEX
5045             BNE next_byte
5046 RTS
5047 ]
5048 NEXT
5049 ENDPROC

```

*Program 10.2. PROCmulti\_sub - subtracts one multi-byte number from another.*

**Multi-byte Multiplication (Program 10.3)**

Program 10.3 takes two multi-byte numbers (unsigned) stored low byte first, multiplies the 'first' by the 'second' and stores the result over the

'first'. In addition to requiring two vectored addresses, a 256- byte work buffer is required by the program. The TOTAL number of bytes to be multiplied together is expected in 'totlen' while the variable 'count' is used as a general loop counter by the program. The multiplication technique employed is a standard add-and-shift one. If the current bit being tested in the multiplier is a one, the multiplicand is added to the partial product, which is then rotated by one bit. If, on the other hand, the multiplier bit is 0 only the rotate is performed.

Because of the way 'mb\_mult' is implemented, only the least significant bytes of the product are returned, i.e. the total number of bytes in the multiplier and multiplicand. The most significant bytes are always available in 'buffer' if required. Therefore, the user should check the 'buffer' for any overflow if it is suspected.

```

10 REM *** MULTI-BYTE MULTIPLICATION
***
20 PROCmulti_mult (&70,&72,&74,&75,&4
000,&4200)
30 !&70=&3000
40 !&72=&3100
50 ?&74=4
60 !&3000=1234
70 !&3100=1234
80 CALL mb_mult
90 PRINT,Result of multiplication :";
100 PRINT!&3000
110 END
120 :
5050 DEF PROCmulti_mult(first,second,to
tlen,count,buffer,addr)
5051 FOR pass=0 TO 3 STEP 3
5052 P%=addr
5053 [
5054 OPT pass
5055 .mb_mult
5056 LDA second
5057 SEC
5058 SBC #1
5059 STA second
5060 LDA second+1
5061 SBC #0
5062 STA second+1
5063 LDA first
5064 SEC
5065 SBC #1
5066 STA first
5067 LDA first+1
5068 SBC #0
5069 STA first+1

```

```

5070          LDA totlen
5071          BEQ finished
5072          STA count
5073          LDA #0
5074          ASL count
5075          ROL A
5076          ASL count
5077          ROL A
5078          ASL count
5079          ROL A
5080          STA count+1
5081          INC count
5082          BNE over
5083          INC count+1
5084 .over
5085          LDX totlen
5086          LDA #0
5087 .save_loop
5088          STA buffer-1,X
5089          DEX
5090          BNE save_loop
5091          CLC
5092 .loop
5093          LDX totlen
5094 .rotate_loop
5095          ROR buffer-1,X
5096          DEX
5097          BNE rotate_loop
5098          LDY totlen
5099 .rotate_save
5100          LDA (first),Y
5101          ROR A
5102          STA (first),Y
5103          DEY
5104          BNE rotate_save
5105          BCC no_add
5106          LDY #1
5107          LDX totlen
5108          CLC
5109 .add_loop
5110          LDA (second),Y
5111          ADC buffer-1,Y
5112          STA buffer-1,Y
5113          INY
5114          DEX
5115          BNE add_loop
5116 .no_add
5117          DEC count
5118          BNE loop
5119          LDX count+1
5120          BEQ finished
5121          DEX
5122          STX count+1

```

```

5123             JMP loop
5124 .finished
5125             RTS
5126             J
5127             NEXT
5128             ENDPROC

```

*Program 10.3. PROCmulti\_mult - multiplies two multi-byte numbers*

The program operates as follows:

*Lines 5056 to 5062:* Subtract 1 from address of 'second'.  
*Lines 5063 to 5069:* Subtract 1 from address of 'first'.  
*Lines 5070 to 5071:* If total length is zero then end.  
*Lines 5072:* Set number of bytes to count.  
*Lines 5073 to 5079:* Multiply count by eight.  
*Lines 5080 to 5083:* Add one to value of count.  
*Lines 5084 to 5091:* Save high product in buffer.  
*Lines 5092 to 5098:* Shift carry bit into buffer and bit 0 of high product into the carry flag.  
*Lines 5099 to 5104:* Rotate carry into most significant bit of 'first' and shift next bit of multiplier into the carry flag.  
*Line 5105:* Carry clear so no addition required.  
*Lines 5106 to 5115:* Carry flag is set so add \*second' and high product together.  
*Lines 5116 to 5123:* Decrement bit count and exit if zero, else repeat for the next bit.

The lines of BASIC show how the routine needs to be set up before calling it. In a larger assembler program these introductory peeks and pokes would be performed using assembler and the multiplication routine called as a subroutine from the main program. Lines 30 and 40 place the two addresses of data into the zero page vectors, while lines 60 and 70 place the values to be multiplied (both 1234) into these data buffers. Previously, in line 50, the total number of bytes to be combined, four (1234 can be held in two bytes), is poked into location &74 which corresponds to the variable 'totlen' in the procedure. After calling the subroutine (line 80) the final result is displayed. Check it on a calculator if you wish!

**Multi-byte Division (Program 10.4)**

Program 10.4 will divide two unsigned multi-byte number using a standard shift and subtract procedure whereby a 1 is placed in the quotient each time a subtraction is possible, and a 0 if not. The dividend is located at 'first' and the divisor at 'second'; during the division the quotient overwrites the dividend. Any remainder from the division is placed at the address given by 'hidiv\_pointer'.

```

10 REM *** MULTI-BYTE DIVISION ***
20 PROCmult_div(&70,&72,&74,&75,&77,&
79,&3000,&3100,&4000)
30 !&70=&3400
40 !&72=&3500
50 ?&74=3
60 !&3400=10000
70 !&3500=2
80 CALL &4000
90 PRINT "Result is :";
100 PRINT!&3400
110 PRINT"Remainder :";
120 PRINT!&3000
130 END
140 :
150 DEF PROCmult_div(first,second,totl
en,count,hidiv_pointer,pointer,buffer1,b
uffer2,addr)
5151          FOR pass=0 TO 3 STEP 3
5152          P%=addr
5153          [
5154          OPT pass
5155 .multi_div
5156          LDA totlen
5157          BNE begin
5158          JMP okay_out
5159 .begin
5160          STA count
5161          LDA #0
5162          ASL count
5163          ROL A
5164          ASL count
5165          ROL A
5166          ASL count
5167          ROL A
5168          STA count+1
5169          INC count
5170          BNE over
5171          INC count+1
5172 .over

```

```

5173          LDX totlen
5174          LDA #0
5175 .clear
5176          STA buffer1-1,X
5177          STA buffer2-1,X
5178          DEX
5179          BNE clear
5180          LDA #buffer1 MOD 256
5181          STA hidiv_pointer
5182          LDA #buffer1 DIV 256
5183          STA hidiv_pointer+1
5184          LDA #buffer2 MOD 256
5185          STA pointer
5186          LDA #buffer2 DIV 256
5187          STA pointer+1
5188          LDX totlen
5189          LDY #0
5190          TYA
5191 .check
5192          ORA (second),Y
5193          INY
5194          DEX
5195          BNE check
5196          CMP #0
5197          BNE divide
5198          JMP error
5199 .divide
5200          CLC
5201 .set_loop
5202          LDX totlen
5203          LDY #0
5204 .loop
5205          LDA (first),Y
5206          ROL A
5207          STA (first),Y
5208          INY
5209          DEX
5210          BNE loop
5211 .dec_count
5212          DEC count
5213          BNE set_shift
5214          LDX count+1
5215          BEQ okay_out
5216          DEX
5217          STX count+1
5218 .set_shift
5219          LDX totlen
5220          LDY #0
5221 .shift_loop
5222          LDA (hidiv_pointer),Y
5223          ROL A
5224          STA (hidiv_pointer),Y

```

```

5225             INY
5226             DEX
5227             BNE shift_loop
5228             LDY #0
5229             LDX totlen
5230             SEC
5231 .subtract
5232             LDA (hidiv_pointer),Y
5233             SBC (second),Y
5234             STA (pointer),Y
5235             INY
5236             DEX
5237             BNE subtract
5238             BCC set_loop
5239             LDY hidiv_pointer
5240             LDX hidiv_pointer+1
5241             LDA pointer
5242             STA hidiv_pointer
5243             LDA pointer+1
5244             STA hidiv_pointer+1
5245             STY pointer
5246             STX pointer+1
5247             JMP set_loop
5248 .okay_out
5249             CLC
5250             BCC finished
5251 .error
5252             SEC
5253 .finished
5254             RTS
5255             J
5256 NEXT
5257 ENDPROC

```

*Program 10.4. PROCmulti\_div - divides one multi-byte number by another*

The total number of bytes to be referenced in the division is placed in 'totlen' prior to the call. On exit from the routine, the carry flag bit is set if an error occurred during the division - otherwise it returns clear. The program operates as follows:

*Lines 5156 to 5158:* Get 'totlen' if zero then perform a no error finish.

*Lines 5160 to 5166:* Set count and then multiply by 8 to obtain total number of bits to do.

*Lines 5167 to 5171:* Add one to bit counter.

*Lines 5173 to 5179:* Initialise the high dividend result buffer to zero.

*Lines 5180 to 5187:* Point vectors to buffers.

*Lines 5188 to 5198:* Check that the divisor, held in 'second' is not zero!

*Lines 5199 to 5200:* Clear carry flag on entry into 'divide'.



*Lines 5201 to 5210:* Move the carry flag bit into the low dividend, 'first', to use as the next quotient bit. Then move the most significant bit of the low dividend into the carry flag bit.

*Lines 5211 to 5217:* Decrement '^count' by one and branch to 'okay\_out' if all bits are done.

*Lines 5218 to 5227:* Transfer the carry flag bit into the least significant bit of the high dividend.

*Lines 5228 to 5237:* Subtract 'second' from high dividend and save result at 'pointer'.

*Lines 5238 to 5246:* If the carry flag bit is set then the trial subtraction worked! Therefore, set the quotient bit and switch pointers to replace remainder and dividend. If the carry flag is clear, the trial subtraction failed; therefore skip swap over and branch direct as next quotient bit is zero.

*Line 5247:* Do next bit.

*Lines 5248 to 5250:* Finished with no errors detected.

*Lines 5251 to 5254:* Finished with an error present.

Once again, the first few programs lines show how the procedure can be set up, using BASIC. The procedure is assembled passing workspace, vectors and buffer locations as parameters (line 20). The two vectors at 'first' and 'second' are poked with buffer addresses (lines 30 and 40), which are subsequently seeded with the dividend and divisor (lines 60 and 70). The dividend is 10000 and the divisor 2, which require a total of three bytes' storage, as indicated in line 50 which pokes the byte count into 'totlen'.

After calling the routine the result is extracted from the buffer at &3400 and the remainder from the buffer at &3000.

Finding the square root of a number in machine code might at first sight seem rather difficult. However, there is a quite straightforward solution. The method is simply this: 'the square root of an integer number is equal to the total number of successively higher odd integer numbers that can be subtracted from it'. Consider the number 36: first we subtract one from it, then three, then five and so on until we have no remainder. The total number of odd numbers subtracted is its square root! Thus,

```
36-1=35 : partial root = 1
35-3=32 : partial root = 2
32-5=27 : partial root = 3
27-7=20 : partial root = 4
20-9=11 : partial root = 5
11-11=0 : final square root = 6
```

If the final partial root does not yield a result of 0 then a remainder is available which can be 'floated' to provide the decimal portion of the root.

Program 10.5 provides a suitable assembler-based procedure to calculate the square root of any single byte number located at 'byte'. The Y register is used to keep a count of the partial root which is incremented each time round the 'loop'. The location at 'byte+1' is used to hold the odd number to be subtracted. The final root is deposited in 'byte' and any remainder at 'byte+1'.

```

10 REM ***SINGLE BYTE SQUARE ROOT***
20 PROConebyte_square(&70,&C00)
30 ?&70=170
40 CALL square
50 PRINT:Square root =`;?&70
60 PRINT:remainder =`;?&71
70 END
80 :
5270 DEF PROConebyte_square(byte,addr)
5271 FOR pass=0 TO 3 STEP 3
5272 P%=addr
5273 [
5274 OPT pass
5275 .square
5276         LDY #0
5277         LDA #1
5278         STA byte+1
5279         LDA byte
5280 .loop
5281         CMP byte+1
5282         BCC finished
5283         SBC byte+1
5284         INY
5285         INC byte+1
5286         INC byte+1
5287         JMP loop
5288 .finished
5289         STY byte
5290         STA byte+1
5291         RTS
5292 ]
5293 NEXT
5294 ENDPROC

```

*Program 10.5. PROConebyte\_square - calculates the square root of a single-byte number.*

Program 10.5 is simple but effective. On entry to 'square' (line 5275) the Y register is initialised ready to take the partial root count; the

accumulator is loaded with the first odd number to be subtracted which is then written to the location 'byte+1' (lines 5276 to 5279). The subtract and count loop is embodied in lines 5280 to 5287. Line 5281 begins by comparing the contents from byte (the current remainder) with the next odd number, a clear carry flag denotes that the remainder is less than the next odd number and the program branches to 'finish'. A set carry and line 5283 subtracts the current odd number from the current remainder (line 5283) and the Y register is incremented. Before the loop is redone the two is added to the contents of 'byte+1' to move onto the next odd number (lines 5285 and 5286). Note that the program passes the immediate value through to the procedure for splitting into two bytes and storing in 'block' before the shift is performed. If the value is already held in 'block' then 'do-asl' can be called directly.

Program 10.6 is a double-byte version, Program 10.5 finding the square root of an unsigned 16-bit integer value. The two locations at 'byte' hold the integer value while 'temp' counts the double-byte odd number. The program operates virtually the same as its predecessor; but because a two-byte value is involved a subtraction rather than a compare must be performed initially. To ensure that the final subtraction will not erode any remainder, its possible low order byte is preserved in the X register. Looking further down the program listing (line 5322) it seems at first sight that the odd number counter is only being incremented by one. However, two is actually being added as the carry flag will be set at this point, if it is clear where the branch to 'finish' at line 5319 would have been performed.

```

10 REM *** TWO BYTE SQUARE ROOT ***
20 PROCTwobyte_square(&70,&72,&C00)
30 !&70=1234
40 CALL two_square
50 PRINT Square root =";?&70
60 PRINT remainder =";?&71
70 END
80 :
5300 DEF PROCTwobyte_square(byte,temp,a
addr)
5301 FOR pass=0 TO 3 STEP 3
5302 P%=addr
5303 [
5304 OPT pass
5305 .two_square
5306         LDY #1
5307         STY temp
5308         DEY
5309         STY temp+1
5310 .loop
5311         SEC

```

```

5312          LDA byte
5313          TAX
5314          SBC temp
5315          STA byte
5316          LDA byte+1
5317          SBC temp+1
5318          STA byte+1
5319          BCC finished
5320          INY
5321          LDA temp
5322          ADC #1
5323          STA temp
5324          BCC loop
5325          INC temp+1
5326 .finished
5327          STY byte
5328          STX byte+1
5329          RTS
5330 _
5331 NEXT
5332 ENDPROC

```

*Program 10.6. PROCtwobyte\_square - calculates the square root of a 16-bit value.*

### **By the left!**

The final five programs in this chapter deal with double-byte shifts and rotates. It may seem at first that these would be straightforward enough, but this is certainly not the case with the ASL and LSR combinations, as both of these introduce a 0 into bit 0 and bit 7 of the byte they are acting on respectively. Thus, a two-byte ASL will not yield the correct result if the sequence

```

ASL byte
ASL byte+1

```

is used.

To perform an overall ASL on two bytes, the initial ASL must be followed by a ROL. Program 10.7 illustrates the technique while Figure 10.1 shows what is happening. The ASL of line 5359 moves bit 7 of 'block+1' (the low byte in true 6502 back-to-frontness!) into the carry inserting a 0 into bit 0. Line 5360 then performs a ROL which moves bit 7 in the carry into bit 0 of 'block', shuffling the internal bits up one bit. The last bit, bit 7, falls out into the carry. The two-byte value has also been multiplied by two!

```

10 REM*** DOUBLE BYTE ASL ***
20 PROCtwo_byte_asl(1,&70,&C00)
30 CALLset_asl
40 FOR loop=1 TO 15
50 PRINT?&70*256+?&71
60 CALLdo_asl
70 NEXT loop
80 END
90 :
5350 DEF PROCtwo_byte_asl(num,block,addr
n)
5351 P%=addr
5352 [
5353 .set_asl
5354         LDA #num MOD 256
5355         STA block
5356         LDA #num DIV 256
5357         STA block+1
5358 .do_asl
5359         ASL block+1
5360         ROL block
5361         RTS
5362 ]
5363 ENDPROC

```

Program 10.7. PROCtwo\_byte\_asl - arithmetical shift left on a 16-bit value.

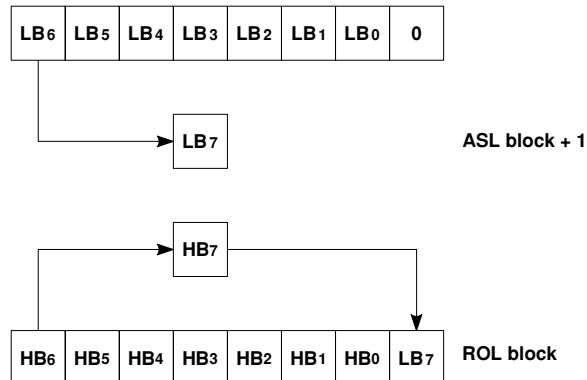


Fig. 10.1. Implementing a 16-bit shift register using an ASL/ROL

Program 10.8 works in the opposite direction performing an overall LSR using an LSR and ROR in conjunction. As the shift works in the opposite direction the bytes are referenced in the opposite order to an ASL. The shift is performed on the low byte in 'block' and the rotate on the high byte in 'block+1'. The total effect is to halve the two-byte number.

```

10 REM*** DOUBLE BYTE LSR ***
20 PROCtwo_byte_lsr(65535,&70,&C000)
30 CALLset_lsr
40 FOR loop=1 TO 15
50 PRINT?&70*256+?&71
60 CALLdo_lsr
70 NEXT loop
80 END
90 :
5370 DEF PROCtwo_byte_lsr(num,block,addr)
n)
5371 P%:=addr
5372 [
5373 .set_lsr
5374         LDA #num DIV 256
5375         STA block
5376         LDA #num MOD 256
5377         STA block+1
5378 .do_lsr
5379         LSR block
5380         ROR block+1
5381         RTS
5382 ]
5383 ENDPROC

```

*Program 10.8. PROCtwo\_byte\_lsr - logical shift right on a 16-bit value.*

Programs 10.9 and 10.10 perform double-byte RORs and ROLs respectively. The only difference to note here is the order in which the bytes in 'block' are rotated. In RORing a two-byte number, the low byte is rotated first. With a ROL it is the high byte that is manipulated first.

```

10 REM*** DOUBLE BYTE ROR ***
20 PROCtwo_byte_ror(32768,&70,&C000)
30 CALLset_ror
40 FOR loop=1 TO 15
50 PRINT?&70*256+?&71
60 CALLdo_ror
70 NEXT loop
80 END
90 :
5390 DEF PROCtwo_byte_ror(num,block,addr)

```

```

r)
5391 P%=addr
5392 [
5393 .set_ror
5394         LDA #num MOD 256
5395         STA block
5396         LDA #num DIV 256
5397         STA block+1
5398 .do_ror
5399         ROR block
5400         ROR block+1
5401         RTS
5402 ]
5403 ENDPROC

```

*Program 10.9. PROCtwo\_byte\_ror - a double-byte rotate right.*

```

10 REM*** DOUBLE BYTE ROL ***
20 PROCtwo_byte_rol(1,&70,&C00)
30 CALLset_rol
40 FOR loop=1 TO 15
50 PRINT?&70*256+?&71
60 CALLdo_rol
70 NEXT loop
80 END
90 :
5410 DEF PROCtwo_byte_rol(num,block,addr
r)
5411 P%=addr
5412 [
5413 .set_rol
5414         LDA #num MOD 256
5415         STA block
5416         LDA #num DIV 256
5417         STA block+1
5418 .do_rol
5419         ROL block
5420         ROL block+1
5421         RTS
5422 ]
5423 ENDPROC

```

*Program 10.10. PROCtwo\_byte\_rol - a double-byte rotate left.*

Finally, Program 10.11 shows how a multi-byte shift, left in this instance, can be implemented on an unsigned value between 2 and 255 bytes in length. The start of the bytes to be shifted are located in 'start' while the number of them is found in 'bytes'. The program commences by placing the 'bytes' count into the Y register and performing the initial

ASL on 'start' (lines 5434 to 5436). The X register is loaded with one and after decrementing the Y register the 'next' loop is entered (lines 5436 to 5438). From here on, indexed addressing is used to facilitate the ROL on the remaining bytes. The first handful of lines in the program point out the sort of interesting, and perhaps useful (!) applications the program can be used for. The test of line 50 is printed onto the MODE 6 screen before the memory is used to hold the test is shifted left twice (lines 60 and 70). The net effect is to provide 3D text!

```

10 REM *** MULTI LEFT SHIFT ***
20 REM *** GIVES 3D CHARACTERS ***
30 PROCmulti_left (&6000,64,&C00)
40 MODE 6
50 PRINT, HELLO THERE!!^
60 CALL&C00
70 CALL&C00
80 END

90 :
5430 DEF PROCmulti_left (start,bytes,ad
dr)
5431 FOR PASS=0 TO 3 STEP3
5432 P%:=addr
5433 [ :OPT PASS
5434             LDY bytes
5435             ASL start
5436             LDY #1
5437             DEY
5438 .next
5439             ROL start,X
5440             INX
5441             DEY
5442             BNE next
5443             RTS
5444 ]
5445 NEXT
5446 ENDPROC

```

*Program 10.11.* PROCmulti\_left - performs an arithmetic shift left on a multi-byte number.

## Program fact sheets

### *Program 10.1*

|                    |                              |
|--------------------|------------------------------|
| Procedure title    | : PROCmulti_add              |
| Variables required | : count, first, second, addr |
| Line numbers       | : 5000 to 5019               |
| Length             | : 16 bytes                   |



Zero page requirements: : five bytes  
 Registers changed : A, X, Y

### *Program 10.2*

Procedure title : PROCmulti\_sub  
 Variables required : count, first, second, addr  
 Line numbers : 5030 to 5049  
 Length : 16 bytes  
 Zero page requirements: : 5 bytes  
 Registers changed : A, X, Y

### *Program 10.3*

Procedure title : PROCmulti\_mult  
 Variables required : first, second, totlen, count buffer, addr  
 Line numbers : 5050 to 5128  
 Length : 114 bytes  
 Zero page requirements: : 6 bytes  
 Registers changed : A, X, Y

### *Program 10.4*

Procedure title : PROCmulti\_div  
 Variables required : first, second, totlen, count, hidiv\_pointer,  
 pointer, 1 buffer2, addr  
 Line numbers : 5150 to 5257  
 Length : 54 bytes  
 Zero page requirements : 11 bytes  
 Registers changed : A, X, Y

### *Program 10.5*

Procedure title : PROConebyte\_square  
 Variables required : byte, addr  
 Line numbers : 5270 to 5294  
 Length : 27 bytes  
 Zero page requirements : 2 bytes  
 Registers changed : A, X, Y

### *Program 10.6*

Procedure title : PROCTwobyte\_square

|                        |                    |
|------------------------|--------------------|
| Variables required     | : byte, temp, addr |
| Line numbers           | : 5300 to 5332     |
| Length                 | : 39 bytes         |
| Zero page requirements | : 4 bytes          |
| Registers changed      | : A, X, Y          |

*Program 10.7*

|                        |                    |
|------------------------|--------------------|
| Procedure title        | : PROCtwo_byte_asl |
| Variables required     | : num, block, addr |
| Line numbers           | : 5350 to 5363     |
| Length                 | : 13 bytes         |
| Zero page requirements | : 2 bytes          |
| Registers changed      | : A                |

*Program 10.8*

|                        |                    |
|------------------------|--------------------|
| Procedure title        | : PROCtwo_byte_lsr |
| Variables required     | : num, block, addr |
| Line numbers           | : 5370 to 5383     |
| Length                 | : 13 bytes         |
| Zero page requirements | : 2 bytes          |
| Registers changed      | : A                |

*Program 10.9*

|  |                    |
|--|--------------------|
| Procedure title                          | : PROCtwo_byte_ror |
| Variables required                       | : num, block, addr |
| 106 The BBC Micro Machine Code Portfolio |                    |
| Line numbers                             | : 5390 to 5403     |
| Length                                   | : 13 bytes         |
| Zero page requirements                   | : 2 bytes          |
| Registers changed                        | : A                |

*Program 10.10*

|                        |                    |
|------------------------|--------------------|
| Procedure title        | : PROCtwo_byte_rol |
| Variables required     | : num, block, addr |
| Line numbers           | : 5410 to 5423     |
| Length                 | : 13 bytes         |
| Zero page requirements | : 2 bytes          |
| Registers changed      | : A                |

Program 10.11

|                        |                      |
|------------------------|----------------------|
| Procedure title        | : PROCmulti_left     |
| Variables required     | : start, bytes, addr |
| Line numbers           | : 5430 to 5446       |
| Length                 | : 16 bytes           |
| Zero page requirements | : 1 byte             |
| Registers changed      | : A, X, Y            |

## Chapter Eleven

# Vision On

This chapter is devoted entirely to exploring the graphics capabilities of the Beeb from machine code. Many of the procedures are based on the VDU driver routine OSWRCH and all the graphics commands available from BASIC are implemented here plus a few more! These extras include two new screen modes which give scaled down versions of MODE 2 and MODE 5, plus a routine utilising the \*640 table in the BASIC interpreter to convert an X, Y coordinate pair into the corresponding screen address.

I use many of these routines as part of a simple graphics compiler (SGC) which uses simple INPUT commands to call the appropriate PROC to compile the necessary machine code but on to the routines.

### Just mode about you

Program 11.1 performs a mode change in machine code. This is done by sending the VDU value 22 to the driver followed by the mode number which should be passed into the procedure via 'action'. The assembled code is very short - just 11 bytes including the RTS.

```

10 REM *** DO MODE ***
20 CLS
30 INPUT"Which MODE ?"M%
40 PROCmode (M%,&C00)
50 CALL mode
60 PRINT"This is MODE ";M%
70 END
80 :
6000 DEF PROCmode (action,addr)
6001 P%=addr
6002 [
6003 .mode
6004             LDA #22
6005             JSR &FFEE
6006             LDA #action
6007             JSR &FFEE
6008             RTS

```

```
6009 J
6010 ENDPROC
```

*Program 11.1. PROCmode - performs a MODE change.*

Program 11.2 provides a new screen mode. As it is made out of the MODE 2 screen I have christened it MODE 2A. This new mode still has all the sixteen colours of a normal MODE 2 available but only requires half the memory, 10K, for displaying them. The screen itself is composed of 25 rows of 20 characters. The program is given in its long-winded form so that I can try to explain its operation better! Obviously, it would be more economical in terms of memory to implement the final version with the VDU codes in a look-up table using an indexing routine to pull them out one by one and send them to OSWRCH.

```
10 REM *** NEW MODE 2A SCREEN ***
20 PROCmode2A (&A00)
30 CALL &A00
40 END
50 :
6100 DEF PROCmode2A (addr)
6101 FOR PASS=0 TO 3 STEP3
6102 Px=addr
6103 C :OPT PASS
6104         LDA #22
6105         JSR &FFEE
6106         LDA #2
6107         JSR &FFEE
6108         LDA #23
6109         JSR &FFEE
6110         LDA #0
6111         JSR &FFEE
6112         LDA #6
6113         JSR &FFEE
6114         LDA #25
6115         JSR &FFEE
6116         JSR SIX
6117         LDA #23
6118         JSR &FFEE
6119         LDA #0
6120         JSR &FFEE
6121         LDA #7
6122         JSR &FFEE
6123         LDA #30
6124         JSR &FFEE
6125         JSR SIX
6126         LDA #23
6127         JSR &FFEE
6128         LDA #0
6129         JSR &FFEE
```

```

6130          LDA #12
6131          JSR &FFEE
6132          LDA #8
6133          JSR &FFEE
6134          JSR SIX
6135          LDA #23
6136          JSR &FFEE
6137          LDA #0
6138          JSR &FFEE
6139          LDA #14
6140          JSR &FFEE
6141          LDA #8
6142          JSR &FFEE
6143          JSR SIX
6144          LDA #5
6145          STA &FE40
6146          LDA #56
6147          STA &302
6148          LDA #24
6149          STA &309
6150          LDA #40
6151          STA &D9
6152          STA &34B
6153          STA &34E
6154          STA &351
6155          STA &354
6156          LDA #&40
6157          STA &7
6158          LDA #0
6159          STA &6
6160          RTS
6161 .SIX
6162          LDA #0
6163          LDX #6
6164 .AGAIN
6165          JSR &FFEE
6166          DEX
6167          BNE AGAIN
6168          RTS
6169 ]
6170 NEXT
6171 ENDPROC

```

*Program 11.2. PROCmode2A - implements a scaled down version of MODE 2.*

It might be easier to understand exactly what is going on if the assembler is broken down into its BASIC equivalent which, incidentally, will also produce the desired effect.

*Line 6104 to 6107* : MODE 2  
*Line 6108 to 6116* : VDU 23;6,25;0;0;0;  
*Line 6117 to 6125* : VDU 23;7,30;0;0;0;  
*Line 6126 to 6134* : VDU 23;12,8;0;0;0;  
*Line 6135 to 6143* : VDU 23;14,8;0;0;0;  
*Line 6144 to 6145* : ?&FE40=5  
*Line 6146 to 6147* : ?&302=56  
*Line 6148 to 6149* : ?&309=24  
*Line 6150 to 6151* : ?&D9=40  
*Line 6152 to 6155* : ?&34B=40  
                               : ?&34E=40  
                               : ?&351=40  
                               : ?&354=40  
*Lines 6156 to 6159* : HIMEM=&4000

The VDU statements (lines 6108 to 6143) reprogram several registers of the 6845 cathode ray tube controller (CRTC) which is responsible for organising the screen memory. The BASIC equivalents show that the first and second parameter bytes are used in programming the CRTC. The first determines the CRTC register and the second the value to be written into it. Taking the four VDU23 statements in turn they perform the following tasks:

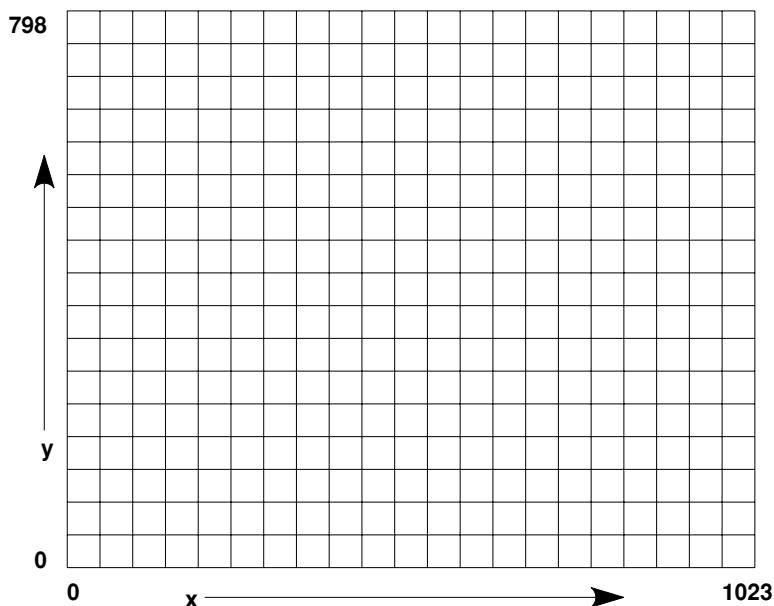
- (a) Program number of lines
- (b) Set position of vertical sync in number of row times
- (c) Set top of screen address
- (d) Set cursor position

The remaining pokes write to the VDU variables directly which, strictly speaking, is rather naughty! The poke to &FE40 is writing to the system VIA scroll-controlling register, while the subsequent two pokes define the bottom row, in pixels, of the graphics window and the bottom row of the text window. &D9 holds the high byte of the current address of the top scan line of a character (HIMEM is being set to &4000, thus the &40); &34B high byte of the top cursor location; &34E top+1 address of user memory; &351 the high byte address of the top left-hand corner of the screen; and finally &354 the high byte of the screen memory size.

Because the screen is not an official mode it is organised rather crookedly. For example, the pixel coordinates for the Y axis do not run from 0 to 1023 as one might expect but from 225 to 1023. Also, the screen itself tends to sit in the middle of the TV rather than using it all. To counteract the Y axis distortion, the graphics origin could be reset to 0,225 using VDU 29, thus:

```
VDU 29,0;225;
MOVE 0,0
```

This will reduce the maximum on-screen Y graphics coordinate to 798 but the range 0 to 798 is easier to use than 225 to 1023. Figure 11.1 provides a suitable map of MODE 2A.



*Fig. 11.1. The MODE 2A screen map.*

Program 11.3 works along similar lines in that it pokes various VDU variables to set up a new graphics mode screen from MODE 5. However, rather than reprogramming the CRTC, it writes to the Video ULA using an OSBYTE call (lines 6027 to 6030). This writes, in fact, to the Video Control Register whose layout is given in Figure 11.2. The byte written is 224 or &E0 in hex, thus causing a large cursor two bytes in width to be displayed.

```
10 REM *** NEW MODE 5A ***
20 PROCmode5A (&A00)
30 DRAW1000,100
40 CALL &A00
50 MOVE 100,100
```



```

60 DRAW 1000,100
70 DRAW 1000,1000
80 DRAW 100,1000
90 DRAW 100,100
100 END
110 :
6020 DEF PROCmode5A (addr)
6021 P% = addr
6022 [
6023         LDA #22
6024         JSR &FFEE
6025         LDA #5
6026         JSR &FFEE
6027         LDA #154
6028         LDX #224
6029         JSR &FFF4
6030         LDA #15
6031         STA &360
6032         LDA #1
6033         STA &361
6034         LDA #32
6035         STA &34F
6036         LDA #855
6037         STA &363
6038         LDA #8AA
6039         STA &362
6040         LDA #9
6041         STA &30A
6042         LDA #20
6043         JSR &FFEE
6044         LDA #854
6045         STA &07
6046         LDA #0
6047         STA &6
6048         JMP &FFEE
6049 ]
6050 ENDPROC

```

*Program 11.3.* PROCmode5A - implements a scaled down version of MODE

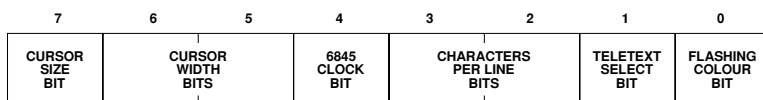


Fig. 11.2. The Video Control Register

This mode requires just 10K of RAM but also allows 16 colours like MODE 2 and MODE 2A! The mode allows 16 rows of 10 characters and HIMEM is set to &5400. The program description follows.

*Lines 6023 to 6026* : Select MODE 5.

*Lines 6027 to 6029* : Write to video ULA cursor control bits.

*Lines 6030 to 6031* : All 16 colours available.

*Lines 6032 to 6033* : Two 4-bit pixels per byte.

*Lines 6034 to 6035* : 32 bytes used per character.

*Lines 6036 to 6039* : Set colour details.

*Lines 6040 to 6041* : 10 characters on each line (0 to 9).

*Lines 6042 to 6043* : Do VDU 20 and rest default colours.

*Lines 6044 to 6048* : Set HIMEM = &5400.

## Moving on

The three drawing-orientated processes, MOVE, DRAW and PLOT, can be performed using a VDU25 sequence, once again passing bytes through OSWRCH. After issuing the VDU25 sequence, OSWRCH expects five more bytes to be passed through to it. The first of these determines exactly what function is to be performed, while the remaining four bytes provide the double-byte values of first the X and then the Y coordinates, low bytes first.

Program 11.4 lists a suitable MOVE procedure. The MOVE code is 4 (line 6186) while the X, Y coordinates are passed for immediate addressing through the variables 'xpos' and 'ypos'. The demo uses the procedure to move the graphics cursor to the centre of the screen at 640,512 before plotting a point there (lines 20 to 50).

```

10 REM *** DO MACHINE CODE MOVE ***
20 PROCmove(640,512,&A00)
30 MODE 5
40 CALL move
50 DRAW 640,512
60 END
70 :
6180 DEF PROCmove(xpos,ypos,addr)
6181 P%=addr
6182 [
6183 .move
6184         LDA #25
6185         JSR &FFEE
6186         LDA #4
6187         JSR &FFEE
6188         LDA #xpos MOD 256
6189         JSR &FFEE
6190         LDA #xpos DIV 256
6191         JSR &FFEE
6192         LDA #ypos MOD 256
6193         JSR &FFEE
6194         LDA #ypos DIV 256
6195         JSR &FFEE
6196         RTS
6197 ]
6198 ENDPROC

```

*Program 11.4. PROCmove - performs MOVE.*

Program 11.5 uses the driver code 6 (line 6206) to execute the machine code equivalent of a DRAW. The positions passed into the procedure are taken to be the coordinates to draw to. The demo program draws a line diagonally across the MODE 4 screen from 0,0 to 1000,1000. Once again, immediate addressing is used in the program to obtain the X, Y coordinates which must therefore be passed into the procedure at assembly time.

```

10 REM *** DO MACHINE CODE DRAW LINE
***
20 PROCdraw(1000,1000,&C00)
30 MODE 4
40 MOVE 0,0
50 CALL &C00
60 END
70 :
6200 DEF PROCdraw(xcord,ycord,addr)
6201 P%=addr
6202 [
6203 .draw_line
6204 LDA #25

```

```

6205 JSR &FFEE
6206 LDA #6
6207 JSR &FFEE
6208 LDA #xcord MOD 256
6209 JSR &FFEE
6210 LDA #xcord DIV 256
6211 JSR &FFEE
6212 LDA #ycord MOD 256
6213 JSR &FFEE
6214 LDA #ycord DIV 256
6215 JSR &FFEE
6216 RTS
6217 ]
6218 ENDPROC

```

*Program 11.5. PROCdraw - performs DRAW.*

```

10 REM *** DO MACHINE CODE PLOT ***
20 PROCplot(85,1000,1000,&C00)
30 MODE 4
40 MOVE 0,0
50 MOVE 1000,0
60 CALL plot
70 END
80 :
6220 DEF PROCplot(code,xcord,ycord,addr
)
6221 P%:=addr
6222 [ OPT 2
6223 .plot
6224             LDA #25
6225             JSR &FFEE
6226             LDA #code
6227             JSR &FFEE
6228             LDA #xcord MOD 256
6229             JSR &FFEE
6230             LDA #xcord DIV 256
6231             JSR &FFEE
6232             LDA #ycord MOD 256
6233             JSR &FFEE
6234             LDA #ycord DIV 256
6235             JSR &FFEE
6236             RTS
6237 ]
6238 ENDPROC

```

*Program 11.6. PROCplot - performs PLOT.*

A PLOT is performed using the driver code which is equivalent to the

plot function required. Program 11.6 shows how the PLOT code is passed into the procedure through the variable 'code'. The demo uses code 85 to draw and fill a triangle in a MODE 4 screen. As you may now realise, the previous two programs were, in fact, simply using the plot codes for move and draw.

## Paint-box

The use of colour is usually desirable for graphics and both COLOUR and GCOL can be readily performed. Program 11.7 can be used to redefine the text colour used by PRINT. It uses the VDU17 command with a second byte in the range 0 to 15 being passed to OSWRCH to define the colour. The number associated with each physical colour is detailed in Figure 11.3 and the chosen value should be passed to the procedure in the 'print\_colour' variable. The demo sets up printing in red on a MODE 2 screen.

| Number | Colour                 |
|--------|------------------------|
| 0      | Black                  |
| 1      | Red                    |
| 2      | Green                  |
| 3      | Yellow                 |
| 4      | Blue                   |
| 5      | Magenta                |
| 6      | Cyan                   |
| 7      | White                  |
| 8      | Flashing black-white   |
| 9      | Flashing red-cyan      |
| 10     | Flashing green-magenta |
| 11     | Flashing yellow-blue   |
| 12     | Flashing blue-yellow   |
| 13     | Flashing magenta-green |
| 14     | Flashing cyan-red      |
| 15     | Flashing white-black   |

*Fig 11.3. The physical colours.*

```

10 REM *** DO PRINT COLOUR ***
20 PROCcolour (1,&C00)
30 MODE 2
40 CALL colour
50 END

```

```

60 :
6250 DEF PROCcolour(print_colour,addr)
6251 P%=addr
6252 [
6253 .colour
6254     LDA #17
6255     JSR &FFEE
6256     LDA #print_colour
6257     JSR &FFEE
6258     RTS
6259 ]
6260 ENDPROC

```

*Program 11.7. PROCcolour - performs COLOUR.*

Program 11.8 shows how the background colour can be redefined using VDU17 again. Essentially the program is the same as its predecessor. To stipulate a background colour, however, the most significant bit of the colour byte must be set. In everyday terms, this simply means adding 128 to the colour value. After passing the background colour to the VDU driver (lines 6276 to 6277) the screen must be cleared. This is facilitated simply by printing the equivalent of a VDU12 (lines 6278 to 6279). The demo program initialises a red MODE 2 screen.

```

10 REM *** DO BACKGROUND COLOUR ***
20 REM *** SET RED BACKGROUND ***
30 PROCbackgrnd (129,&C00)
40 MODE 2
50 CALL backgrnd
60 END
70 :
6270 DEF PROCbackgrnd (back_col,addr)
6271 P%=addr
6272 [
6273 .backgrnd
6274     LDA #17
6275     JSR &FFEE
6276     LDA #back_col
6277     JSR &FFEE
6278     LDA #12
6279     JSR &FFEE
6280     RTS
6281 ]
6282 ENDPROC

```

*Program 11.8. PROCbackgrnd - changes the mode background colour.*

Performing GCOL is almost as easy, however. The GCOL statement requires two parameters. After issuing VDU18 first, the byte depicting the action required (i.e. AND, OR, EOR) should be passed to OSWRCH followed by the colour. These bytes are shown in Program 11.9 as 'action' and 'colour' and the associated demo program (lines 10 to 70) set up a flashing black and white diagonal line across the MODE 2 screen.

The graphics screen can be cleared from BASIC using the command CLG. In machine code this is simplicity itself and only requires the vdu driver to print the code 16 through OSWRCH. Program 11.10 demonstrates this.

```

10 REM *** DO MACHINE CODE GCOL ***
20 REM *** FLASHING B/W LINE ***
30 PROCgcol (0,8,&C00)
40 MODE 2
50 CALL gcol
60 MOVE 0,0:DRAW 1000,1000
70 END
80 :
6285 DEF PROCgcol (action,colour,addr)
6286 P%=addr
6287 [
6288 .gcol
6289 LDA #18
6290 JSR &FFEE
6291 LDA #action
6292 JSR &FFEE
6293 LDA #colour
6294 JSR &FFEE
6295 RTS
6296 ]
6297 ENDPROC

```

*Program 11.9. PROCgcol - performs GCOL.*

```

10 REM**CLEAR GRAPHICS SCREEN -CLG**
20 PROCclg (&C00)
30 MODE 2
40 COLOUR129
50 CLS
60 PRINT"PRESS A KEY TO CLEAR SCREEN"
70 A=GET
80 CALL &C00
90 END
100 :
6300 DEF PROCclg (addr)
6301 P%=addr

```

```

6302 [
6303 .clear_graphics
6304 LDA #16
6305 JSR &FFEE
6306 RTS
6307 ]
6308 ENDPROC

```

*Program 11.10. PROCcgl - performs CLG.*

Programming the palette is done as in BASIC using VDU 19 in the form:

VDU 19, log, phy, 0,0,0

where 'log' and 'phy' refer to the logical and physical colours respectively. Program 11.11 shows how this is translated into assembler. After the 19 is printed (lines 6314 and 6315) the logical and physical colour codes are passed to OSWRCH (lines 6316 to 6319) followed by the three padding zeros (lines 6320 to 6323) reserved for future expansion, whatever that is! Once again, the values passed into the procedure for 'log' and 'phy' are interpreted as immediate values by the assembler.

The lines 10 to 110 show how the procedure is used in this case to re-set the current screen background logical colour to each physical colour in turn.

```

10 REM *** DO VDU 19 ***
20 REM** GO FRU ALL COLOURS **
30 MODE 2
40 FOR loop=1 TO 15
50 PROCchange_palette (0,loop,&C00)
60 CALL chgpalette
70 FOR N=0 TO 999:NEXT
80 NEXT
90 PROCchange_palette (0,0,&C00)
100 CALL chgpalette
110 END
120 :
6310 DEF PROCchange_palette (log,phy,ad
dr)
6311 P%=addr
6312 [ OPT 2
6313 .chgpalette
6314 LDA #19
6315 JSR &FFEE
6316 LDA #log
6317 JSR &FFEE

```



```

6318 LDA #phy
6319 JSR &FFEE
6320 LDA #0
6321 JSR &FFEE
6322 JSR &FFEE
6323 JSR &FFEE
6324 RTS
6325 J
6326 ENDPROC

```

*Program 11.11. PROCchange\_palette - reprograms the palette using OSWORD.*

### **Read it write!**

Occasionally it is useful to be able to know the last two sets of coordinates visited by the graphics cursor, so Acorn have implemented an OSWORD call to enable this feat. The call code is 13 and as with all OSWORD calls an address held with the index registers points to a parameter block where in this case OSWORD deposits the required information, Figure 11.4 details the information contained in the block after the call and Program 11.12 the technique. Lines 10 to 140 demonstrate the call by first moving the graphics cursor to a new positions on the MODE 4 screen before calling the procedure and reading its eight-byte result from the parameter block which in this instant is in zero page.

---

```

XY+0 : previous X coordinate LSB
XY+1 : previous X coordinate MSB
XY+2 : previous Y coordinate LSB
XY+3 : previous Y coordinate MSB
XY+4 : current X coordinate LSB
XY+5 : current X coordinate MSB
XY+6 : current Y coordinate LSB
XY+7 : current Y coordinate MSB

```

---

*Fig. 11.4. OSWORD 13 parameter block for reading last two graphics coordinates.*

```

10 REM *** READ LAST 2 GRAPHICS ***
20 REM *** CURSOR POSITIONS ***
30 MODE 4
40 MOVE 200,200

```

```

50 DRAW 500,500
60 MOVE 700,700
70 DRAW 900,900
80 CLS
90 PROCgcursor(&70,&C00)
100 CALL &C00
110 FOR loop=&70 TO &77
120 PRINT"loop;" ";?loop
130 NEXT loop
140 END
150 :
6330 DEF PROCgcursor(block,addr%)
6331 FOR pass=0 TO 3 STEP3
6332 P%=addr%
6333 [ OPT pass
6334         LDA #13
6335         LDX #block MOD 256
6336         LDY #block DIV 256
6337         JSR &FFF1
6338         RTS
6339 ]
6340 NEXT
6341 ENDPROC

```

*Program 11.12. PROCgcursor - uses OSWORD to read the last two graphics coordinates.*

The condition of any pixel on the screen can also be read using OSWORD with the accumulator holding 9 - in effect, mimicking BASIC's POINT command (see Program 11.13). Before calling the operating system routine, the obligatory parameter block (detailed in Figure 11.5) must have some relevant details placed into it, namely the X,Y coordinates of the byte to be tested. Each coordinate uses two bytes of the parameter block and these are derived in lines 6345 to 6361 of the procedure. The procedure again assumes that the actual coordinates, and not an address containing them, are passed through the variable X and Y. Each byte is then stored in the relevant parameter block location. After seeding the parameter block address into the index registers (lines 6362 to 6364) the OSWORD call is performed leaving the logical colour of the coordinate in the fifth block of the parameter block - or &FF if the print was off of the screen.

```

10 REM READ PIXEL VALUES
20 PROCpixel(&70,100,100,&C00)
30 MODE 2
40 CALL&C00
50 PRINT"block?4

```

```

60 END
70 :
6350 DEF PROCpixel(block,X,Y,addr)
6351 FOR pass=0 TO 3 STEP3
6352 P%=addr
6353 C OPT pass
6354 LDA #X MOD 256
6355 STA block
6356 LDA #X DIV 256
6357 STA block+1
6358 LDA #Y MOD 256
6359 STA block+2
6360 LDA #Y DIV 256
6361 STA block+3
6362 LDX #block MOD 256
6363 LDY #block DIV 256
6364 LDA #9
6365 JSR &FFF1
6366 RTS
6367 J
6368 NEXT
6369 ENDPROC
6332 P%=addr%
6333 C OPT pass
6334 LDA #13
6335 LDX #block MOD 256
6336 LDY #block DIV 256
6337 JSR &FFF1
6338 RTS
6339 J
6340 NEXT
6341 ENDPROC

```

Program 11.13. PROCpixel - reads the state of a screen pixel.

---

```

XY+0 : X coordinate LSB
XY+1 : X coordinate MSB
XY+2 : Y coordinate LSB
XY+3 : Y coordinate MSB
XY+4 : Logical colour of point, &FF if point off screen.

```

---

Fig. 11.5. OSWORD 9 parameter block to perform POINT.

```

10 REM *** READ COLOUR PALETTE ***
20 MODE 4
30 VDU19,1,3,0,0,0

```

```

40 PROCreadpalette (&70,&C00,1)
50 CALL &C00
60 PRINT"Logical colour :";?&70
70 PRINT"Physical colour :";?&71
80 END
90 :
6380 DEF PROCreadpalette (block, addr%,
L%)
6381 FOR pass=0 TO 3 STEP 3
6382 P%=addr%
6383 [ OPT pass
6384         LDA #L%
6385         STA block
6386         LDA #11
6387         LDX #block MOD 256
6388         LDY #block DIV 256
6389         JSR &FFF1
6390         RTS
6391 ]
6392 NEXT pass
6393 ENDPROC

```

*Program 11.14.* PROCreadpalette - reads the physical colour associated with a logical colour.

The colour palette can itself be read using an OSWORD 11 as shown in Program 11.14. The logical colour to be read should be placed into the five-byte parameter block. After the call, the physical colour currently assigned to the logical colour is in the second byte of the parameter block. The remaining three parameter block bytes contain zero - yes, for future expansion! The BASIC demo uses the call to read the physical colour assigned to logical colour 1 on the MODE 4 screen, this having been defined prior to the call in line 30 as 3.

Program 11.15 performs the operation in the reverse direction by writing to the palette using OSWORD 12. The parameter block is identical to that in a read operation except that the physical colour to be written must also be placed into the parameter block. The procedure passes both logical and physical colours to the assembler through the variables L% and PY%. The demo resets the MODE 4 logical colour 0, the background colour, to physical colour yellow, thereby performing an instant change in background colour.

```

10 REM *** WRITE TO PALETTE ***
20 MODE 4
30 PROCwritepalette (&70,0,3,&C00)
40 CALL &C00
50 END
60 :
6400 DEF PROCwritepalette (block,L%,PY%

```

```

,addr%)
6401 P%=addr%
6402 [
6403 LDA # L%
6404 STA block
6405 LDA # PY%
6406 STA block+1
6407 LDA #0
6408 STA block+2
6409 STA block+3
6410 STA block+4
6411 LDA #12
6412 LDX #block MOD 256
6413 LDY #block DIV 256
6414 JSR &FFF1
6415 RTS
6416 ]
6417 ENDPROC

```

*Program 11.15. PROCwritepalette - performs VDU 19.*

## Co-ordinating screen addresses

The final routine in this chapter, Program 11.16, utilises the BASIC interpreter's \*640 table at &C357 to convert an XY coordinate position on the screen (MODES 0, 1 and 2 only) into an absolute memory address. The table is a 32 byte by 2 byte affair which, unusually, is presented high byte first.

```

10 REM ** CONVERT X,Y TO ADDRESS **
20 PROCxyaddr(&80, &72, &71,&900)
30 REPEAT
40 INPUT "What is the X axis value - 0
to 79 "&71
50 INPUT ""What is the Y axis value -
0 to 255 "&72
60 CALLCODE
70 PRINT "&80+&81*256
80 UNTIL0
90 :
6500 DEFPROCxyaddr(vector, yaxis, xaxis
, addr)
6501 FORI%=0TO2 STEP2
6502 P%=addr
6503 [ OPTI%
6504 .CODE
6505             LDA#0
6506             STA vector

```

```

6507          STA vector+2
6508          LDA#&30
6509          STA vector+1
6510          LDA yaxis
6511          AND#7
6512          STA yaxis +1
6513          EOR yaxis
6514          LSRA
6515          LSRA
6516          TAY
6517          INY
6518          LDA&C375,Y
6519          CLC
6520          ADC vector
6521          ADC yaxis +1
6522          STA vector
6523          DEY
6524          LDA&C375,Y
6525          ADC vector+1
6526          STA vector+1
6527          LDA xaxis
6528          LDX#3
6529 .LOOP
6530          ASLA
6531          ROL vector+2
6532          DEX
6533          BNE LOOP
6534          ADC vector
6535          STA vector
6536          LDA#0
6537          ADC vector+2
6538          ADC vector+1
6539          STA vector+1
6540          LDY#0
6541          LDA#&FF
6542          STA(vector),Y
6543          RTS
6544 ]
6545 NEXT
6546 ENDPROC

```

*Program 11.16.* PROCxy\_addr - converts an X,Y coordinate into a screen address.

The program begins by clearing a few bytes of memory (lines 6505 to 6509) and setting vector to the start screen address. The MOD 8 value of the 'yaxis' is then calculated along with the DIV 8 value (lines 6510 to 6513). The actual value to be calculated is, in fact,  $Y \text{ DIV } 8 * 640$ . However, since the table values are two-byte the DIV is restricted to 4 (lines 6514 to 6516). The accumulator is transferred into the Y register

to get the index into the table, and is subsequently incremented to get the second, low byte (lines 6516 to 6518). The low byte is added to give Y axis MOD 8 (lines 6519 to 6522) and after extracting the high byte from the table this is added to give Y axis DIV 8 \*640 (lines 6523 to 6527). Finally, the X axis value is multiplied by 8 and any bits falling off are caught in 'vector+3' (lines 6528 to 6533). This is then added to the low byte of the screen address to give the final address (lines 6534 to 6539). By way of demonstration, &F is then poked into screen memory at this point: to see this the program will need to be run in MODE 2 (lines 6540 to 6542).

## **Program fact sheets**

### *Program 11.1*

|                        |                |
|------------------------|----------------|
| Procedure title        | : PROCmode     |
| Variables required     | : action, addr |
| Line numbers           | : 6000 to 6010 |
| Length                 | : 11 bytes     |
| Zero page requirements | : none         |
| Registers changed      | : A            |

### *Program 11.2*

|                        |                |
|------------------------|----------------|
| Procedure title        | : PROCmode2A   |
| Variables required     | : addr         |
| Line numbers           | : 6100 to 6170 |
| Length                 | : 153 bytes    |
| Zero page requirements | : none         |
| Registers changed      | : A, X         |

### *Program 11.3*

|                        |                |
|------------------------|----------------|
| Procedure title        | : PROCmode5A   |
| Variables required     | : addr         |
| Line numbers           | : 6020 to 6049 |
| Length                 | : 58 bytes     |
| Zero page requirements | : none         |
| Registers changed      | : A            |

*Program 11.4*

|                        |                    |
|------------------------|--------------------|
| Procedure title        | : PROCmove         |
| Variables required     | : xpos, ypos, addr |
| Line numbers           | : 6180 to 6198     |
| Length                 | : 31 bytes         |
| Zero page requirements | : none             |
| Registers changed      | : A                |

*Program 11.5*

|                        |                      |
|------------------------|----------------------|
| Procedure title        | : PROCdraw           |
| Variables required     | : xcord, ycord, addr |
| Line numbers           | : 6200 to 6218       |
| Length                 | : 31 bytes           |
| Zero page requirements | : none               |
| Registers changed      | : A                  |

*Program 11.6*

|                        |                            |
|------------------------|----------------------------|
| Procedure title        | : PROCplot                 |
| Variables required     | : code, xcord, ycord, addr |
| Line numbers           | : 6220 to 6238             |
| Length                 | : 31 bytes                 |
| Zero page requirements | : none                     |
| Registers changed      | : A                        |

*Program 11.7*

|                        |                      |
|------------------------|----------------------|
| Procedure title        | : PROCcolour         |
| Variables required     | : print_colour, addr |
| Line numbers           | : 6250 to 6260       |
| Length                 | : 11 bytes           |
| Zero page requirements | : none               |
| Registers changed      | : A                  |

*Program 11.8*

|                        |                  |
|------------------------|------------------|
| Procedure title        | : PROCbackgrnd   |
| Variables required     | : back_col, addr |
| Line numbers           | : 6270 to 6282   |
| Length                 | : 16 bytes       |
| Zero page requirements | : none           |
| Registers changed      | : A              |



*Program 11.9*

|                        |                        |
|------------------------|------------------------|
| Procedure title        | : PROCgcol             |
| Variables required     | : action, colour, addr |
| Line numbers           | : 6285 to 6297         |
| Length                 | : 16 bytes             |
| Zero page requirements | : none                 |
| Registers changed      | : A                    |

*Program 11.10*

|                        |                |
|------------------------|----------------|
| Procedure title        | : PROCclg      |
| Variables required     | : addr         |
| Line numbers           | : 6300 to 6308 |
| Length                 | : 6 bytes      |
| Zero page requirements | : norie        |
| Registers changed      | : A            |

*Program 11.11*

|                        |                      |
|------------------------|----------------------|
| Procedure title        | : PROCchange_palette |
| Variables required     | : log, phy, addr     |
| Line numbers           | : 6310 to 6326       |
| Length                 | : 27 bytes           |
| Zero page requirements | : none               |
| Registers changed      | : A                  |

*Program 11.12*

|                        |                |
|------------------------|----------------|
| Procedure title        | : PROCgcursor  |
| Variables required     | : block, addr  |
| Line numbers           | : 6330 to 6341 |
| Length                 | : 10 bytes     |
| Zero page requirements | : none         |
| Registers changed      | : A, X, Y      |

*Program 11.13*

|                    |                     |
|--------------------|---------------------|
| Procedure title    | : PROCpixel         |
| Variables required | : block, X, Y, addr |
| Line numbers       | : 6350 to 6369      |
| Length             | : 26 bytes          |

Zero page requirements : none  
Registers changed : A, X, Y

*Program 11.14*

Procedure title : PROCreadpalette  
Variables required : block, addr, L%  
Line numbers : 6380 to 6393  
Length : 14 bytes  
Zero page requirements : none  
Registers changed : A, X, Y

*Program 11.15*

Procedure title : PROCwritepalette  
Variables required : block, L%, PY%, addr  
Line numbers : 6400 to 6417  
Length : 26 bytes  
Zero page requirements : none  
Registers changed : A, X, Y  
Vision On129

*Program 11.16*

Procedure title : PROCxy\_addr  
Variables required : vector, yaxis, xaxis, addr  
Line numbers : 6500 to 6545  
Length : 69 bytes  
Zero page requirements : 6 bytes  
Registers changed : A, X, Y



## Chapter Twelve

# Assembling Data and Lists

Most programs written by most advanced BASIC programmers require the manipulation of data at some stage. Everyday life revolves around manipulating data and lists correctly. A telephone directory or an address book are samples of ordered lists (though a look at my address book with its loose and sellotaped pages would make you think otherwise!) whereby each entry is in alphabetical order. Searching through the pages for a particular address or phone number is quite simple. Imagine the problems if these entries were unordered.

Performing searches, adding and deleting items from lists and sorting in machine code is not as easy as its BASIC counterparts. The procedures in this chapter cover each of these aspects and should provide you with the basis for most of the data handling you require.

The programs provided in this chapter are:

*Program 12.1:* Byte search.

*Program 12.2:* Add a byte to an ordered list.

*Program 12.3:* Delete a byte from an ordered list.

*Program 12.4:* Find minimum and maximum values in an unordered list.

*Program 12.5:* Delete a byte from an unordered list.

*Program 12.6:* Access a byte in a one-dimensional byte array.

*Program 12.7:* Access a byte in a two-dimensional byte array.

*Program 12.8:* Access a word from a one-dimensional word array.

*Program 12.9:* Four-byte signed integer sort.

*Program 12.10:* Form new list from an old list of every nth element.

*Program 12.11:* Perform quicksort on a four-byte integer array.

### **Byte search**

Program 12.1 provides a single-byte binary search algorithm through an ordered list. Just to clarify, an ordered list is a list in which its element

are arranged in an ascending order. For example,

1,2,3,4,5,6. . .

would be an example of an ordered list, whereas

4,9,2,6,8,12,34,2,1,0. . .

is an example of an unordered list.

Because the list is ordered, it is not necessary for the machine code to search through the entire list. What the binary search technique does is to divide the list into half, calculate which half the search byte is in and divide this section in half again. This process continues until the search byte is located by zeroing in on it.

```

10 REM *** SINGLE BYTE BINARY SEARCH
***
20 PROCbin_search (&70,&71,&73,&74,&A
00)
30 FOR loop=0 TO 150
40 loop?&4001=loop
50 NEXT loop
60 ?&4000=150
70 !&71=&4000
80 ?&70=75
100 CALL bin_search
110 RESULT%=?&73
120 IF RESULT%=0 PRINT"NOT FOUND" : EN
D
130 PRINT"BYTE LOCATED AT +";RESULT%
140 end
150 :
7000 DEF PROCbin_search (byte,list,pos,
temp,addr)
7001 FOR PASS=0 TO 3 STEP 3
7002 P%=addr
7003 C
7004 OPT PASS
7005 .bin_search
7006         LDY #0
7007         LDA (list),Y
7008         STA pos
7009         STA temp
7010         INY
7011 .next_byte
7012         LSR pos
7013         BNE not_finished
7014         BCS over
7015         RTS
7016 .not_finished

```

```

7017          BCC over
7018          INC pos
7019 .over
7020          LDA (list),Y
7021          CMP byte
7022          BEQ byte_found
7023          BCS sub_inc
7024          TYA
7025          ADC pos
7026          CMP temp
7027          BEQ equal
7028          BCS next_byte
7029 .equal
7030          TAY
7031          JMP next_byte
7032 .sub_inc
7033          TYA
7034          SBC pos
7035          BEQ next_byte
7036          BCS set
7037          BMI next_byte
7038 .set
7039          TAY
7040          JMP next_byte
7041 .byte_found
7042          STY pos
7043          RTS
7044          ]
7045          NEXT
7046          ENDPROC

```

*Program 12.1. PROCbin\_search - performs a binary search on an ordered list.*

The program searches the list looking for the 8-bit value held in 'byte'. The list is addressed indirectly so the vector 'list' is used to hold its address, &4000 in the demo. Note that the very first byte of the list is not, in fact, an element but the length of the list itself. The list proper therefore starts at (list)+1. The variable 'pos' is used to return the position of the element in the list; if this byte contains 0 it means that the element was not found. Remember that a value of 1 would be returned if the element was the very first in the list.

The binary search begins by obtaining the length of the list from the length of list element (lines 7005 to 7009). The search proper is then begun by executing a logical shift right on the list length byte in 'pos' (line 7012), thus dividing it by two. A result of zero indicates that the list does not contain the element being searched for and the RTS of line 7015 returns back to the calling routine leaving 'pos' holding zero. If the carry flag is set, control continues from 'over' (line 7019). The INC

instruction of line 7018 is used to round any odd numbers up to an even one should the division have left an odd value in 'pos'.

The byte comparison is nothing unusual. If the byte is found, the branch to 'byte\_found' is performed (line 7022) where the Y register's contents are placed in 'pos' and an RTS performed (lines 7041 to 7043). If the byte is not located then the program needs to determine which half of the section in which it is located contains the byte so that the program can halve that section. Assuming that the byte is larger than the element tested, the branch to 'sub\_inc' is performed (line 7023). Here the current 'pos' is subtracted from the Y register, now transferred into the accumulator (lines 7032 to 7034) resulting in the lower portion of the list half being searched for the 'byte'. If, on the other hand, the byte is less than the element tested the branch does not take place and the 'pos' is added to the Y register so that the search continues in the upper section of the list half (lines 7024 to 7028).

The demo section of the program (lines 30 to 130) shows how the data needs to be set up before calling the subroutine. The procedural call assembles the routine at &A00 using five locations in zero page for variable storage, though only 'list' need be there. The FOR. .NEXT loop then pokes an ordered list into memory from &4000 placing the number of elements in the list, 150, into the first byte (lines 30 to 60), before placing the address of the list in 'list' (line 70). The byte to be searched for - in this case 75 - is then poked into location &70 as this corresponds to 'byte'. After running the program, the result returned is

BYTE LOCATED AT +76

which is correct because  $75+1=76$ .

## **An ordered addition**

Figure 12.1 flowcharts very simply the steps required in adding an element to a list of ordered elements. It would be easy to look through each item in the list in turn, starting with the first element, moving onto the next and so forth until a number less than the byte and greater 134 The BBC Micro Machine Code Portfolio than the byte to be added is found. A space can be made for the byte by moving the distal portion of the list up memory by a byte, and the byte is inserted. This is not particularly efficient especially as we now have a binary search subroutine to hand! Program 12.2 combines Program 12.1, further illustrating the use of procedures to assemble segments of code, while the procedure PROCordered\_add uses 'bin\_search' as a subroutine call

(line 7155) to locate the desired position of the new element to be added.

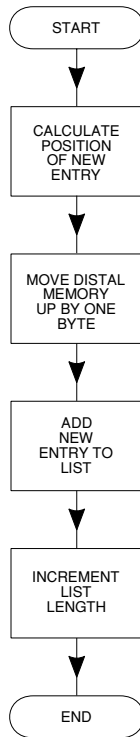


Fig. 12.1. Flowchart for PROCordered\_add.

```

10 REM *** ADDITION OF AN ELEMENT TO
***
20 REM *** AN ORDERED LIST
***
30 PROCbin_search (&70,&71,&73,&74,&3
000)
40 addr=P%
50 PROCordered_add(&70,&71,&73,&74,ad
dr)
60 FOR loop=0 TO 254 STEP2
70 ?(&4000+(loop/2))=loop

```



```

80 NEXT
90 ?&4000=127
100 !&71=&4000
110 ?&70=221
120 FOR N=&4000 TO (&4000+128)
130 PRINT "N;" ";?N
140 NEXT
150 PRINT"Press a key to execute "
160 A=GET
170 CALL add_element
180 FOR N=&4000 TO (&4000+128)
190 PRINT "N;" ";?N
200 NEXT
210 END
220 :
7100 DEF PROCbin_search (byte,list,pos,
temp,addr)
7101 FOR PASS=0 TO 3 STEP 3
7102 P%=addr
7103 [
7104 OPT PASS
7105 .bin_search
7106             LDY #0
7107             LDA (list),Y
7108             STA pos
7109             STA temp
7110             INY
7111 .next_byte
7112             LSR pos
7113             BNE not_finished
7114             BCS over
7115             RTS
7116 .not_finished
7117             BCC over
7118             INC pos
7119 .over
7120             LDA (list),Y
7121             CMP byte
7122             BEQ byte_found
7123             BCS sub_inc
7124             TYA
7125             ADC pos
7126             CMP temp
7127             BEQ equal
7128             BCS next_byte
7129 .equal
7130             TAY
7131             JMP next_byte
7132 .sub_inc
7133             TYA
7134             SBC pos
7135             BEQ next_byte
7136             BCS set

```

```

7137             BMI next_byte
7138 .set
7139             TAY
7140             JMP next_byte
7141 .byte_found
7142             STY pos
7143             RTS
7144 ]
7145 NEXT
7146 X=addr
7147 ENDPROC
7148 :
7149 DEF PROCordered_add(byte,list,pos,
temp,addr)
7150             FOR PASS=0 TO 3 STEP 3
7151             P%=addr
7152             [
7153             OPT PASS
7154 .add_element
7155             JSR bin_search
7156             LDA pos
7157             BNE present
7158             STY pos
7159             SEC
7160             LDA temp
7161             SBC pos
7162             TAX
7163             LDA byte
7164             CMP (list),Y
7165             BCS greater
7166             INY : INX
7167             JMP get_index
7168 .greater
7169             INC pos
7170             CPX #0
7171             BEQ enter_element
7172 .get_index
7173             LDY temp
7174 .next_element
7175             LDA (list),Y
7176             INY
7177             STA (list),Y
7178             DEY
7179             DEY
7180             DEX
7181             BNE next_element
7182 .enter_element
7183             LDA byte
7184             LDY pos
7185             STA (list),Y
7186             INC temp
7187             LDA temp

```

```

7188             LDY #0
7189             STA (list),Y
7190 .present
7191             RTS
7192 J
7193 NEXT
7194 ENDPROC

```

*Program 12.2. PROCordered\_add - adds a value to an ordered list.*

The PROCordered\_add procedure (lines 7149 to 7194) uses the same variables/locations as the binary search procedure. Before it is called, the machine code assembled by the former expects to find the element to be added to the ordered list in 'byte', the location of the list in 'list' and the first byte of the list stating the number of elements in the list.

After the 'bin\_search' subroutine call, the accumulator's contents are loaded with 'pos'. Remember, if the list did not contain the byte being searched out, this will be zero. If the byte is non-zero, the list already contains the element and need not be added - therefore the branch to 'present' (line 7157) is performed and the program completes. If the byte is zero the byte is not present, and the Y register holds the position of the last element to be examined before the search was exited. As it happens, this also corresponds to the position in the list where the binary search routine expected to find it! The Y register is therefore saved in 'pos' (line 7158) and the position where the byte to be added is to one side of this element.

Before the routine locates exactly where the byte is to be added it must first calculate how many elements must be moved up a byte to make space for the new addition. This is really quite simple as it just requires 'pos' to be subtracted from 'temp' (lines 7159 to 7161), where 'temp' is used to hold the list's length. The result is then transferred across into the X register (line 7162) to act as a loop counter when the move takes place.

Calculating the exact position of the byte in the list is facilitated with a simple comparison with the element pointed to by the Y register index (line 7164). If this sets the carry flag, the position is immediately following the element pointed to by the index register. Therefore the branch to 'greater' is performed (line 7165) where 'pos' is incremented. The compare X with zero instructions (lines 7170 to 7171) test to see whether the entry position will be outside the list in which case no space needs to be made for it. If the comparison clears the carry flag then after incrementing the X register (line 7166) a jump is performed.

Moving the upper section of the list is straightforward. Starting with the highest element, each byte is read, the Y register incremented and the byte stored (lines 7172 to 7177). Subtracting two from the Y register

restores the index at the next byte, while the X register acting as counter is decremented to signify one less element to move (lines 7178 to 7181). Ensuring that the move is performed in the reverse order, down memory, is important so as not to overwrite other elements in the list before they are also transferred!

Finally, the 'enter\_element' routine pokes the new element into its correct position and the number of elements in the list is updated by adding one to it (lines 7182 to 7189).

The BASIC demo provides details on the ordered add routine's use. The two sections of assembler are assembled (lines 30 to 50) passing the value of the program counter through 'addr' to ensure that the two subroutines occupy successive bytes in memory. The FOR...NEXT loop then pokes an ordered list into memory from &4000 which consists of only even numbers (lines 60 to 80). Lines 90 and 100 set up the number of elements in the list and the 'list' vector itself. The value to be inserted into the list, 221 - an odd number - is then poked into 'byte'.

The entire contents of the list are then printed out to ensure that only even numbers in steps of two are present (lines 120 to 160). After the 'add\_element' call the list is reprinted and the new element can be seen at the top of the screen (lines 170 to 210).

## An ordered delete

Deleting an element from an ordered list is performed simply by using a slightly modified Program 12.2. All that is required is first to find the position of the element in the list using the 'bin\_search' routine and then move all the elements distal to the byte down memory by one, thereby overwriting the byte to be deleted. Program 12.3 lists the delete program in its entirety while the BASIC demo is similar to the one previously described.

```

10 REM *** DELETE AN ENTRY FROM WITHI
N ***
20 REM *** AN ORDERED LIST
***
30 PROCbin_search (&70,&71,&73,&74,&3
000)
40 addr=P%
50 PROCordered_del(&70,&71,&73,&74,ad
dr)
60 FOR N%=0 TO 200
70 ?(&4001+N%)=N%
80 NEXT

```

```

90  ?&70=179
100 ?&4000=200
110 !&71=&4000
120 CALL del_element
130 FOR N%=0 TO 200
140 PRINT"(N%+&4001);" ";?(N%+&4001)
150 NEXT
160 END
170 :
7200 DEF PROCbin_search (byte,list,pos,
temp,addr)
7201 FOR PASS=0 TO 3 STEP 3
7202 P%=addr
7203 [
7204 OPT PASS
7205 .bin_search
7206             LDY #0
7207             LDA (list),Y
7208             STA pos
7209             STA temp
7210             INY
7211 .next_byte
7212             LSR pos
7213             BNE not_finished
7214             BCS over
7215             RTS
7216 .not_finished
7217             BCC over
7218             INC pos
7219 .over
7220             LDA (list),Y
7221             CMP byte
7222             BEQ byte_found
7223             BCS sub_inc
7224             TYA
7225             ADC pos
7226             CMP temp
7227             BEQ equal
7228             BCS next_byte
7229 .equal
7230             TAY
7231             JMP next_byte
7232 .sub_inc
7233             TYA
7234             SBC pos
7235             BEQ next_byte
7236             BCS set
7237             BMI next_byte
7238 .set
7239             TAY
7240             JMP next_byte
7241 .byte_found
7242             STY pos

```

```

7243             RTS
7244 ]
7245 NEXT
7246 X=addr
7247 ENDPROC
7248 :
7249 DEF PROCordered_del(byte,list,pos,
temp,addr)
7250 FOR PASS=0 TO 3 STEP 3
7251 P%=addr
7252 [
7253 OPT PASS
7254 .del_element
7255             JSR bin_search
7256             LDA pos
7257             BEQ all_done
7258             INY
7259 .next_element
7260             LDA (list),Y
7261             DEY
7262             STA (list),Y
7263             INY
7264             INY
7265             CPY temp
7266             BCC next_element
7267             BEQ next_element
7268             LDA temp
7269             SBC #1
7270             LDY #0
7271             STA (list),Y
7272 .all_done
7273             RTS
7274 ]
7275 NEXT
7276 ENDPROC

```

*Program 12.3. PROCordered\_del - deletes a value from an ordered list.*

## **A maximum minimum**

The ability to be able to locate the maximum and minimum values in a list is important for example, in processing data from the ADVAL channels to determine a range of results. Program 12.4 performs this task on an unordered list; in an ordered list these would be the last and first bytes respectively in the list!

```

10 REM *** FIND MINIMUM AND MAXIMUM *
**

```

```

20 REM *** VALUES IN AN UNORDERED LIS
T ***
30 PROCmax_min_list(&70,&71,&72,&C00)
40 !&72=&4000
50 FOR loop=1 TO 100
60 loop?&4000=RND(255)
70 NEXT
80 ?&4000=100
90 CALL minmax
100 PRINT "Minimum value was :";?&70
110 PRINT "Maximum value was :";?&71
120 END
130 :
7300 DEF PROCmax_min_list(min,max,list,
addr)
7301 FOR PASS=0 TO 3 STEP 3
7302 P%=addr
7303 C OPT PASS
7304 .minmax
7305         LDY #0
7306         LDA (list),Y
7307         TAX
7308         INY
7309         LDA (list),Y
7310         STA min
7311         STA max
7312 .next_byte
7313         DEX
7314         BEQ all_done
7315         INY
7316         LDA (list),Y
7317         CMP min
7318         BCS test_max
7319         STA min
7320 .test_max
7321         CMP max
7322         BCC next_byte
7323         BEQ next_byte
7324         STA max
7325         JMP next_byte
7326 .all_done
7327         RTS
7328 ]
7329 NEXT
7330 ENDPROC

```

*Program 12.4. PROCmax\_min\_list - finds the maximum and minimum values in an unordered list.*

The routine finds these values by taking the first element from the list and then using this initially as the maximum and minimum values. Then each of the remaining elements in the list are compared in turn. If an

element is found to be larger than the present maximum value it becomes the new maximum value. Similarly, if an element is located that is smaller than the current minimum value it takes the current minimum value's place. When the last element in the list has been sampled, the maximum and minimum values have been located.

The 'minmax' routine performs this get and compare procedure. The address of the unordered list is held within the vector 'list' while the variables 'min' and 'max' are used as stores for the two extremes. As with the previous list operations, the first byte in the list holds its length. The subroutine begins by accessing this length byte and moving it across into the X register to act as a counter after which the first element is read and placed in the two variable stores (lines 7304 to 7311).

The main loop of the program is entered at line 7312. The X register counter is decremented, and if zero all the elements have been shifted through so the program exits (lines 7313 to 7314). The indexing register is incremented and the next element in the list sought (lines 7315 to 7316). The element in the accumulator is then tested against that in 'min'. If this clears the carry flag a smaller element is indicated so this is stored as the new minimum value. If the carry is set by the comparison a larger value than 'min' is indicated so a branch to 'test\_max' is performed (lines 7318 to 7320). Here, a comparison against 'max' takes place. If the byte in the accumulator is found to be greater, it is stored at 'max', otherwise the next element in the list is sought out (lines 7321 to 7325).

The BASIC primer pokes 100 random single-byte values into a list starting at &4000 (lines 50 to 70) and the maximum and minimum values are ascertained by the 'minmax' routine.

## **An un-ordered delete**

Program 12.5 shows how a byte can be deleted from an unordered list. Because the list is unordered, the binary search technique employed in the ordered lists cannot be used; instead, starting at the front of the list, each byte must be compared in turn. Once the byte is located, all that is required is to move all the distal elements remaining down through memory by a single byte, thus overwriting the deleted byte.

```

10 REM *** DELETE ITEM FROM UNORDERED
LIST ***
20 PROCunordered_del(&70,&71,&C00)
30 ?&70=255
40 !&71=&4000
50 FOR N=1 TO 100
60 ?(&4000+N)=N

```



```

70 ?&4000=100
80 NEXT
90 ?&4050=255
100 FOR N=&4000 TO &4064
110 PRINT"N;" ";?N
120 NEXT
130 A=GET
140 CALL &C00
150 FOR N=&4000 TO &4064
160 PRINT"N;" ";?N
170 NEXT
180 END
190 :
7400 DEF PROCunordered_del(byte,list,ad
dr)
7401 FOR PASS=0 TO 3 STEP3
7402 P%:=addr
7403 [ OPT PASS
7404             LDY #0
7405             LDA (list),Y
7406             TAX
7407             LDA byte
7408 .next
7409             INY
7410             CMP (list),Y
7411             BEQ delete
7412             DEX
7413             BNE next
7414             RTS
7415 .delete
7416             DEX
7417             BEQ updat
7418             INY
7419             LDA (list),Y
7420             DEY
7421             STA (list),Y
7422             INY
7423             JMP delete
7424 .updat
7425             LDA (list,X)
7426             SBC #1
7427             SYA (list,X)
7428             RTS
7429 ]
7430 NEXT
7431 ENDPROC

```

*Program 12.5. PROCunordered\_del - deletes a byte from an unordered list.*

As with the other list processing programs, the address of the list is held in the vector 'list' while the first element in the list itself is its length. The byte to be deleted is placed in 'byte' prior to the call. Note that only the

first occurrence of the 'byte' is deleted, not all occurrences.

The BASIC program sets up an unordered list (well, it's actually ordered but who cares!) and then pokes the value 1155 into location &4050 (now its unordered!). The list is displayed both prior to and after the machine code call to show that the element has indeed been deleted from the list (lines 30 to 170).

## First bytes

In many respects, a one-dimensional byte array can be thought of simply as a list either ordered or unordered. The purpose of Program 12.6 is to calculate the absolute address of an element in the byte array by summing the array's base address and index, and then to extract that byte from the array.

The assembler requires two variables to be passed into it; 'subscript' is the index into the array while 'array' is its base address. Because 'subscript' is a single-byte value the array may only be a maximum of 256 bytes in length. The addition of 'array' and 'subscript' is performed in lines 7506 to 7511, then using indirect addressing the element is extracted and stored in 'subscript' (lines 7513 to 7515).

The BASIC tester sets up an ordered byte array at &4000 then extracts the 100th element (lines 20 to 90). Note that, unlike a list, the byte array does not need its length to be placed in the first byte of the array, which therefore starts from the address given by 'array' rather than this address plus one.

```

10 REM **GET BYTE FROM BYTE ARRAY**
20 PROCbyte_array (&70,&71,&C000)
30 FOR array=0 TO 255
40 ?(array+&4000)=array
50 NEXT
60 !&71=&4000
70 ?&70=100
80 CALL byte_array
90 PRINT"Element in array was:";?&70
100 END
110 :
7500 DEF PROCbyte_array (subscript,arra
y,addr)
7501 FOR pass=0 TO 3 STEP 3
7502 P% =addr
7503 [
7504 OPT pass
7505 .byte_array
7506             LDA subscript
7507             CLC

```

```

7508          ADC array
7509          STA array
7510          BCC over
7511          INC array+1
7512 .over
7513          LDY #0
7514          LDA (array),Y
7515          STA subscript
7516          RTS
7517 J
7518 NEXT
7519 ENDPROC

```

*Program 12.6.* PROCbyte\_array - extracts a value from a one-dimensional byte array.

Accessing a byte from a two-dimensional byte array is a little less straightforward as there are two subscripts to take into consideration. These two subscripts are the row length and the column length. The resultant program is listed as Program 12.7 and basically it works by multiplying the row subscript by the row size and then adding the column subscript to its result. This result is then added to the base address of the array to give an absolute address.

```

10 REM *** ACCESSING A TWO DIMENSIONAL
L ***
20 REM *** BYTE ARRAY ANYWHERE IN RAM
***
30 PROCtwodim_byte(&?0,&?2,&?4,&?6,&?
8,&3000)
40 FOR count=1 TO 32
50 ?(count+&4000)=count
60 NEXT
70 !&?0=2
80 !&?2=4
90 !&?4=8
100 !&?8=&4000
110 CALL twodimbyte
120 @%=0
130 PRINT'''
140 PRINT"Address of element in array:
&";
150 PRINT"!&?8 AND &FFFF
160 PRINT'"Byte located here :";
170 PRINT?&?0
180 END
190 :
7530 DEF PROCtwodim_byte (subscript1,su
bscript2,sub_size,temp,array,addr)

```

```

7531 FOR PASS=0 TO 3 STEP 3
7532 P%=addr
7533 [
7534 OPT PASS
7535 .twodimbyte
7536         LDA #0
7537         STA temp
7538         STA temp+1
7539         LDX #17
7540         CLC
7541 .multiply
7542         ROR temp+1
7543         ROR temp
7544         ROR subscript1+1
7545         ROR subscript1
7546         BCC no_add
7547         CLC
7548         LDA sub_size
7549         ADC temp
7550         STA temp
7551         LDA sub_size+1
7552         ADC temp+1
7553         STA temp+1
7554 .no_add
7555         DEX
7556         BNE multiply
7557         LDA subscript1
7558         CLC
7559         ADC subscript2
7560         STA subscript1
7561         LDA subscript1+1
7562         ADC subscript2+1
7563         STA subscript1+1
7564         LDA array
7565         CLC
7566         ADC subscript1
7567         STA array
7568         LDA array+1
7569         ADC subscript1+1
7570         STA array+1
7571         LDY #1
7572         LDA (array),Y
7573         STA subscript1
7574         RTS
7575 ]
7576 NEXT
7577 ENDPROC

```

*Program 12.7. PROCtwodim\_byte - extracts a value from a two-dimensional byte array.*

The program commences by clearing two bytes at 'temp' which will act as a partial product during the multiplication procedure which is based on a standard shift and add type of affair. The X register is then initialised as a counter, to count out the shifts required during the multiplication (lines 7536 to 7539). The 'multiply' routine (lines 7541 to 7556) then performs the row subscript (row length multiplication). When this is completed, the second subscript, the column, is added to the product of the multiplication (lines 7558 to 7563) and then to the base address of the array itself (lines 7565 to 7570). Finally, the array element is loaded into the accumulator and placed at 'subscript1'.

The BASIC program sets up the two-dimensional byte array using concurrent numbers. Of course, the array is stored physically in memory as a continuous list but is implemented as depicted in Figure 12.2, consisting of 4 rows of 8 columns. The position of any point in the array is given by (row,column), therefore the byte at (2,5) would be 22. The two-byte subscripts are poked into their two-byte locations at 'subscript1' and 'subscript2' (lines 70 and 80). Line 90 then places the row length into the two-byte variable 'sub\_size'. After calling the machine code, the absolute address of the element is extracted from 'array' and the byte that is located there is printed (lines 110 to 170).

|     |   | COLUMN |    |    |    |    |    |    |    |
|-----|---|--------|----|----|----|----|----|----|----|
|     |   | 0      | 1  | 2  | 3  | 4  | 5  | 6  | 7  |
| ROW | 0 | 1      | 2  | 3  | 4  | 5  | 6  | 7  | 8  |
|     | 1 | 9      | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|     | 2 | 17     | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
|     | 3 | 25     | 26 | 27 | 28 | 29 | 30 | 31 | 32 |

Fig. 12.2. Construction of a two-dimensional byte array.

### Word arrays

Program 12.8 takes the one-dimensional byte array program a step further and implements the extraction of a two-byte word from a one-dimensional word array. As each word entry is two bytes long, all that the program needs to do to calculate the address of a particular element is to multiply the subscript by two and then add this to the base address of the array.

```

10 REM *** GET WORD FROM SINGLE WORD
ARRAY ***
20 PROCword_array(&70,&72,&C00)
30 FOR array=0 TO 255
40 ?(array+&4000)=array
50 NEXT
60 !&70=100
70 !&72=&4000
80 CALL word_array
90 PRINT"Word element is :";!&70 AND
&FFFF
100 END
110 :
7600 DEF PROCword_array (subscript,arra
y,addr)
7601 FOR pass=0 TO 3 STEP 3
7602 P%=addr
7603 [
7604 OPT pass
7605 .word_array
7606         LDA subscript
7607         ASL A
7608         STA subscript
7609         LDA subscript+1
7610         ROL A
7611         STA subscript+1
7612         CLC
7613         LDA array
7614         ADC subscript
7615         STA array
7616         LDA array+1
7617         ADC subscript+1
7618         STA array+1
7619         LDY #0
7620         LDA (array),Y
7621         STA subscript
7622         INY
7623         LDA (array),Y
7624         STA subscript+1
7625         RTS
7626 ]
7627 NEXT
7628 ENDPROC

```

*Program 12.8. PROCword\_array - extracts a value from a one-dimensional word array.*

To perform the multiplication on the two-byte subscript, a two-byte shift left is performed using the ASL/ROL combination (lines 7606 to 7611). The double subscript is then added to 'array' (lines 7612 to 7618) and the

two-byte word extracted and placed in 'subscript' (lines 7619 to 7624).

## Integer sort

Handling single-byte sorts is relatively easy but arrays of multi-byte numbers are more complex to handle. Program 12.9 provides an algorithm to sort a set of four-byte integer numbers stored consecutively in memory. Note that it assumes signed values.

```

10 REM *** 4 BYTE SIGNED INTEGER SORT
***
20 PROCsort32 (&70,&72,&74,&76,&C00)
30 INPUT "How many numbers to sort ?"c
count
40 ?&76=count-1
50 buffer=&4000
60 ?&74=0: ?&75=&40
70 FOR random=0 TO count-1
80 ! (buffer+4*random)=RND
90 NEXT random
100 CALL &C00
110 FOR look=0 TO count-1
120 PRINT ! (buffer+4*look)
130 NEXT
140 END
150 :
7700 DEF PROCsort32 (one,two,vector,count,addr )
7701 FOR pass=0 TO 3 STEP 3
7702 P%=addr
7703 [
7704 OPT pass
7705 .entry
7706             LDA vector
7707             STA two
7708             LDA vector+1
7709             STA two+1
7710             LDA #0
7711             STA loop
7712 .once_more
7713             LDY #0
7714             LDA two+1
7715             STA one+1
7716             LDA two
7717             STA one
7718             CLC
7719             ADC #4
7720             STA two
7721             BCC no_inc

```

```

7722          INC two+1
7723 .no_inc
7724          LDX #4
7725          SEC
7726 .subtract
7727          LDA (two),Y
7728          SBC (one),Y
7729          INY
7730          DEX
7731          BNE subtract
7732          BVC vclear
7733          EOR #800
7734 .vclear
7735          EOR #0
7736          BPL no_swap
7737          DEY
7738 .swap
7739          LDA (one),Y
7740          STA store
7741          LDA (two),Y
7742          STA (one),Y
7743          LDA store
7744          STA (two),Y
7745          DEY
7746          BPL swap
7747 .no_swap
7748          INC loop
7749          LDA loop
7750          CMP count
7751          BNE once_more
7752          DEC count
7753          BNE entry
7754          RTS
7755 .loop
7756          EQU$ " "
7757 .store
7758          EQU$ " "
7759 ]
7760 NEXT
7761 ENDPROC

```

*Program 12.9. PROCsort32 - sorts a list of four-byte values.*

The procedure passes four variables used by the assembler. The variable 'vector' is, as its name implies, a zero page vector that the machine code expects to contain the start address of the array. On entry to the code at 'entry' this address is passed into the two working vectors 'one' and 'two' (how's that for originality!), lines 7705 to 7711. The sort routine is, in fact, a 'bubble sort' procedure. This works by working through the numbers in the array and comparing sets of two contiguous



numbers. If the lower number is greater than the second number then they are swapped over. This process continues through all the numbers in the array until there are none left. The net effect is that numbers seem to bubble up through the array, thus the terminology. The disadvantage of a bubble sort is that it is very slow, although this is not so noticeable in machine code. However, it is not nearly as fast as the quicksort described later.

Let's get back to the program description. After seeding both vectors, the address in 'two', which points to the second of the two integers, is placed in 'one' (lines 7713 to 7717) and the vector 'two' is incremented by 4 to give it the address of the next vector in the array (lines 7718 to 7722). The X register is used as a byte counter so is initialised to 4 (line 7724) whereupon the integer 'one' is subtracted from the integer at 'two'. If on completion of the subtraction the overflow flag is set, it is necessary to reverse the sign of the most significant bit of the result now in the accumulator. This is performed in line 7733, and the EOR #&80 will set the negative flag to the value of the most significant bit of the accumulator. This process is particularly important as the negative flag is used to determine whether a swap is needed or not. If the flag is clear, no swap is indicated and a branch to 'no\_swap' performed. The swap takes place, therefore, if the negative flag is set and is carried out by lines 7738 to 7746.

The final bytes of code (lines 7747 to 7753) test to see if the bubble sort has been completed, i.e. when a pass through it results in no swaps being performed after which control is passed back to BASIC. The BASIC demo routine at the start of the program pokes a random array of four-byte integers into a 'buffer' from &4000. After the sorting routine has been completed the array is displayed to show each four-byte integer in ascending order.

## **New lists for old**

Program 12.10 uses an assembler routine to form a new list from an old one. What actually happens is that it extracts every nth item and places this in a list buffer elsewhere to form the list. This has many applications. For example, a list of four-byte integer numbers could be sorted into sub-lists of correspondingly significant bytes grouping all the most significant bytes together and so forth, which is useful if look-up tables are being used by another section of the program. The program is straightforward and the assembler expects three variables. The first 'source' is the address of the main list, while 'new' is the address of the new list. Note that these are not implemented as vectored addresses but

this could be used if desired. Finally, 'step' is the increment size determining the elements to be extracted.

After initialising the index registers, the main program loop is entered at 'next\_byte'. The first byte of the source list is accessed and saved in the new list (lines 7777 to 7778). The 'new' list indexing register is then incremented and the 'source' list indexing register incremented by the value of 'step'. As the first byte of the source list holds its length, this byte is compared to the new index value to see if the end of the list has been passed. If not, the loop branches to repeat again, otherwise the contents of X are saved at 'new' to provide its length details.

```

10 REM *** FORM NEW LIST FROM OLD ***
20 PROCnew_list (&4000,&4200,5,&C00)
30 FOR N=0 TO 100
40 ?(&4001+N)=N
50 NEXT
60 ?&4000=100
70 CALL &C00
80 C=?&4200
90 FOR N=0 TO C-1
100 PRINT?(&4201+N)
110 NEXT
120 END
130 :
7770 DEF PROCnew_list (source,new,step,
addr)
7771 FOR pass=0 TO 3 STEP 3
7772 PX=addr
7773 [ OPT pass
7774             LDY #0
7775             LDX #0
7776 .next_byte
7777             LDA source+1,Y
7778             STA new+1,X
7779             INX
7780             TYA
7781             CLC
7782             ADC #step
7783             TAY
7784             CMP source
7785             BCC next_byte
7786             STX new
7787             RTS
7788 ]
7789 NEXT
7790 ENDPROC

```

*Program 12.10. PROCnew\_list - creates a sublist from a main list.*

### A fast quicksort!

The final program in this chapter, Program 12.11, provides a very fast four-byte integer sorting routine based on the 'quicksort' algorithm, also known in some areas of Highbury as a fastsort!

The quicksort procedure is less well known than the more illustrious bubble sort so a brief description of its working is probably useful. Consider the set of ten simple integers shown arranged randomly in Figure 12.3(a). One of these numbers is selected and is called the key. In the figure, the key is 46 and is shaded to make its position clear. Working from right to left, the key is in turn compared with each byte until a smaller byte is encountered. First time through, the first smaller value encountered is the third one in, 24. The key then swaps positions with this byte as shown in Figure 12.3(b). Next, the search process is repeated but this time, working from left to right, the first byte encountered that is larger than the key is swapped with the key 70 in this instance (Figure 12.3(c)). The process repeats again until no more swaps are possible, as Figure 12.3(d) shows.

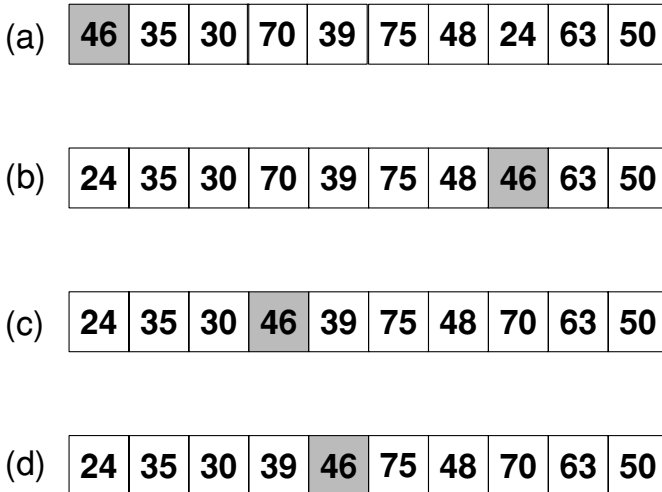


Fig. 12.3. (a) Assigning the key in a quicksort. (b) The array after the first quicksort pass. (c) The array after the second quicksort pass. (d) The array after the third quicksort pass.

Looking at Figure 12.3(d) carefully shows that it is divided into two halves. All the numbers on the left of the key are smaller than the key itself while those on the right are larger. In other words, the key has now found its final position in the list. The two sections of the list can now be sorted independently using new keys, and then the sections these provide and so on until the quicksort is completed.

Because the number of elements to be sorted reduces each time through the quicksort the time taken for it to complete its task is substantially quicker than the bubble sort method described earlier which processes the whole array each time through. In fact, to sort 1000 four-byte integers using the bubble sort would take around 50 seconds, compared with under two seconds for the quicksort. A BASIC version of the quicksort is only slightly slower than the assembler bubble sort!

```

10 REM *** FOUR BYTE INTEGER FASTSORT
***
20 PROCquick(&3900,&70,&72,&74,&76,&7
8,&7A,&80)
30 !&80=&5000:!(&80+2)=20
40 FOR N=0 TO 20 STEP4
50 !(&5000+N)=RND:NEXT
60 CALL fastsort
70 FOR N=0 TO 20 STEP4
80 PRINT !(&5000+N):NEXT
90 END
100 :
7800 DEF PROCquick(softstk,left,right,c
urrent_left,current_right,stack,middle,d
ata)
7801 FOR pass=0 TO 3 STEP 3
7802 P%=&4000
7803 C OPT pass
7804 .fastsort
7805         LDA #softstk MOD 256
7806         STA stack
7807         LDA #softstk DIV 256
7808         STA stack+1
7809         LDA data+2
7810         STA left
7811         LDA data+3
7812         STA left+1
7813         LDY #1
7814 .setup
7815         LDA (left),Y
7816         STA current_left,Y
7817         DEY
7818         BPL setup
7819         LDY #2
7820 .shift_two

```

```

7821          ASL  current_left
7822          RDL  current_left+1
7823          DEY
7824          BNE  shift_two
7825          LDA  data
7826          CLC
7827          ADC  current_left
7828          STA  right
7829          LDA  data+1
7830          ADC  current_left+1
7831          STA  right+1
7832          LDA  data
7833          SEC
7834          SBC  #4
7835          STA  left
7836          LDA  data+1
7837          SBC  #0
7838          STA  left+1
7839 .save_value
7840          LDA  left
7841          CLC
7842          ADC  #4
7843          STA  current_left
7844          LDA  left+1
7845          ADC  #0
7846          STA  current_left+1
7847          LDA  right
7848          STA  current_right
7849          SEC
7850          SBC  current_left
7851          BNE  over
7852          LDA  right+1
7853          SBC  current_left+1
7854          BNE  over
7855          JMP  pull
7856 .over
7857          LDA  right+1
7858          STA  current_right+1
7859          JSR  swap
7860          LDY  #3
7861 .back
7862          LDA  (current_left),Y
7863          STA  key,Y
7864          DEY
7865          BPL  back
7866 .adjust_right
7867          LDA  current_right
7868          SEC
7869          SBC  #4
7870          STA  current_right
7871          BCS  compare_hiright
7872          DEC  current_right+1
7873 .compare_hiright

```

```

7874          LDA current_left+1
7875          CMP current_right+1
7876          BCC not_right
7877          LDA current_left
7878          CMP current_right
7879          BEQ equal
7880 .not_right
7881          LDX #4
7882          LDY #0
7883          SEC
7884 .compare_keyright
7885          LDA (current_right),Y
7886          SBC key,Y
7887          INY
7888          DEX
7889          BNE compare_keyright
7890          BVC no_mask
7891          EOR #$80
7892 .no_mask
7893          AND #$FF
7894          BPL adjust_right
7895          DEY
7896 .exchange
7897          LDA (current_right),Y
7898          STA (current_left),Y
7899          DEY
7900          BPL exchange
7901 .adjust_left
7902          LDA current_left
7903          CLC
7904          ADC #4
7905          STA current_left
7906          BCC compare_lefthigh
7907          INC current_left+1
7908 .compare_lefthigh
7909          LDA current_left+1
7910          CMP current_right+1
7911          BCC not_left
7912          LDA current_left
7913          CMP current_right
7914          BEQ equal
7915 .not_left
7916          LDX #4
7917          LDY #0
7918          SEC
7919 .compare_keyleft
7920          LDA key,Y
7921          SBC (current_left),Y
7922          INY
7923          DEX
7924          BNE compare_keyleft
7925          BVC no_mask_again

```

```

7926          EOR  #80
7927 .no_mask_again
7928          AND  #8F
7929          BPL  adjust_left
7930          DEY
7931 .exchange_over
7932          LDA  (current_left),Y
7933          STA  (current_right),Y
7934          DEY
7935          BPL  exchange_over
7936          BMI  adjust_right
7937 .equal
7938          LDY  #3
7939 .exc_loop
7940          LDA  key,Y
7941          STA  (current_left),Y
7942          DEY
7943          BPL  exc_loop
7944          LDA  current_left
7945          SEC
7946          SBC  left
7947          STA  word
7948          LDA  current_left+1
7949          SBC  left+1
7950          STA  word+1
7951          LDA  right
7952          SEC
7953          SBC  current_left
7954          STA  temp
7955          LDA  right+1
7956          SBC  current_left+1
7957          STA  temp+1
7958          LDA  word
7959          SEC
7960          SBC  temp
7961          LDA  word+1
7962          SBC  temp+1
7963          BCC  save_hi
7964 .save_lo
7965          LDY  #0
7966          LDA  left
7967          STA  (stack),Y
7968          INY
7969          LDA  left+1
7970          STA  (stack),Y
7971          INY
7972          LDA  current_left
7973          STA  (stack),Y
7974          STA  left
7975          INY
7976          LDA  current_left+1
7977          STA  (stack),Y
7978          STA  left+1

```

```

7979      JMP update
7980 .save_hi
7981      LDY #2
7982      LDA right
7983      STA (stack),Y
7984      INY
7985      LDA right+1
7986      STA (stack),Y
7987      INY
7988      LDA current_left
7989      STA (stack),Y
7990      STA right
7991      INY
7992      LDA current_left+1
7993      STA (stack),Y
7994      STA right+1
7995 .update
7996      CLC
7997      LDA stack
7998      ADC #4
7999      STA stack
8000      BCC update1
8001      INC stack+1
8002 .update1
8003      JMP save_value
8004 .pull
8005      LDA stack
8006      SEC
8007      SBC #softstk MOD 256
8008      BNE pull1
8009      LDA stack+1
8010      SBC #softstk DIV 256
8011      BNE pull1
8012      RTS
8013 .pull1
8014      LDA stack
8015      SEC
8016      SBC #4
8017      STA stack
8018      BCS pull2
8019      DEC stack+1
8020 .pull2
8021      LDY #3
8022 .pull3
8023      LDA (stack),Y
8024      STA left,Y
8025      DEY
8026      BPL pull3
8027      JMP save_value
8028 .swap
8029      LDA current_right
8030      SEC

```



```

8031          SBC current_left
8032          AND #&F8
8033          STA middle
8034          LDA current_right+1
8035          SBC current_left+1
8036          STA middle+1
8037          LSR middle+1
8038          ROR middle
8039          LDA current_left
8040          CLC
8041          ADC middle
8042          STA middle
8043          LDA current_left+1
8044          ADC middle+1
8045          STA middle+1
8046          LDY #3
8047 .swap_loop
8048          LDA (current_left),Y
8049          STA word
8050          LDA (middle),Y
8051          STA (current_left),Y
8052          LDA word
8053          STA (middle),Y
8054          DEY
8055          BPL swap_loop
8056          RTS
8057 .key    EQU 0
8058 .word   EQUW 0
8059 .temp   EQUW 0
8060 J NEXT
8061 ENDPROC

```

*Program 12.11. PROCquick - implements a four-byte quicksort routine*

The main areas operation of Program 12.11 are as follows:

*Lines 7805 to 7808:* Set up vector software stack which will be used to hold pointers and data for future reference by the routine.

*Lines 7809 to 7813:* Save base address of the integer array in 'left'.

*Lines 7814 to 7818:* Seed integer into the 'current\_left' position.

*Lines 7819 to 7855:* Seed next integer into 'current\_right' position and test to see if they are equal. If both are equal, then pull pointers and data from stack and move onto next subsection.

*Lines 7856 to 7860:* If items are not equal perform the swap.

*Lines 7861 to 7865:* Then save key for future reference.

*Lines 7866 to 7900:* Compare key with integers to the right of it and perform the swap if greater.

*Lines 7901 to 7936:* Compare key with integers to the left of it and

perform swap if less than.

*Lines 7937 to 8043:* Place key back in 'current\_left'.

*Lines 7944 to 7963:* Now save pointers of unsorted sections of integer array on software stack. Concentrate on smallest section first.

*Lines 7964 to 8003:* Routine to push pointers and data items onto software stack.

*Lines 8004 to 8027:* Routine to pull all pointers and data items off software stack.

*Lines 8028 to 8055:* Subroutine to perform the key integer swap.

Two sets of two variables are used by the assembler routine. The boundaries of the current section half being sorted are held in 'left' and 'right'. The current left- and right-hand numbers being tested with the key are held in 'current\_left' and 'current\_right' respectively. The BASIC primer sets up an array of random integer values at &5000. After calling the quicksort, the sorted array is displayed (lines 20 to 90).

## **Program fact sheets**

### *Program 12.1*

|                        |                              |
|------------------------|------------------------------|
| Procedure title        | : PROCbin_search             |
| Variables required     | : bvt, list, pos, temp, addr |
| Line numbers           | : 7000 to 7046               |
| Length                 | : 57 bytes                   |
| Zero page requirements | : 5 bytes                    |
| Registers changed      | : A, X, Y                    |

### *Program 12.2*

|                        |  |
|------------------------|--|
| Procedure title        | : PROCordered_add (also requires PROCbin_search) |
| Variables required     | : byte, list, pos, temp, addr                    |
| Line numbers           | : 7100 to 7194                                   |
| Length                 | : 115 bytes                                      |
| Zero page requirements | : 5 bytes  |
| Registers changed      | : A, X, Y  |

### *Program 12.3*

|                    |  |
|--------------------|--|
| Procedure title    | : PROCordered_del (also requires PROCbin_search) |
| Variables required | : byte, list, pos, temp, addr                    |

Line numbers : 7200 to 7276  
Length : 87 bytes  
Zero page requirements : 5 bytes  
Registers changed : A, X, Y

*Program 12.4*

Procedure title : PROCmax\_min\_list  
Variables required : min, max, list, addr  
Line numbers : 7300 to 7330  
Length : 36 bytes  
Zero page requirements : 4 bytes  
Registers changed : A, X, Y

*Program 12.5*

Procedure title : PROCunordered\_del  
Variables required : byte, list, addr  
Line numbers : 7400 to 7431  
Length : 36 bytes  
Zero page requirements : 3 bytes  
Registers changed : A, X, Y

*Program 12.6*

Procedure title : PROCbyte\_array  
Variables required : subscript, array, addr  
Line numbers : 7500 to 7519  
Length : 18 bytes  
Zero page requirements : 3 bytes  
Registers changed : A, Y

*Program 12.7*

Procedure title : PROCTwodim\_byte  
Variables required : subscript1, subscript2, sub\_size, temp,  
array, addr  
Line numbers : 7530 to 7577  
Length : 68 bytes  
Zero page requirements : 10 bytes  
Registers changed : A, X, Y

*Program 12.8*

|                        |                          |
|------------------------|--------------------------|
| Procedure title        | : PROCword_array         |
| Variables required     | : subscript, array, addr |
| Line numbers           | : 7600 to 7628           |
| Length                 | : 34 bytes               |
| Zero page requirements | : 3 bytes                |
| Registers changed      | : A, X, Y                |

*Program 12.9*

|                        |                                 |
|------------------------|---------------------------------|
| Procedure title        | : PROCsort32                    |
| Variables required     | : one, two, vector, count, addr |
| Line numbers           | : 7700 to 7761                  |
| Length                 | : 86 bytes                      |
| Zero page requirements | : 8 bytes                       |
| Registers changed      | : A, X, Y                       |

*Program 12.10*

|                        |                           |
|------------------------|---------------------------|
| Procedure title        | : PROCnew_list            |
| Variables required     | : source, new, step, addr |
| Line numbers           | : 7770 to 7790            |
| Length                 | : 25 bytes                |
| Zero page requirements | : 1 byte                  |
| Registers changed      | : A, X, Y                 |

*Program 12.11*

|                        |   |
|------------------------|---|
| Procedure title        | : PROCquick   |
| Variables required     | : softstk, left, right, current_left,<br>current_right, stack, middle, data |
| Line numbers           | : 7800 to 8061  |
| Length                 | : 437 bytes   |
| Zero page requirements | : 14 bytes  |
| Registers changed      | : A, X, Y   |



# Chapter Thirteen

## Communication

An important part of good software is good communication between the program and the user. Excellent software is very often degraded because the writer has not made any attempt to make the program user-friendly by presenting instructions neatly onto the screen and using sensible keys for inputting information. This chapter provides some short but important procedures that will enable the programmer both to neaten up screen presentation and have the program input data with minimal fuss. Most programs are based around the excellent set of operating system commands, thus reducing the amount of coding.

The routines included are:

*Program 13.1* : Perform a CLS.  
*Program 13.2* : Perform VPOS and POS.  
*Program 13.3* : Perform SPC.  
*Program 13.4* : Perform STRING\$.  
*Program 13.5* : Perform TAB (X).  
*Program 13.6* : Perform TAB (X,Y).  
*Program 13.7* : Perform GET.  
*Program 13.8* : Perform INKEY.  
*Program 13.9* : Super quick key test.  
*Program 13.10* : Read line.  
*Program 13.11* : Read a VDU definition.  
*Program 13.12* : Hexadecimal to ASCII.  
*Program 13.13* : Packed BCD to ASCII.  
*Program 13.14* : ASCII to packed BCD.

### **Onto the screen**

The first six programs presented here deal with formatting text on the screen. Program 13.1 performs a simple CLS to clear the screen, by printing a control code 12 through OSWRCH.

```

10 REM*** CLEAR SCREEN -CLS ***
20 PROCcls (&C00)
30 PRINT"PRESS A KEY TO CLEAR SCREEN"
40 A=GET
50 CALL &C00
60 END
70 :
8000 DEF PROCcls (addr)
8001 P%=addr
8002 [
8003 .clear_screen
8004             LDA #12
8005             JSR &FFEE
8006             RTS
8007 ]
8008 ENDPROC

```

*Program 13.1. PROCcls - performs CLS*

Knowing where the cursor is at a particular time is another useful function to perform. In BASIC, the POS and VPOS functions return the horizontal (X axis) and vertical (Y axis) components of the cursor. These two functions have a direct equivalent within the MOS, an OSBYTE &86 call. Program 13.2 shows that the X and Y coordinates of the cursor are returned in the respective index registers which can be saved for evaluation.

```

10 REM *** DO POS & VPOS ***
20 PROCcursor (&70,71,&C00)
30 CLS
40 PRINTTAB(10,10);
50 CALLcursor
60 PRINT"Cursor positions were : "
70 PRINT"POS = ";?&70
80 PRINT"VPOS= ";?&71
90 END
100 :
8010 DEF PROCcursor (pos,vpos,addr)
8011 P%=&C00
8012 [ OPT 2
8013 .cursor
8014             LDA #&86
8015             JSR &FFF4
8016             STX pos
8017             STY vpos
8018             RTS

```

```

8019 J
8020 ENDPROC

```

*Program 13.2. PROCcursor - returns the X,Y coordinates of the text cursor.*

Program 13.3 imitates the BASIC command SPC, to print a specified number of spaces from the current cursor position. The number of spaces to be printed should be passed into the procedure via the variable 'spc'. At assembly time, this variable is treated as an immediate value being loaded directly into the X register to act as a simple loop control. Prior to entering 'loop', the accumulator is loaded with 32, the ASCII code of a space, and the required number is printed.

```

10 REM *** DO MACHINE CODE SPC ***
20 CLS
30 INPUT "How many spaces ?" spc
40 PROCspace (spc,&C00)
50 CALL space
60 END
70 :
8030 DEF PROCspace (spc,addr)
8031 P%=addr
8032 C OPT 2
8033 .space
8034             LDX #spc
8035             LDA #32
8036 .loop
8037             JSR &FFEE
8038             DEX
8039             BNE loop
8040             RTS
8041 J
8042 ENDPROC

```

*Program 13.3. PROCspace - performs SPC.*

STRING\$ is a BASIC command that allows a specified number of the same string to be printed. This can result in a great saving of memory space. For example, it is much neater to print 40 asterisks using

```
PRINT STRING$(40,"*")
```

rather than enclosing 40 asterisks inside quotes or from a machine code point of view in an ASCII data table. Program 13.4 emulates this



command by printing a string located at 'buffer', 'num' number of times.

```

10 REM *** DO STRING$ ***
20 CLS
30 INPUT "Enter your string :"$&C50
40 INPUT "How many times : "num
50 PROCstring (&C50,num,&C00)
60 CALL string
70 END
80 :
8050 DEF PROCstring (buffer,num,addr)
8051 FOR pass=0 TO 2 STEP 2
8052 P%=addr
8053 [ OPT pass
8054 .string
8055         LDY #num
8056 .count
8057         LDX #0
8058 .next_chr
8059         LDA buffer,X
8060         JSR &FFE3
8061         INX
8062         CMP #13
8063         BNE next_chr
8064         DEY
8065         BNE count
8066         RTS
8067 ]
8068 NEXT
8069 ENDPROC

```

*Program 13.4. PROCstring - performs STRING\$*

The program commences by loading the Y register with the 'num' count (line 8055) and then setting the X register to zero (line 8057), which is to be used as an absolute index into 'buffer'. The get and display loop is embodied in lines 8058 to 8063. Each character is extracted from 'buffer' and printed in turn until a carriage return has been printed. The Y register is decremented and the 'count' loop repeated until it reaches zero. Note that in the code the carriage return at the end of the string (put there by BASIC's INPUT statement - line 30) is printed, so that each string occupies a new line rather than being printed continuously across the screen. The CMP #13 test could be performed earlier so that the program exists before issuing a return if so required.

Positioning text on the screen is performed using the TAB function. There are two bytes of TAB, namely TAB(X) and TAB(X,Y). The simplest way to perform a TAB(X) is to print the move cursor right

code, ASCII 9, the required number of times. Program 13.5 details the assembler, the required value of X passing into the procedure through 'xpos'. Once again, a simple loop is used printing the code 9 through OSWRCH until the X register has been decremented to zero. It is worth bearing in mind that this routine is in fact different from the one given in Program 13.3 as it has no effect on any text the cursor passes over. Only the cursor is moved and no spaces are output as in the former program.

```

10 REM *** DO TAB(X)***
20 CLS
30 INPUT "Number of tabs : "xpos
40 PROCTabx(xpos,&C00)
50 CLS
60 CALL tabx
70 PRINT "*"
80 PRINT "* marks the TAB position"
90 END
100 :
8080 DEF PROCTabx (xpos,addr)
8081 P%=addr
8082 C OPT 2
8083 .tabx
8084             LDA #9
8085             LDX #xpos
8086 .xtab
8087             JSR &FFEE
8088             DEX
8089             BNE xtab
8090             RTS
8091 ]
8092 ENDPROC

```

*Program 13.5. PROCTabx - performs TAB(X)*

TAB(X,Y) is performed through OSWRCH using the driver code 31 followed by first the X and then the Y coordinate to tab to. Program 13.6 uses immediate addressing to pass the two TAB parameters into the assembler via 'xpos' and 'ypos'.

```

10 REM *** DO TAB(X,Y) ***
20 CLS
30 INPUT "Tab X position : "xpos
40 INPUT "Tab Y position : "ypos
50 PROCTabxy (xpos,ypos,&C00)
60 CLS

```

```

70 CALL tabxy
80 PRINT"*"
90 PRINT"* marks the TAB position"
100 END
110 :
8100 DEF PROCtabxy (xpos,ypos,addr)
8101 P%=addr
8102 C OPT 2
8103 .tabxy
8104         LDA #31
8105         JSR &FFEE
8106         LDA #xpos
8107         JSR &FFEE
8108         LDA #ypos
8109         JSR &FFEE
8110         RTS
8111 J
8112 ENDPROC

```

*Program 13.6. PROCtabxy - performs TAB(X,Y).*

## The key to detection

I doubt if there are many programs that do not require some sort of interaction from the user at the keyboard, whether it be a simple 'press key to continue' affair or more complex data input. Whatever it is, the need to perform the task efficiently and correctly is important. A simple GET type keyboard read can be performed by calling OSRDCH at &FFE9 directly (see Program 13.7). This call waits for a key to be pressed and returns with its ASCII value in the accumulator. However, when using this call it is important to test to see if the ESCAPE key was the key pressed. This can be performed simply by comparing the accumulator contents with &1B (line 8126). If the key was pressed then it must be acknowledged with an OSBYTE &7E call (lines 8128 to 8129) otherwise the MOS will hang up or do crazy things!

```

10 REM *** TEST FOR KEY **
20 CLS
30 PRINT"Press key to test for";
40 chr%=GET$
50 chr=ASC(chr%)
60 PROCgetkey(chr,&C00)
70 PRINT'"Press ";chr%;" to end";
80 CALL getstring
90 PRINT'"Finished!"
100 END

```

```

110 :
8120 DEF PROCgetkey (chr,addr)
8121 FOR pass=0 TO 2 STEP 2
8122 P%=addr
8123 [ OPT pass
8124 .getstring
8125         JSR &FFE0
8126         CMP #&1B
8127         BNE no_escape
8128         LDA #&7E
8129         JSR &FFF4
8130 .no_escape
8131         CMP #chr
8132         BNE getstring
8133         RTS
8134 ]
8135 NEXT
8136 ENDPROC

```

Program 13.7. PROCgetkey - performs GET.

Using OSBYTE &81, an INKEY timed input can be performed. The index registers are used to hold the wait period which is specified in centiseconds. Program 13.8 shows how it is set up in the procedure PROCinkey. Prior to the actual OSBYTE call an \*FX15,1 is performed to flush all input buffers (lines 8145 to 8148). The wait period is passed into the assembler via the variable 'wait', the high and low bytes are loaded into the respective registers using the MOD and DIV operators (lines 8149 to 8152). As with the previous procedure, the ESCAPE key should be tested for and acknowledged with the appropriate call if needed (lines 8153 to 8156). Note that in this instance the escape code is returned in the Y register. If a key is detected in the allotted time period it is returned from OSBYTE in the X register and both the Y register and carry flag are clear. If no character is detected within the time period, Y returns containing &FF and the carry is set.

```

10 REM *** DO MACHINE CODE INKEY ***
20 PROCinkey (1000,&70,&C00)
30 CLS
40 PRINT"Press key within time limit
"
50 CALL inkey
60 PRINT"Key pressed was :";CHR$(?&70
)
70 END
80 :
8140 DEF PROCinkey (wait,result,addr)

```

```

8141 FOR pass=0 TO 2 STEP 2
8142 P%=addr
8143 [ OPT pass
8144 .inkey
8145         LDA #15
8146         LDX #1
8147         LDY #0
8148         JSR &FFF4
8149         LDA #&81
8150         LDX #wait MOD 256
8151         LDY #wait DIV 256
8152         JSR &FFF4
8153         CPY #&1B
8154         BNE no_escape
8155         LDA #&7E
8156         JSR &FFF4
8157 .no_escape
8158         STX result
8159         RTS
8160 ]
8161 NEXT
8162 ENDPROC

```

*Program 13.8. PROCinkey - performs INKEY.*

OSBYTE &81 can also be used to perform a single keyboard scan if it is called with the Y register holding &FF and the X register the negative INKEY value.

The demonstration program performs an INKEY(1000) equivalent, which basically causes the MOS to look at the keyboard for 10 seconds or until a key is pressed.

Both of the above two routines suffer from one drawback. They are slow! Well, in machine code terms they are. Consider that the fastest MOS-based routine, using OSBYTE &81 with X holding the negative inkey value will take at least 300 cycles and anything up to 1200 cycles. Program 13.9 does the whole scan in a mere 12 cycles and what's more it can test for two keys being pressed at once! The code assembled by PROCkeytest looks at locations &EC and &ED. If a key is pressed at any time then the MOS places zero into &ED and &EC contains the key's number. The actual numbers stored by the MOS are internal key numbers +128. For almost all purposes the internal key numbers are the negative INKEY numbers made positive and then decremented by one. For example, C is equal to INKEY(-83) so its internal number is calculated as ABS(-83)-1 or 83-1=82. Testing for C using 'keytest' therefore requires a test for 82+128=210.

If two keys are pressed almost simultaneously then &ED contains the number of the first key pressed and &EC the second key. If no keys are detected then both these bytes are zero.

```

10 REM *** QUICK TEST FOR KEY ***
20 PROCkeytest (&900)
30 VDU15
40 CALL start
50 END
60 :
8300 DEFPROCkeytest (addr)
8301 FOR pass=0 TO 2 STEP 2
8302 P%=addr
8303 [
8304 OPT pass
8305 .start
8306             LDA&ED
8307             BEQ check_EC
8308             JSR valid_key
8309             BEQ check_EC
8310             JSR&FFEE
8311 .check_EC
8312             LDA&EC
8313             BEQ start
8314             JSR valid_key
8315             BEQ start
8316             JSR&FFEE
8317             JMP start
8318 .valid_key
8319             CMP#&F0
8320             BNE next1
8321             PLA
8322             PLA
8323             LDA#15
8324             JSR&FFF4
8325             RTS
8326 .next1
8327             CMP#&E1
8328             BNE next2
8329             LDA#&5A
8330             RTS
8331 .next2
8332             CMP#&C2
8333             BNE next3
8334             LDA#&58
8335             RTS
8336 .next3
8337             CMP#&D2
8338             BNE next4
8339             LDA#&43
8340             RTS
8341 .next4
8342             CMP#&E3
8343             BNE next5

```

```

8344          LDA#&56
8345          RTS
8346 .next5
8347          LDA#0
8348          RTS
8349 J
8350 NEXT
8351 ENDPROC

```

*Program 13.9. PROCkeytest - a 12-cycle key test.*

As it stands, the routine has been set up to look for Z, X, C, V and ESCAPE. The hex begins by peeking &ED. If this is zero then &EC can be tested straightaway so the branch to 'check\_EC' is performed (lines 8306 to 8307). The subroutine 'valid\_key' tests for each of the above keys. The first tested is ESCAPE, code &F0 (line 8319). If it is detected then the RTS address is pulled from the stack and the MOS entered with 15 in the accumulator to handle the ESCAPE. The following bytes then look for each key in turn. The codes for each are:

```

&E1 = Z
&C2 = X
&D2 = C
&E3 = V

```

If any of these compare, the letter is printed out. The 'check\_EC' routine works exactly the same.

If you run the program and then press either the Z, X, C, or V keys then you'll see just how fast this key test routine is. The screen half fills with letters before you can lift your finger off the key! Finally, I should point out that this method is not condoned by Acorn as it is MOS-dependent. It will work on OS 1.0 and OS 1.2 but I haven't tried it on OS 0.1 so it may not work if you are using this version of MOS. The GET single key type routines could be employed to read in a string of characters, placing each one into a defined buffer until a set number of characters is reached or a return character detected. This does involve some extra coding, though, as a loop and buffer would need to be implemented. A neater way is to use the MOS line input routine OSWORD &00. This is a very useful call as it allows a number of parameters to be specified regarding the characters being input, Figure 13.1 details the parameter block. The first two bytes contain the address of the input buffer, the second byte the maximum number of characters to be placed in the buffer, while the last two bytes determine the maximum and minimum acceptable ASCII characters that will be accepted and

placed in the buffer!

This OSWORD call does have one major disadvantage, though. Although only characters in the specified ASCII range will be placed into the buffer, any other characters presses will be echoed to the screen even though they are not deposited in the buffer. Program 13.10 provides a suitable procedure. The parameter block address for the call is defined in 'block' while B% determines the input line buffer location; L% the number of characters acceptable, i.e. the buffer's maximum length; and 'max', 'min' the acceptable character range.

---

|      |   |
|------|---|
| XY+0 | : LSB of input buffer address                 |
| XY+1 | : MSB of input buffer address                 |
| XY+2 | : Maximum number of characters                |
| XY+3 | : Minimum ASCII value of character acceptable |
| XY+4 | : Maximum ASCII value of character acceptable |

---

Fig. 13.1. OSWORD &00 parameter block

```

10 REM ** READ LINE FROM INPUT **
20 PROCinputline(&70,&C00,10,ASC"A",A
SC"Z",&4000)
30 CALL &4000
40 PRINT$&C00
50 END
8170 DEF PROCinputline(block,B%,L%,max,
min,addr)
8171 FOR pass=0 TO 3 STEP3
8172 P%=addr
8173 [ OPT pass
8174         LDA #B% MOD 256
8175         STA block
8176         LDA #B% DIV 256
8177         STA block+1
8178         LDA #L%
8179         STA block+2
8180         LDA #max
8181         STA block+3
8182         LDA #min
8183         STA block+4
8184         LDA #0
8185         LDX #block MOD 256
8186         LDY #block DIV 256
8187         JSR &FFF1
8188         RTS
8189 ]

```



```
8190 NEXT
8191 ENDPROC
```

*Program 13.10. PROCinputline - input a line of text*

Program 13.11 will read the bit map definition of any ASCII or defined VDU character. OSWORD &9A performs the task and all that is required prior to the read is to define a nine-byte parameter block, 'block' in the program. The ASCII code of the character to be read should be located in the first byte of the parameter block and on return the following eight bytes contain the character's definition starting with the top row of the character.

```
10 REM **READ VDU CHR DEFINITION**
20 CLS
30 PRINT"PRESS A KEY TO DISPLAY ITS D
EFINITION";
40 chr$=GET$
50 chr=ASC(chr$)
60 PROCread_chr(&70,chr,&4000)
70 CALL &4000
80 CLS
90 PRINT"THE DEFINITION OF ";chr$;" I
S : "
100 FOR N=&71 TO &78:PRINT?N:NEXT
110 END
8200 DEF PROCread_chr(block,chr,addr%)
8201 FOR pass=0 TO 3 STEP 3
8202 P%=addr%
8203 [ OPT pass
8204         LDA #chr
8205         STA block
8206         LDA #10
8207         LDY #block MOD 256
8208         LDY #block DIV 256
8209         JSR &FFF1
8210         RTS
8211 ]
8212 NEXT
8213 ENDPROC
```

*Program 13.11. PROCread\_chr - reads the eight-byte definition of any character.*

## **A simple change**

The final three programs provide some simple conversion routines.

Program 13.12 will convert the hexadecimal value at 'byte' and print it to the screen as two ASCII hex bytes. Thus if 'byte' held &FF then the letters F and F will be printed. The program works as follows. After loading the byte for conversion into the accumulator, the logical AND ensures that only the lowest four bits are set (lines 8233 to 8234). After setting the decimal flag, the addition of &90 to binary values 0 to 9 will result in a value of &90 to &99 with the carry flag clear. A further addition of &40 will convert these characters to values in the range &30 to &39 with the carry set. Remember that decimal addition is in operation so that adding 1 to &99 will give a result of &00 rather than &9A.

```

10 REM *** SIMPLE HEX TO ASCII ***
20 PROChex_asc(&70,&71,&72,&C00)
30 ?&70=255
40 CALL &C00
50 PRINT'''
60 PRINTCHR$(?&71);CHR$(?&72)
70 END
80 :
8230 DEF PROChex_asc(byte,high,low,addr
)
8231 P%:=addr
8232 [
8233         LDA byte
8234         AND #15
8235         SED
8236         CLC
8237         ADC #&90
8238         ADC #&40
8239         CLD
8240         STA low
8241         LDA byte
8242         LSR A
8243         LSR A
8244         LSR A
8245         LSR A
8246         SED
8247         CLC
8248         ADC #&90
8249         ADC #&40
8250         CLD
8251         STA high
8252         RTS
8253 ]
8254 ENDPROC

```

*Program 13.12. PROChex\_asc - convert a hexadecimal number into two ASCII values.*

Adding &90 to the binary values &A to &F results in a byte in the range &00 to &05 with the carry set. A further addition of &40 (plus the set carry) converts this to values &41 to &46, the ASCII codes for the letters A to F.

The byte is then saved and the next four bits treated likewise after shifting them into the lower nibble position with four logical shifts. Both ASCII codes are stored at 'high' and 'low' for future reference. If you wish not to save the two results but to print them directly then remember that the high nibble must be treated first and then the low nibble as the digits are printed, most significant first, on the screen.

Program 13.13 converts a packed BCD digit into its component ASCII codes. To perform the conversion the byte must first be transformed into its two component nibbles, which should be placed in the low nibble position before having bit 5 forced to 1 using ORA #&30. The high nibble is treated first. After loading the packed byte from 'bcd' it is pushed onto the hardware stack for future reference. The high nibble is then shifted into the low nibble position (lines 8263 to 8268). Bit 5 is then forced and the ASCII character code placed in 'high' - it could at this point be printed using JSR &FFEE instead. The stack is pulled and the high nibble masked out with an AND (lines 8271 to 8272). Bit 5 is forced and the result placed in 'low' (lines 8273 to 8274).

```

10 REM *** PACKED BCD TO ASCII ***
20 PROCbcd_ascii(&70,&71,&72,&C00)
30 ?&70=&12
40 CALL &C00
45 PRINT''
50 PRINT CHR$(?&72); CHR$(?&71)
60 END
70 :
8260 DEF PROCbcd_ascii(bcd,low,high,addr)
r)
8261 P%:=addr
8262 [
8263         LDA bcd
8264         PHA
8265         LSR A
8266         LSR A
8267         LSR A
8268         LSR A
8269         ORA #&30
8270         STA high
8271         PLA
8272         AND #15
8273         ORA #&30
8274         STA low

```

```

8275             RTS
8276 ]
8277 ENDPROC

```

*Program 13.13. PROCbcd\_ascii - converts a packed BCD byte into two ASCII values.*

Performing the reverse conversion, two ASCII digits to packed BCD, involves reversing the procedure as depicted in Program 13.14. The high digit is extracted from 'high' shifted right so that bit 5 is lost and only the binary bits remain. This byte is pushed onto the hardware stack. The 'low' digit is loaded into the accumulator, the low nibble preserved, and the stack pointer copied into the X register (lines 8289 to 8291). The two digits have now been stripped of bit 5, and all that is now required is to merge them together. This is done by logically ORing the two together (lines 8292). The X register is incremented and copied back into the stack pointer thus 'popping' the byte from the stack. Finally the result is placed at 'bcd'.

```

10 REM *** ASCII TO PACKED BCD ***
20 PROCasc_bcd(&70,&71,&72,&C00)
30 ?&70=ASC("6")
40 ?&71=ASC("9")
50 CALL &C00
60 PRINT"?&72
70 END
80 :
8280 DEF PROCasc_bcd(high,low,bcd,addr)
8281 P%=addr
8282 [
8283             LDA high
8284             ASL A
8285             ASL A
8286             ASL A
8287             ASL A
8288             PHA
8289             LDA low
8290             AND #15
8291             TSX
8292             ORA &101,X
8293             INX
8294             TXS
8295             STA bcd
8296             RTS
8297 ]
8298 ENDPROC

```

*Program 13.14. PROCasc\_bcd - converts two ASCII values into a packed*

BCD byte.

## **Program fact sheets**

### *Program 13.1*

|                        |                |
|------------------------|----------------|
| Procedure title        | : PROCcls      |
| Variables required     | : addr         |
| Line numbers           | : 8000 to 8008 |
| Length                 | : 6 bytes      |
| Zero page requirements | : none         |
| Registers changed      | : A            |

### *Program 13.2*

|                        |                   |
|------------------------|-------------------|
| Procedure title        | : PROCcursor      |
| Variables required     | : pos, vpos, addr |
| Line numbers           | : 8010 to 8020    |
| Length                 | : 10 bytes        |
| Zero page requirements | : 2 bytes         |
| Registers changed      | : A, X, Y         |

### *Program 13.3*

|                        |                |
|------------------------|----------------|
| Procedure title        | : PROCspace    |
| Variables required     | : spc, addr    |
| Line numbers           | : 8030 to 8042 |
| Length                 | : 11 bytes     |
| Zero page requirements | : none         |
| Registers changed      | : A, X         |

### *Program 13.4*

|                        |                     |
|------------------------|---------------------|
| Procedure title        | : PROCstring        |
| Variables required     | : buffer, num, addr |
| Line numbers           | : 8050 to 8069      |
| Length                 | : 19 bytes          |
| Zero page requirements | : none              |
| Registers changed      | : A, X, Y           |

### *Program 13.5*

|                 |            |
|-----------------|------------|
| Procedure title | : PROCTabx |
|-----------------|------------|

|                        |                |
|------------------------|----------------|
| Variables required     | : xpos, addr   |
| Line numbers           | : 8080 to 8092 |
| Length                 | : 17 bytes     |
| Zero page requirements | : none         |
| Registers changed      | : A, X         |

*Program 13.6*

|                        |                    |
|------------------------|--------------------|
| Procedure title        | : PROCTabxy        |
| Variables required     | : xpos, ypos, addr |
| Line numbers           | : 8100 to 8112     |
| Length                 | : 16 bytes         |
| Zero page requirements | : none             |
| Registers changed      | : A                |

*Program 13.7*

|                        |                |
|------------------------|----------------|
| Procedure title        | : PROCgetkey   |
| Variables required     | : chr, addr    |
| Line numbers           | : 8120 to 8136 |
| Length                 | : 17 bytes     |
| Zero page requirements | : none         |
| Registers changed      | : A            |

*Program 13.8*

|                        |                      |
|------------------------|----------------------|
| Procedure title        | : PROCinkey          |
| Variables required     | : wait, result, addr |
| Line numbers           | : 8150 to 8162       |
| Length                 | : 31 bytes           |
| Zero page requirements | : 1 byte             |
| Registers changed      | : A, X, Y            |

*Program 13.9*

|                        |                |
|------------------------|----------------|
| Procedure title        | : PROCkeytest  |
| Variables required     | : addr         |
| Line numbers           | : 8300 to 8351 |
| Length                 | : 69 bytes     |
| Zero page requirements | : none         |
| Registers changed      | : A            |

*Program 13.10*

|                        |                                 |
|------------------------|---------------------------------|
| Procedure title        | : PROCinputline                 |
| Variables required     | : block, B%, L%, max, min, addr |
| Line numbers           | : 8170 to 8191                  |
| Length                 | : 26 bytes                      |
| Zero page requirements | : 5 bytes                       |
| Registers changed      | : A, X, Y                       |

*Program 13.11*

|                        |                    |
|------------------------|--------------------|
| Procedure title        | : PROCread_chr     |
| Variables required     | : block, chr, addr |
| Line numbers           | : 8200 to 8213     |
| Length                 | : 14 bytes         |
| Zero page requirements | : 9 bytes          |
| Registers changed      | : A, X, Y          |

*Program 13.12*

|                        |                         |
|------------------------|-------------------------|
| Procedure title        | : PROChex_asc           |
| Variables required     | : byte, high, low, addr |
| Line numbers           | : 8230 to 8254          |
| Length                 | : 29 bytes              |
| Zero page requirements | : 3 bytes               |
| Registers changed      | : A                     |

*Program 13.13*

|                        |                        |
|------------------------|------------------------|
| Procedure title        | : PROCbcd_ascii        |
| Variables required     | : bcd, low, high, addr |
| Line numbers           | : 8260 to 8277         |
| Length                 | : 19 bytes             |
| Zero page requirements | : 3 bytes              |
| Registers changed      | : A                    |

*Program 13.14*

|                        |                        |
|------------------------|------------------------|
| Procedure title        | : PROCasc_bcd          |
| Variables required     | : high, low, bcd, addr |
| Line numbers           | : 8280 to 8289         |
| Length                 | : 20 bytes             |
| Zero page requirements | : 3 bytes              |
| Registers changed      | : A, X                 |

# Chapter Fourteen

## Odd One Out

This final chapter in the Portfolio draws together eight programs that offer a variety of functions. The programs are:

- Program 14.1* : Find highest IRQ.
- Program 14.2* : Timer 1 delay.
- Program 14.3* : Timer 2 delay.
- Program 14.4* : One second delay.
- Program 14.5* : Save all processor registers.
- Program 14.6* : Restore all processor registers.
- Program 14.7* : Two-byte incrementing counter.
- Program 14.8* : Two-byte decrementing counter.

### Interrupt polling

Program 14.1 is not a complete routine as it stands as it expects extra code, written by the user, to be tagged onto it. Basically it is an interrupt polling sequence for the User VIA, capable of identifying the highest priority interrupt request on any one of the seven lines capable of having an IRQ.

In order to know which interrupt servicing routine to call, the source of the IRQ must be determined. To find this out, bit 7 of the Interrupt Flag Register (IFR7) must be tested. If this bit is set then an IRQ has been issued. The IFR is read using an OSBYTE &96 call to read Sheila. As the IFR occupies location &6D in Sheila this value is placed in the X register. After the call, the Y register contains the byte just read, which is transferred into the accumulator. If bit 7 is clear the branch to 'next\_device' will be executed (lines 9006 to 9010). What is required now is to read the Interrupt Enable Register (IER) at Sheila &6E, as a set bit in this register will give the identity of the IRQ. This is performed by lines 9012 to 9015. For an interrupt to have occurred, the corresponding bits in the IFR and IER must have been set; to determine the actual bit these two bytes are logically ANDed together to preserve the set bit (line



9015 to 9016). Now all that is required is to shift the byte to condition the negative flag. Setting the negative flag will determine that the bit just shifted was the line associated bit that caused the IRQ and thus the BMI for that test will proceed.

```

10 REM *** FIND HIGHEST IRQ ***
20 REM ***needs extra user coding***
30 REM **to run sequence correctly**
40 :
9000 DEF PROChighestIRQ (temp,addr)
9001 FOR pass=0 TO 3 STEP 3
9002 P%=addr
9003 [
9004 OPT pass
9005 .findIRQ
9006         LDA #896
9007         LDX #6D
9008         JSR &FFF4
9009         TYA
9010         BPL next_device
9011         PHA
9012         LDA #896
9013         LDX #6E
9014         JSR &FFF4
9015         STY temp
9016         PLA
9017         AND temp
9018         ASL A
9019         BMI timer1
9020         ASL A
9021         BMI timer2
9022         ASL A
9023         BMI cb1
9024         ASL A
9025         BMI cb2
9026         ASL A
9027         BMI shift_reg
9028         ASL A
9029         BMI ca1
9030         ASL A
9031         BMI ca2
9032         JMP error
9033 .timer1
9034         JMP T1service
9035 .timer2
9036         JMP T2service
9037 .cb1
9038         JMP cb1service
9039 .cb2
9040         JMP cb2service
9041 .shift_reg

```

```

9042          JMP srsservice
9043 .ca1
9044          JMP ca1service
9045 .ca2
9046          JMP ca2service
9047 .error
9048          \ error service routine here
9049 .next_device
9050          \ more polling here
9051 J
9052 NEXT
9053 ENDPROC

```

*Program 14.1. PROChighestIRQ - locates the highest priority interrupt.*

In Program 14.1 I have used a left to right priority system, so that bit 6 has a greater priority than bit 5. Therefore an interrupt on T1 interrupt enable has a greater priority than an interrupt on T2 and so forth. You can arrange your own priorities to suit, though the test procedure might not be a simple shift and branch sequence, and more complex coding might be required.

### **A timed delay**

Both the timers in the User VIA can be used to produce delays. Program 14.2 uses Timer 1 to provide one-millisecond delay using it in its one-shot mode of operation. To place T1 into this mode, zero must be written to the Auxillary Control Register at Sheila &6B. Next the delay must be loaded into the latches. One millisecond corresponds to 1000 cycles, however, and it should be remembered that T1 has an operating overhead of 1.5 cycles, so the actual value loaded into the latches must be the actual value minus 2. Thus, 998 is to be deposited into the T1 latches. Lines 9070 to 9075 perform this using the hex equivalent &3E8; writing to the msb latch starts the timer running. On timing out, the T1 bit in the IFR will be set. To test for this, &40, is loaded into the accumulator and the IFR tested using the BIT operation. This small loop (lines 9077 to 9079) continues until the BEQ fails, denoting time out. The T1 flag is then cleared by reading the latch (line 9080).

```

10 REM *** MILLISECOND DELAY USING T1
***
20 PROCTimerone_delay (&C00)
30 CALL millisec1
40 END

```

```

50 :
9060 DEF PROCTimerone_delay (addr)
9061 FOR pass=0 TO 3 STEP 3
9062 P%=addr
9063 [
9064 OPT pass
9065 .millisec1
9066         LDA #897
9067         LDX #86B
9068         LDY #0
9069         JSR &FFF4
9070         LDX #864
9071         LDY #8E8
9072         JSR &FFF4
9073         LDX #865
9074         LDY #3
9075         JSR &FFF4
9076         LDA #840
9077 .loop
9078         BIT &FE6D
9079         BEQ loop
9080         LDA &FE64
9081         RTS
9082 ]
9083 NEXT
9084 ENDPROC

```

*Program 14.2. PROCTimerone\_delay - a one millisecond delay using Timer 1.*

Program 14.3 performs a similar delay using Timer 2. Only the addresses in the program and the bit mask change.

```

10 REM *** MILLISECOND DELAY USING T2
***
20 PROCTimertwo_delay (&C00)
30 CALL millisec
40 END
50 :
9100 DEF PROCTimertwo_delay (addr)
9101 FOR pass=0 TO 3 STEP 3
9102 P%=addr
9103 [
9104 OPT pass
9105 .millisec
9106         LDA #897
9107         LDX #86B
9108         LDY #0
9109         JSR &FFF4
9110         LDX #868
9111         LDY #8E8
9112         JSR &FFF4

```

```

9113             LDX #&69
9114             LDY #3
9115             JSR &FFF4
9116             LDA #&20
9117 .loop
9118             BIT &FE6D
9119             BEQ loop
9120             LDA &FE6B
9121             RTS
9122 J
9123 NEXT
9124 ENDPROC

```

*Program 14.3. PROCtimertwo\_delay - a one millisecond delay using Timer 2.*

The timers are fine for providing very short delay loops but for substantial delays they are not really suitable. Program 14.4 will provide a 1-second delay. It does this by just executing a series of timed loops. As the clock on the Beeb operates at 2MHz, the delay loop need only count out 2000000 cycles to create the delay.

```

10 REM *** 1.0 SECOND DELAY ***
20 PROCdelay (&C00)
30 INPUT "How many seconds delay ? : " w
ait
40 TIME=0
50 FOR loop=1 TO wait
60 CALL &C00
70 NEXT
80 time%=TIME
90 time%=(time%/100)
100 PRINT "Time taken was : ";time%;
110 PRINT " second(s)"
120 END
130 :
9130 DEF PROCdelay (addr)
9131 FOR PASS=0 TO 3 STEP 3
9132 P%=addr
9133 [ OPT PASS
9134             PHP
9135             PHA
9136             TXA
9137             PHA
9138             TYA
9139             PHA
9140             LDY outer
9141 .loop1
9142             TYA

```

```

9143          PHA
9144          LDX inner
9145 .loop2
9146          LDY #5
9147 .loop3
9148          DEY
9149          BNE loop3
9150          DEX
9151          BNE loop2
9152          LDY #2
9153 .loop4
9154          DEY
9155          BNE loop4
9156          PLA
9157          TAY
9158          DEY
9159          BNE loop1
9160          LDY fine
9161 .loop5
9162          DEY
9163          BNE loop5
9164          PLA
9165          TAY
9166          PLA
9167          TAX
9168          PLA
9169          PLP
9170          RTS
9171 .outer
9172          EQUB 251
9173 .inner
9174          EQUB 0
9175 .fine
9176          EQUB 197
9177 ]
9178 NEXT
9179 ENDPROC

```

*Program 14.4. PROCdelay - a one second delay loop.*

The main loop counter is provided by 'outer' while the finer inner loop counter is 'inner'. The program commences by pushing all processor registers onto the stack thus preserving their status on return. This process takes 16 cycles (lines 9134 to 9139). The Y register is then loaded with 'outer' (4 cycles line 9140) and 'loop1' entered. This major outer loop has a smaller loop within it between lines 9145 and 9151 which takes a total of  $256 \times 31 - 1$  cycles or 7935 cycles to execute. As the outer 'loop1' is controlled by the contents of the Y register, 251, the main loop between lines 9141 and 9159 takes  $251 \times 7964 - 1$  or 1998963 cycles

to run. In both cases, the -1 is needed because the final branch does not take place and therefore only uses 2 cycles and not the 3 allowed in the calculation. The final 'fine' loop plus restoring the registers add a further 30+984 (the loop in lines 9162 to 9163) cycles to the overall delay. The total delay provided by the loop is therefore calculated as  $1998963 + 16 + 4 + 30 + 984 = 1999997$  cycles. This is obviously three cycles short of the desired delay, which doesn't really bear thinking about!

The BASIC demo asks how long a delay you would like. Because there is an overhead in the BASIC operations, don't be too surprised if you enter 20 in response to the prompt and get an answer of 23 seconds back. The extra three seconds were created by the BASIC interpreter working through the program! Now a question. Add the following line to the program -

25 CLS

and run it. Why does it seem to work twice as quick? Don't expect the answer; I'm still trying to fathom it out for myself!

## **A push me pull you**

The last program showed that a subroutine call need not destroy the contents of the processor registers if their contents are important. With the exception of two programs in this book all the assembler procedures alter the contents of at least the accumulator and many of the index registers as well. Programs 14.5 and 14.6 provide suitable procedures to save and then restore all processor registers. The main point to note here is that the assembler is not implemented as a subroutine; in other words it does not end with an RTS. This means that the code must be placed at the point it is needed, with the register changing hex following straight after. It would be possible to implement it as a subroutine if required though I would not recommend it as it would need some jiggery pokery with the stack to put the RTS address after the pushed register values.

```
10 REM*SAVE ALL PROCESSOR REGISTERS*
20 REM*DOES NOT HAVE RTS MUST BE *
30 REM*USED DIRECTLY IN CODE. *
40 :
9200 DEF PROCpush_all(addr)
9201 PX=addr
9202 C OPT 2
9203 .pushall
```

```

9204             PHP
9205             PHA
9206             TXA
9207             PHA
9208             TYA
9209             PHA
9210 ]
9211 ENDPROC

```

*Program 14.5. PROCpush\_all - save all processor registers on hardware stack.*

```

10 REM*RESTORE ALL PROCESSOR REGISTER
S*
20 REM*DOES NOT HAVE RTS MUST BE *
30 REM*USED DIRECTLY IN CODE. *
40 :
9220 DEF PROCpull_all(addr)
9221 P%=addr
9222 [ OPT 2
9223 .pullall
9224 PLA
9225 TAY
9226 PLA
9227 TAX
9228 PLA
9229 PLP
9230 ]
9231 ENDPROC

```

*Program 14.6. PROCpull\_all - restore all processor registers off of the hardware stack.*

## Count on it

And so to the last two of the 75 programs in this book, which I do hope you have found informative and useful. The two programs implement double-byte counters, useful for loop control with a count greater than 255 or for updating a two-byte memory address.

Program 14.7 is an incrementing counter. The procedure first loads the start value of the counter, 'num' into the two bytes from 'block' (lines 9244 to 9248). The incrementing starts at 'plus\_one' (line 9249) where 'block' has one added to it (line 9250). Any carry is detected by the zero flag and if set, one is added to 'block+1' else a return via 'no\_inc' is performed.

```

10 REM *** TWO BYTE COUNTER ***
20 PROCinc_count (5000,&70,&C00)
25 CALL seed_value
30 REPEAT
40 PRINT?&71*256+?&70
50 CALL plus_one
60 UNTIL ?&71=0
70 END
80 :
9240 DEF PROCinc_count (num,block,addr)
9241 FOR pass=0 TO 3 STEP 3
9242 Px=addr
9243 [ OPT pass
9244 .seed_value
9245         LDA #num MOD 256
9246         STA block
9247         LDA #num DIV 256
9248         STA block+1
9249 .plus_one
9250         INC block
9251         BNE no_inc
9252         INC block+1
9253 .no_inc
9254         RTS
9255 ]
9256 NEXT
9257 ENDPROC

```

*Program 14.7. PROCinc\_count - performs a double-byte increment.*

```

10 REM *** DOUBLE BYTE DECREMENT ***
20 PROCdec_count (5000,&70,&C00)
25 CALL seed_value
30 REPEAT
40 PRINT?&71*256+?&70
50 CALL minus_one
60 UNTIL ?&71=0
70 END
80 :
9260 DEF PROCdec_count (num,block,addr)
9261 FOR pass=0 TO 3 STEP 3
9262 Px=addr
9263 [ OPT pass
9264 .seed_value
9265         LDA #num MOD256
9266         STA block
9267         LDA #num DIV256
9268         STA block+1
9269 .minus_one
9270         LDA block

```



```

9271                BNE no_dec
9272                DEC block+1
9273 .no_dec
9274                DEC block
9275                RTS
9276 J
9277 NEXT
9278 ENDPROC

```

*Program 14.8. PROCdec\_count - performs a double-byte decrement.*

The application program in lines 20 to 60 shows that once a count value has been seeded only 'plus\_one' should be called to increment the block.

Decrementing a two-byte counter is a little less straightforward (Program 14.8). As before, the count start value is first seeded through 'num' (lines 9264 to 9268). The decrement process begins at 'minus\_one' by first loading the low byte of the count at 'block' into the accumulator (line 9270). If this byte should be zero then the decrement must take the high page byte into consideration and decrement this (line 9272). Finally, the low byte is decremented (line 9274).

As with the previous program, after the initial set up it is 'no\_dcc' that must be called to perform the decrement as the BASIC demo illustrates.

## Program fact sheets

### *Program 14.1*

|                        |                  |
|------------------------|------------------|
| Procedure title        | : PROChighestIRQ |
| Variables required     | : temp, addr     |
| Line numbers           | : 9000 to >9050  |
| Length                 | : variable       |
| Zero page requirements | : none           |
| Registers changed      | : A, X, Y        |

### *Program 14.2*

|                        |                      |
|------------------------|----------------------|
| Procedure title        | : PROctimerone_delay |
| Variables required     | : addr               |
| Line numbers           | : 9060 to 9084       |
| Length                 | : 34 bytes           |
| Zero page requirements | : none               |
| Registers changed      | : A, X, Y            |

*Program 14.3*

|                        |                      |
|------------------------|----------------------|
| Procedure title        | : PROCtimertwo_delay |
| Variables required     | : addr               |
| Line numbers           | : 9100 to 9124       |
| Length                 | : 34 bytes           |
| Zero page requirements | : none               |
| Registers changed      | : A, X, Y            |

*Program 14.4*

|                        |                |
|------------------------|----------------|
| Procedure title        | : PROCdelay    |
| Variables required     | : addr         |
| Line numbers           | : 9130 to 9179 |
| Length                 | : 48 bytes     |
| Zero page requirements | : none         |
| Registers changed      | : none         |

*Program 14.5*

|                        |                |
|------------------------|----------------|
| Procedure title        | : PROCpush_all |
| Variables required     | : addr         |
| Line numbers           | : 9200 to 9211 |
| Length                 | : 6 bytes      |
| Zero page requirements | : none         |
| Registers changed      | : none         |

*Program 14.6*

|                        |                |
|------------------------|----------------|
| Procedure title        | : PROCpull_all |
| Variables required     | : addr         |
| Line numbers           | : 9220 to 9231 |
| Length                 | : 6 bytes      |
| Zero page requirements | : none         |
| Registers changed      | : A, X, Y      |

Odd One Out193

*Program 14.7*

|                    |                    |
|--------------------|--------------------|
| Procedure title    | : PROCinc_count    |
| Variables required | : num, block, addr |
| Line numbers       | : 9240 to 9257     |
| Length             | : 15 bytes         |

Zero page requirements : 2 bytes  
Registers changed : A

*Program 14.8*

Procedure title : PROCdec\_count  
Variables required : num, block, addr  
Line numbers : 9260 to 9278  
Length : 17 bytes  
Zero page requirements : 2 bytes  
Registers changed : A

# Index

- Acorn User, 10
- ADC channels, 72
- addition, 88
- ASCII, 2
- ASCII to BCD conversion, 179
- ASCII to decimal conversion, 25
- ASL, 88, 101
- assembler formatter, 32, 36
- autorun, 85
  
- bar code programs, 195
- BASIC I, 7
- BASIC II, 1, 7
- BASIC formatter, 32, 33
- BCD to ASCII conversion, 178
- binary search, 131
- binary to Hex ASCII conversion, 177
- BRKV, 80
- bubble sort, 152
  
- CLG, 119
- clock, 72
- CLS, 166
- CNTR L, 18
- COLOUR, 117
- compact, 81
- CRTC, 36, 111, 112
  
- delay one second, 187
- decrementing counter, 192
- division, 88, 94
- DRAW, 115
  
- escape, 80
- ELSE, 36
- Epson, 41
- errors, 78
- error lister, 78
- EQU, 7
- EQUB, 7
- EQU D, 7
- EQU S, 7
- EQU W, 7
- events, 72
- events, list of, 73
- EVNTV, 72, 76
  
- fastsort, 155
- FN, 7
- function key buffer, 11
- function key listing, 19
- function keys, 10
- GET, 170
- GCOL, 117, 118
- global search and replace, 61
- graphics cursor position, 121
- GREPL, 61
  
- hex to ASCII decimal conversion, 59
- HIMEM, 24
  
- IER, 185
- IF, 36
- IFR, 185
- incrementing counter, 190
- INKEY, 171, 172
- integer sort, 150
- interrupt polling, 183
- interval timer, 72
- IRQ, 183
  
- library, 1, 2
- LISTO, 32, 33, 36
- load screen memory, 45
- LOMEM, 24
- LSR, 88, 102
  
- maximum-minimum values, 142
- memory remaining, 24
- millisecond delay TI, 185

millisecond delay T2, 186  
 MODE, 3, 108  
 MODE2A, 109  
 MODE2A screen map, 112  
 MODE5A, 113  
 MOS, 3, 13, 36, 54  
 MOVE, 3, 114  
 multiplication, 88  
  
 new list, 153  
 next free location, 24  
  
 one dimensional byte array, 146  
 ordered addition, 134  
 ordered delete, 139  
 OPT, 4, 7, 9  
 OSBYTE, 112, 170, 171, 172, 183  
 OSFILE, 41, 44  
 OSFILE call codes, 42  
 OSFILE parameter block, 41, 121  
 OSWORD, 51, 73, 121, 122, 174, 176  
 OSWORD parameter block, 51, 123, 175  
 OSWRCH, 50, 51, 109, 114, 118, 124  
  
 P%, 4  
 pack, 81  
 PAGE, 24  
 physical colours, 117  
 PLOT, 3, 116  
 POINT, 122  
 pointer bytes, 10  
 POS, 166  
 printer screen dumper, 46  
 PROC, 2  
 PROC\_screen\_dump, 47  
 PROCasc\_bcd, 179  
 PROCbasic\_format, 33  
 PROCbackgrnd, 118  
 PROCbcd\_ascii, 178  
 PROCbin\_search, 132  
 PROCbyte\_array, 146  
 PROCchange\_palette, 120  
 PROCclg, 119  
 PROCcls, 166  
 PROCcolour, 117  
 PROCcursor, 166  
 PROCdec\_count, 191  
 PROCdelay, 187  
 PROCdraw, 115  
 PROCerror, 79  
 PROCgcol, 119  
 PROCgcursor, 121 .  
 PROCgetkey, 170  
 PROCgrepl, 63  
 PROChex\_asc, 177  
 PROChighestIRQ, 184  
 PROCinc\_count, 191  
 PROCinfo, 20  
 PROCinkey, 171  
 PROCinputline, 175  
 PROCkeys1, 13  
 PROCkeys2, 16  
 PROCkeytest, 173  
 PROCloadscreen, 45  
 PROCmax\_min, 142  
 PROCmode, 108  
 PROCmode2A, 109  
 PROCmode5A, 113  
 PROCmove, 114  
 PROCmultii\_add, 89  
 PROCmulti\_div, 94  
 PROCmulti\_mult, 91  
 PROCmulti\_sub, 90  
 PROCnew\_list, 154  
 PROConebyte\_square, 98  
 PROCordered\_add, 135  
 PROCordered\_del, 139  
 PROCpack, 82  
 PROCpixel, 122  
 PROCplot, 116  
 PROCpull\_all, 190  
 PROCpush\_a}l, 189  
 PROCquick, 156  
 PROCreadchr, 176  
 PROCreadpalette, 123  
 PROCsavescreen, 42  
 PROCsort32, 151  
 PROCspace, 167  
 PROCstring, 168  
 PROCTabx, 169  
 PROCTabxy, 169  
 PROCtime, 74  
 PROCTimerone\_delay, 185  
 PROCTimertwo\_delay, 186  
 PROCTwo\_asl, 101  
 PROCTwobyte\_square, 100  
 PROCTwo\_byte\_lsr, 102  
 PROCTwo\_byte\_ror, 103  
 PROCTwo\_byte\_rol, 104  
 PROCTwodim\_byte, 147  
 PROCunordered\_del, 144  
 PROCvars, 26  
 PROCvduchrs, 56  
 PROCword\_array, 149

PROCwritepalette,124  
 PROCxyaddr, 125  
 program fact sheets,19, 31, 40, 52, 60, 71, 77, 87, 105, 106, 107, 127, 128, 129, 130, 162, 163, 164, 180, 181, 182, 192, 193, 194  
 program formatters, 32  
 program information, 20  
 program information service, 25  
 program size, 24  
  
 quicksort, 155  
  
 REM, 81, 84  
 ROL, 88  
 ROR, 88, 103  
  
 save screen memory, 41  
 screen dump, 52  
 simple graphics compiler, 2  
 soft character buffer, 54  
 spaces, 81, 84  
 SPC, 167  
 square roots, 88, 98  
 Star, 41  
 status, 20, 24  
 STRING\$, 167  
  
 subtraction, 88, 90  
  
 TAB(X), 168  
 TAB(X,Y), 168  
 TOP, 24  
 top pointer, 13  
  
 unordered delete, 144  
 user defined characters, 53  
 user VIA, 183  
  
 variable storage, 27, 28  
 variables, 20  
 VARTOP, 24  
 video control register,113,114  
 VDU, 51, 54, 108, 112  
 VDU19, 120  
 VDU23, 53,111  
 VDU25,114  
 VPOS. 166  
  
 word array, 149  
  
 WRDCH: 33, 36, 39  
  
 \*EXEC, 1, 3, 5  
 \*SPOOL, 2, 3  
 \*640 table, 125

