Assembly Language for Arcade Games and other Fast Spectrum Programs

Stuart Nicholls

ASSEMBLY LANGUAGE FOR ARCADE GAMES AND OTHER FAST SPECTRUM PROGRAMS

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To my wife Fran for all her help in typing the original manuscript (a task carried out without understanding a word of it).

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PREFACE

So you have ploughed your way through handbooks or manuals on Z80 machine language programming for the Spectrum and have been given a fair knowledge of all the instructions! But just as they were getting interesting you end up with a few examples of how to add and subtract and are then left to fend for yourself.

This book will take you on to the next stage, carrying on where the others left off, and showing you how to *use* your knowledge of Spectrum routines to produce full working programs written entirely in machine code.

We shall look at the easier routines such as printing and also at the more complicated routines such as random numbers and the use of the calculator with floating point numbers.

The final Chapter shows how to apply the information given in the book to convert a BASIC games program entirely into machine code and, for those of you who cannot spend the time programming from the listings, an accompanying tape with demonstration programs of all the points discussed (including the BASIC and machine code versions of the main program for comparison) is available (see the last page in this book).

The machine code listings have all been produced using the McGraw-Hill Assembler. I cannot stress too highly that anyone who is serious about writing machine language programs should use an Assembler, since it does remove all the tedious table-searching normally associated with machine language and, more importantly, it enables you to modify your program easily when it crashes (which will happen all too often when you first start out).

1 PRINTING WITH COLOUR

Although printing in machine code is the most tedious and time-consuming of tasks, it is also one of the most important. A good program can be spoilt by a bad layout and display with perhaps ambiguous input prompts and, likewise, a mediocre program can be improved by a good layout. Before any program is developed, a good deal of thought must go into the visual presentation.

The Spectrum has 21 user-definable graphics (UDGs) so make full use of them. For example, if you are developing a space invaders type of game, do not stop at redefining the invaders, bombs, and shots; use the remaining characters to redefine numbers zero to nine to give futuristic characters for scoring or to create interesting landscapes. Use colours sensibly; do not put *red* and *magenta* together (or *yellow* and *white*) and it may be wise to run your program on a black and white set to see whether it still looks right since many Spectrum owners will not have easy access to a colour set.

As every program requires printing of information in one form or another, in this Chapter we will look at methods of converting BASIC PRINT into machine code.

The first BASIC program command usually involves the setting up of BORDER, PAPER, and INK permanent colours followed by CLS to put these colours on to the screen.

The BORDER colour is probably the easiest to set up in machine code and takes just five bytes. The A register is first loaded with the 'colour number' required and a call then made to the ROM routine 8859 d (229Bh). This routine sets the screen to the required border

```
10 BORDER 5: REM green


org 23760
23760 3E 05       ld a,5

CALL BORDER SET

23762 CD 9B 22    call 8859
23765 C9          ret
```

Program 1.1

and stores the colour value in the systems variable BORDCR 23624 (the value stored is in fact eight times the colour value) that is bits 5 – 3. The other bits are used to store the INK, BRIGHT, and FLASH parameters for the lower half of the screen (the *input lines*).

Program 1.1 shows the machine code version for the setting of BORDER 5 (green).

The permanent colours for PAPER and INK are held in the systems variable ATTR-P (23693). Bits 0–2 hold the INK colours and bits 3–5 the PAPER colours. The remaining bits 6 and 7 are used to indicate FLASH and BRIGHT. For FLASH 0 bit 7 is reset; for FLASH 1 bit 7 is set. BRIGHT 0 has bit 6 reset and BRIGHT 1 has bit 6 set.

Program 1.2 shows the setting of PAPER 3: INK 1: CLS and demonstrates the fact that ATTR-P (23693) can be regarded as IY + 83. The IY register is used as a pointer to systems variable and holds value 23610. If you wish to 'LD(23609), A' for example this can be considered as (IY − 1) or (IY + 255).

```
  5 REM set up permanent screen
colours
 10 PAPER 3: INK 1: CLS


Ld (ATTR-P),colours

23762 FD 36 53 19 ld (iy+83),25
```

```
Call open channel 2

23766 3E 02       ld a,2
23768 CD 01 16    call 5633

call CLS

23771 CD 6B 0D    call 3435
23774 C9          ret
```

Program 1.2

The CLS command CALL 3435 clears the screen and sets the screen parameters as in the BASIC CLS *but* you will notice that before the call to CLS is made there is a call to ROM routine 5633. This is most important and will be used many times throughout this Chapter. The call is necessary to open channel 2 allowing information to go to the top half of the screen, that is, lines 0 to 21. Once our permanent screen parameters are set up, we can move on to actually printing on the screen.

Program 1.3 shows the method of printing a character on the screen in the *next* print position; this will be 0,0; if a CLS command has been executed. You will notice again that 'channel 2' requires opening first and that the code of the character to be printed is held in the A register.

The ROM routine to print a character is called using RST 16 d which in fact is a call to routine 5618 d. This routine prints the character in the A register and moves the print position along one place.

```
 REM print a character using
permanent colours
 10 PRINT "A";

org 23760

Open channel 2

23760 3E 02       ld a,2
23762 CD 01 16    call 5633
```

```
LOAD ACC. CODE CHR A

23765 3E 41       ld a,65

CALL PRINT

23767 D7          rst 16
23768 C9          ret
```

Program 1.3

Program 1.4 expands the above to enable a 'short' word to be printed. Again channel 2 is opened and the A register loaded with each character in turn until the whole word is printed.

```
10 REM Print a string of chrs.
20 PRINT "HELLO"



org 23760

Open channel 2

23760 3E 02       ld a,2
23762 CD 01 16    call 5633
23765 3E 48       ld a,72
H
23767 D7          rst 16
23768 3E 45       ld a,69
```

```
E
23770 D7          rst 16
23771 3E 4C       ld a,76
L
23773 D7          rst 16
23774 3E 4C       ld a,76
L
23776 D7          rst 16
23777 3E 4F       ld a,79
O


23779 D7          rst 16
23780 C9          ret
```

Program 1.4

You can see however that the above method would become time and memory consuming if a long word or sentence were to be printed and would be better tackled in a different way.

There are several options open to us as are demonstrated in Program 1.5. The main idea is to hold the message as DATA to be read one character at a time until all of DATA is printed.

```
10 REM Print a LONG string
20 Print "HELP ME"



org 23760
23760 3E 02       ld a,2
23762 CD 01 16    call 5633
23765 11 E4 5C    ld de,DATA
23768 01 07 00    ld bc,7

String length
```

```
Loop
23771 78          ld a,b
23772 B1          or c
23773 0B          dec bc
23774 C8          ret z
23775 1A          ld a,(de)
23776 13          inc de
23777 D7          rst 16
23778 18 F7       jr Loop
DATA
defb 72 69 76 80 32 77 69
```

Program 1.5

In *version 1* the DE register holds the address of the start of DATA and is used as a pointer to each character; the BC register holds the length of the string and an RST 16 call is made for each character in turn until BC = 0.

```
org 23760
23760 3E 02       ld a,2
23762 CD 01 16    call 5633
23765 11 DF 5C    ld de,DATA
23768 01 07 00    ld bc,7
```

```
CALL PRINT STRING

23771 CD 3C 20    call 8252
23774 C9          ret
DATA
defb 72 69 76 80 32 77 69
```

Version 2 is in fact the same as version 1 except that the ROM routine 8252d is used which in fact is a copy of version 1 routine from address 23771 to 23778.

```
org 23760
23760 3E 02       ld a,2
23762 CD 01 16    call 5633
23765 11 E5 5C    ld de,DATA
Loop
23768 1A          ld a,(de)
23769 CB 7F       bit 7,a
23771 20 04       jr nz,END
23773 D7          rst 16
```

```
23774 13          inc de
23775 18 F7       jr Loop
END
23777 CB BF       res 7,a
23779 D7          rst 16
23780 C9          ret
DATA
defb 72 69 76 80 32 77 197
```

Version 3 can be used for printing strings of any length but is limited to character codes 0 to 127. The last character is used as a marker to indicate the end of the string by having 128 added to its code, in effect setting bit 7, then before a character is printed a check is made to see whether bit 7 is zero. If it is then the PRINT loop is repeated; if not, a jump is made to the END routine which resets bit 7,A, prints the character, and continues with the program, in this case RET.

Version 3 can be used as a 'PRINT subroutine' in a program where several messages can be stored together with end markers and all that would be necessary would be to load DE with the start address of the message required and to make a call to the PRINT subroutine. A similar, though more complicated, routine is used by the Spectrum for printing keywords and error messages; this routine starts at address 3082 d.

The error messages 1 to R as listed in the Spectrum manual Appendix B can be printed easily by using the RST 8 command. The byte following the RST 8 instruction points to the error message required. For example, if you require the message 'K invalid colour' which is in fact the twenty-first error message, then use:

```
RST 8
defb 19d (message number – 2)
```

There is no need for a return instruction as the ROM will automatically return to BASIC after printing the error.

We can now move on to printing characters or strings at a specific line and column, as in the BASIC PRINT AT line, column; 'message'. Again, if you look at Appendix A of the Spectrum manual, you will see that character codes 6 to 23 are control codes and in particular code 22 is the code for 'AT'. Now luckily for us the RST 16 instruction will recognize code 22 as 'PRINT AT' and will use the next two bytes of DATA as the x,y; coordinates to give the start position of the message. Program 1.6 demonstrates this using defb 22,3,5 for PRINT AT 3,5;

```
10 REM Print string at x,y
20 PRINT AT 3,5;"Thank you"


org 23760
23760 3E 02       ld a,2
23762 CD 01 16    call 5633
23765 11 DF 5C    ld de,DATA
23768 01 0C 00    ld bc,12
23771 CD 3C 20    call 8252
23774 C9          ret
DATA

AT 3 5

defb 22 3 5
defs Thank you
```

Program 1.6

The same principle can be used for TAB (CODE 23). Note also that ENTER (CODE 13d) will give the same effect as NEWLINE.

So now we should be able to print any message in any position on lines 0 to 21 using the permanent colours. All that now remains to complete normal screen printing is to print messages in local colours, BRIGHT, FLASH, OVER, and INVERSE.

Program 1.7 shows how this is achieved and follows the same principles as Program 1.6, in that the control codes for PAPER, INK, BRIGHT, etc. are held in DATA with the byte following the control code specifying the parameters.

```
1000 REM Printing in colours
1010 PRINT AT 4,7; PAPER 2; INK
4; FLASH 1; BRIGHT 1; OVER 1; IN
VERSE 1;"Can you read this"

org 23760
23760 3E 02       ld a,2
23762 CD 01 16    call 5633
23765 11 E2 5C    ld de,DATA
23768 01 24 00    ld bc,36
23771 CD 3C 20    call 8252
RESET PERMANENT COLOURS
AND BRIGHT 0 FLASH 0

23774 CD 4D 0D    call 3405
23777 C9          ret
DATA
defb 22 4 7 17 2 14 4 18 1
defb 19 1 21 1 20 1
defs Can you read this
defb 21 0 20 0
```

Program 1.7

After local colours are used it is necessary to reset the permanent colours for further printing. In the case of OVER and INVERSE this requires the resetting to be carried out using RST 16, but the PAPER, INK, BRIGHT, and FLASH can all be reset by a call to the ROM routine 3405d which copies the value in ATTR P (23693) into ATTR T (23695).

Finally, we consider printing on the 'lower half' of the screen, that is the input lines 22 and 23. This uses exactly the same method as described for printing on the upper half, except that a different channel requires opening before RST 16 is used. Program 1.8 gives an example of how this is achieved.

```
10 REM Printing on INPUT lines
20 PRINT #0 AT 0,10;"Input line
0";AT 1,10;"Input line 1"
30 PAUSE 0


org 23760

Open channel -3

23760 3E FD       ld a,253
23762 CD 01 16    call 5633
23765 11 EA 5C    ld de,DATA
23768 01 1E 00    ld bc,30
23771 CD 3C 20    call 8252

WAIT
23774 76          halt

If key presed then
BIT 5,FLAGS will be SET

23775 FD CB 01 6E bit 5,(iy+1)
23779 28 F9       jr z,WAIT
23781 FD CB 01 AE res 5,(iy+1)
23785 C9          ret
DATA

defb 22 0 10
defs Input line 0
defb 22 1 10
defs Input line 1
```

Program 1.8

The channel in this case is −3 (253).

The BASIC program is interesting in that it is not mentioned in the manual that PRINT # 0; will print on the input lines. The PAUSE 0 instruction is necessary to stop the program without the instruction 0 O.K. which would remove the input line printing.

Similarly this machine code routine requires the equivalent of PAUSE 0. This is achieved by continually checking bit 5 of FLAGS (23611) or (IY + 1) after a HALT instruction. The HALT instruction in effect waits for the next KEYSCAN routine and, if a key is pressed, sets bit 5 of FLAGS. So we wait in the loop until bit 5 is set and then return to BASIC. Note that line 22 is counted as line 0 and line 23 as line 1.

One ROM routine that can be very useful for clearing printing on the input lines but leaves the upper screen intact, can be found at 3652, which is a 'clear specified number of lines routine' the number of lines are counted from the bottom of the screen and must be greater than 0. The number of lines is placed in the B register (1–24) and then the call made; the colours used to clear the lines are those held in ATTR P. The input lines can be cleared with the instructions

LD B, 2
CALL 3652
(Return)

Before moving on to the next Chapter there is an important point to note concerning user-definable graphics. If you have written a program that is intended to run on both 16K and 48K machines then the UDGs will need to be correctly located on each machine. The easiest way to achieve this is to set up the UDGs starting at address 32600, that is for a 16K machine, and then to use Program 1.9 to relocate the UDGs as necessary to the address held in the systems variable UDG (23675).

```
  10 REM Transfer 16K UDG's to
correct location for 48K machine
  20 LET de=PEEK 23675+256*PEEK
23676
  30 LET hl=32600
  40 LET bc=168
  50 POKE de,PEEK hl
  60 LET hl=hl+1
  70 LET de=de+1
  80 LET bc=bc-1
  90 IF bc<>0 THEN GO TO 50
 100 REM return
```

```
org 23760
23760 ED 5B 7B 5C ld de,(23675)
23764 21 58 7F    ld hl,32600
23767 01 A8 00    ld bc,168
23770 ED B0       ldir
23772 C9          ret
```

Program 1.9

2 PLOT, DRAW, AND CIRCLE

PLOT

The BASIC command PLOT x,y involves the setting of *pixel* column x, row y in the permanent ink colour. Pixel position 0,0 is considered as the bottom left-hand corner of the screen and 175, 255 as the top right-hand corner.

In machine language there are two useful entry points to the ROM PLOT routine: the first of these, which is probably the more useful and the easier to use, is CALL 8933. Before the routine is called the B register must hold the value of y (in the range 0 to 175) and the C register must hold the value of x (0–255). Program 2.1 shows the simple BASIC command PLOT 75,125.

```
1000 REM Plot x,y
1010 PLOT 75,175

org 23760
23760 06 7D       ld b,125
23762 0E 4B       ld c,75
23764 CD E5 22    call 8933
23767 C9          ret
```

Program 2.1

Using decimal instead of hexadecimal numbers it is easier to follow the program by loading the B and C registers separately. We could of course have saved memory by using LD BC, 32075 but this would have been very confusing.

The second entry point is at 8924. This requires the values of x and y to be placed on the *calculator stack* with the value of y being the top value. Program 2.2 demonstrates this with the same PLOT 75,125.

```
org 23760
23760 3E 4B       ld a,75

STACK 75

23762 CD 28 2D    call 11560
23765 3E 7D       ld a,125

STACK 175

23767 CD 28 2D    call 11560

CALL PLOT

23770 CD DC 22    call 8924
23773 C9          ret
```

Program 2.2

The ROM routine at 11560 is used to place the value held in the A register on top of the calculator stack. With the PLOT routine entered at 8924, the top two values are removed from the stack and the pixel plotted. The calculator stack thus being reduced by two values.

The use of the calculator will be discussed more fully in Program 2.5. This second entry point is useful if the calculator has been used to manipulate a formula for plotting graphs etc.

Program 2.3 shows how PLOT OVER 1; x, y is achieved.

```
10 REM Plot OVER 1;x,y
20 PLOT OVER 1;25,40


org 23760
SET OVER 1
SET BITS 0 & 1 OF P-FLAG

23760 3E 03       ld a,3
23762 FD 77 57    ld (iy+87),a
23765 06 28       ld b,40
23767 0E 19       ld c,25
23769 CD E5 22    call 8933

SET OVER 0
SET BITS 0 & 1 OF P-FLAG

23772 AF          xor a
23773 FD 77 57    ld (iy+87),a
23776 C9          ret
```

Program 2.3

This involves the setting of bits 0 and 1 of P FLAG (IY + 87) before the PLOT call is made, and then resetting 0 and 1 of P FLAG afterwards. If OVER 0 is not reset then any future plotting or printing will be carried out as OVER 1.

PLOT INVERSE is identical in form to PLOT OVER requiring the setting of bits 2 and 3 of P FLAG; the systems variable thus being set to value 12.

Using entry point 8933 we can write a program to plot a character anywhere on the screen. The only limitations being that the code of the character must be from 32 (space) to 127 (copyright), that is, one that has its eight-byte make-up held in the ROM character generator.

```
org 23760
Load L with code of CHR.

23760 2E 7F       ld l,127
23762 26 00       ld h,0

Multiply x8

23764 29          add hl,hl
23765 29          add hl,hl
23766 29          add hl,hl

Add to (23606) to find
start of character

23767 ED 5B 36 5C ld de,(23606)
23771 19          add hl,de
Byte count


23772 06 08       ld b,8
L3
Store pointer HL

23774 E5          push hl

Bit count

23775 0E 08       ld c,8
23777 7E          ld a,(hl)
L2
23778 C5          push bc
```

```
Get plot position x,y

23779 ED 4B 0E 5D ld bc,(XY)

Check if BIT SET

23783 17          rla
23784 F5          push af

23785 30 05       jr nc,L1

If SET then PLOT

23787 C5          push bc
23788 CD E5 22    call 8933
23791 C1          pop bc
L1

Move PLOT to x+1,y

23792 0C          inc c
23793 ED 43 0E 5D ld (XY),bc
23797 F1          pop af
23798 C1          pop bc
23799 0D          dec c
23800 20 E8       jr nz,L2
23802 C5          push bc

Reset PLOT to x-8,y-1

23803 ED 4B 0E 5D ld bc,(XY)
23807 05          dec b
23808 3E F8       ld a,248
23810 81          add a,c
23811 4F          ld c,a
23812 ED 43 0E 5D ld (XY),bc
23816 C1          pop bc
23817 E1          pop hl
23818 23          inc hl

Repeat until BYTE count=0

23819 10 D1       djnz L3
23821 C9          ret
XY
defb 100 20
```

Program 2.4

You can see from Program 2.4 that the code of the character required is placed in the L register (address 23761) and is then multiplied by eight and added to the value stored in the systems variable (23606) to find the start of the eight bytes that make up the character shape in the character generator. The HL register is then used as a *pointer* holding the address of the character byte being examined. The BC register is used as a counter for the eight bit × eight bit matrix of the character and the A register is used to hold the byte being examined.

An RLA instruction is carried out eight times on each character byte and if a bit is set, that is, if after RLA the CARRY flag is set then the pixel is plotted.

After each RLA instruction the x, y coordinates are updated. The x,y start coordinates denote the top left-hand pixel position of the character being plotted. To remain on the screen therefore the value of y must be between 7 and 175. The value of x can be from 0 to 255 as any attempt to take x over 255 will result in the value being reset to 0, that is, if C = 255 then 'inc C' will give C = 0.

This program can be easily modified to plot characters with a 90 degrees anticlockwise rotation.

```
org 23760
Load L with code of CHR.

23760 2E 60        ld l,96
23762 26 00        ld h,0

Multiply x8

23764 29           add hl,hl
23765 29           add hl,hl
23766 29           add hl,hl

Add to (23606) to find
start of character

23767 ED 5B 36 5C ld de,(23606)
23771 19           add hl,de

Byte count


23772 06 08        ld b,8
L3
Store pointer HL

23774 E5           push hl

Bit count

23775 0E 08        ld c,8
23777 7E           ld a,(hl)
L2
23778 C5           push bc

Get plot position x,y

23779 ED 4B 0E 5D ld bc,(XY)

Check if BIT SET

23783 17           rla
23784 F5           push af
23785 30 05        jr nc,L1

If SET then PLOT

23787 C5           push bc
23788 CD E5 22     call 8933
23791 C1           pop bc
L1

Move PLOT to x,y+1

23792 04           inc b
23793 ED 43 0E 5D ld (XY),bc
23797 F1           pop af
23798 C1           pop bc
23799 0D           dec c
23800 20 E8        jr nz,L2
23802 C5           push bc

Reset PLOT to x+1,y-8

23803 ED 4B 0E 5D ld bc,(XY)
23807 0C           inc c
23808 3E F8        ld a,248
23810 80           add a,b
23811 47           ld b,a
23812 ED 43 0E 5D ld (XY),bc
23816 C1           pop bc
23817 E1           pop hl
23818 23           inc hl

Repeat until BYTE count=0

23819 10 D1        djnz L3
23821 C9           ret
XY
defb 100 20
```

Program 2.5

In Program 2.5 the x,y coordinates are updated to give a *vertical* byte plot instead of a *horizontal* one as in Program 2.4; there the x,y start coordinates denote the *bottom* left-hand pixel, and so the range for y is 0 to 167.

Having studied the method of plotting a character we can now move on to our first serious program to *plot a message* anywhere on the screen and, to make it more useful, we shall allow the character height and width to be selected. A copy of the program is available on tape – LOAD 'PLOTDEMO'.

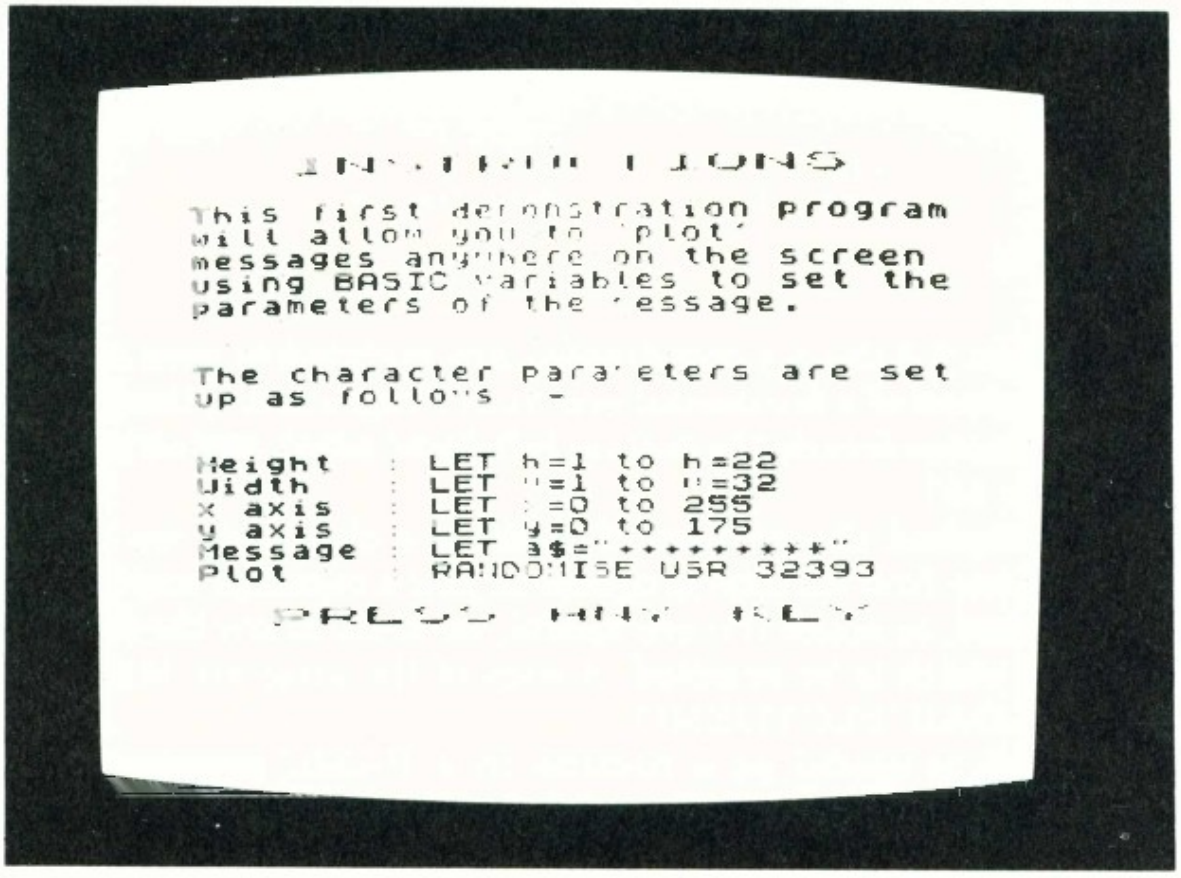
Because it is useful as a routine in a BASIC program I have attached it to a 'search' routine so that the parameters height/width, x/y plot positions, and message can be set up using

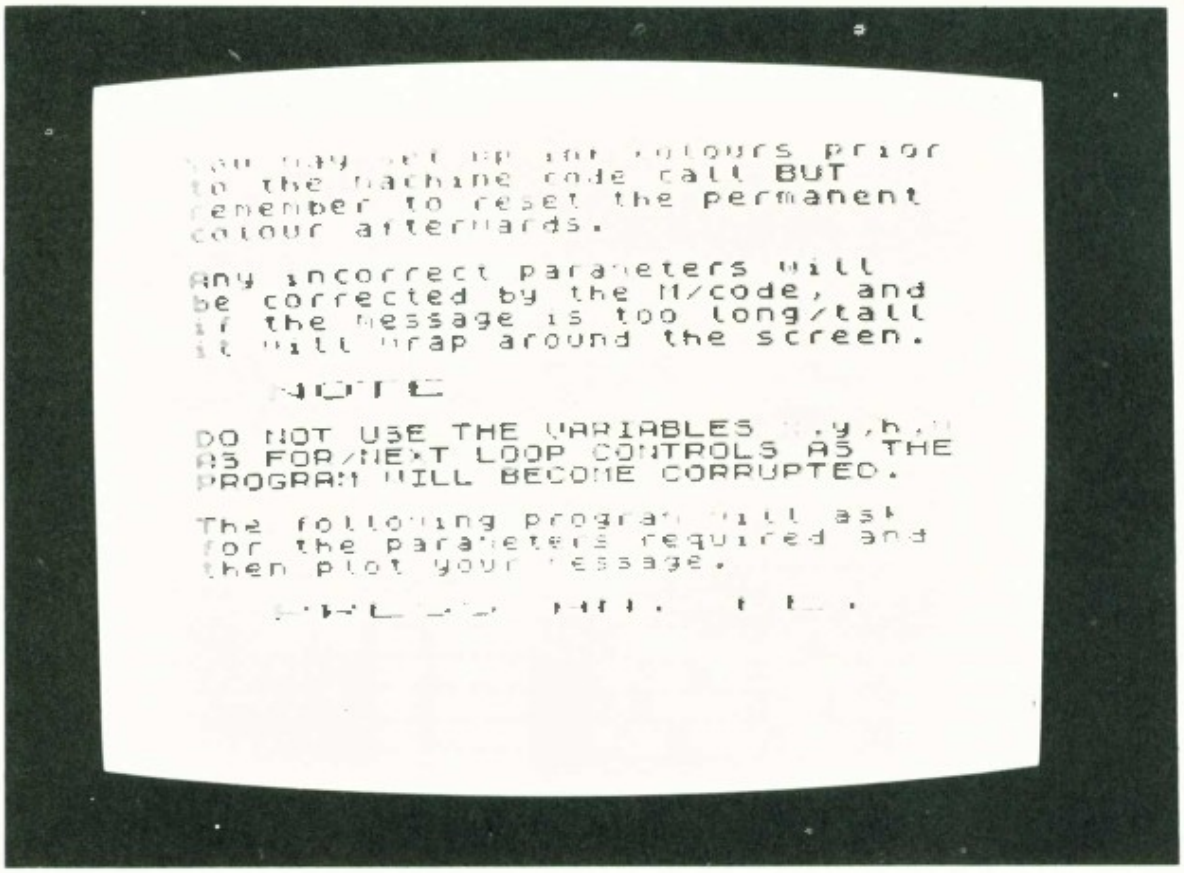
BASIC variables and so negating the need to POKE them into machine code. If you wish to use the routine within a machine code program then the search routine is unnecessary and can be omitted, the parameters can be copied directly into the printer buffer. The BASIC program is self-explanatory and allows the reader to experiment with different values of height/width, x,y, and message (a$).

The machine code is an extension of Program 2.4. The values of x,y,h, and w are found using the search routine. This routine works through the variables store until the required variable CODE is found and then stores the value of the variable (0–255) in the *printer buffer*. Once the simple variable value has been stored, the LEN a$ is found and stored, again (0–255), and finally the message is copied into the Printer buffer (a most useful place for storing data). The 'PLOT' routine includes a CATCH-ALL instruction and will reset any wrong parameters to acceptable ones, and consists of five nested loops:

(L1) Plot a SET bit for WIDTH w
(L2) Repeat L1 for eight bits
(L3) Repeat HEIGHT h times
(L4) Repeat for eight bytes
(L5) Repeat until end of message

But note program comment on FOR/NEXT LOOP variables.






```
  5 OVER 0: INK 0: PAPER 6: BORD
ER 3: CLS
 10 LET x=24: LET y=79: LET h=5:
 LET w=2: LET a$="STOP THE TAPE"
 15 INK 2: RANDOMIZE USR 32393
 18 PAUSE 100
 20 LET w=8: LET y=150: LET x=0:
 LET a$="PLOT"
 30 INK 1: RANDOMIZE USR 32393
 35 LET a$="____": LET y=140
 36 INK 1: RANDOMIZE USR 32393
 40 FLASH 1: GO SUB 0000
 50 FLASH 0
 60 PAUSE 0
 70 PAPER 7: INK 0: BORDER 7: CL
S

 80 LET x=32: LET y=175: LET h=1
: LET w=2: LET a$="INSTRUCTIONS"
 90 INK 2: RANDOMIZE USR 32393:
INK 0
 100 PRINT AT 2,0;"This first dem
onstration programwill allow you
to 'plot'          messages anywher
e on the screen using BASIC varia
bles to set theparameters of the
message."
 110 PRINT '''"The character param
eters are setup as follows :-"
 120 PRINT ''"Height  : LET h=1 t
o h=22"'"Width   : LET w=1 to w=3
2"
 130 PRINT "x axis  : LET x=0 to
255"'"y axis  : LET y=0 to 175"
 140 PRINT "Message : LET a$=";CH
R$ 34;"**********";CHR$ 34
 150 PRINT "Plot     : RANDOMISE U
SR 32393"
 160 GO SUB 8000
 170 IF INKEY$<>"" THEN  GO TO 17
0
 175 IF INKEY$="" THEN  GO TO 175
 178 CLS
 180 PRINT "You may set up ink co
lours priorto the machine code ca
ll BUT    remember to reset the p
ermanent colour afterwards."
 190 PRINT '"Any incorrect parame
ters will   be corrected by the M
/code. and if the message is too
long/tall it will wrap around the
 screen."
 200 LET a$="NOTE": LET y=95: INK
 2: RANDOMIZE USR 32393: INK 0
 210 PRINT AT 12,0;"DO NOT USE TH
E VARIABLES x,y,h,wAS FOR/NEXT LO
OP CONTROLS AS THEPROGRAM WILL BE
COME CORRUPTED."
 220 PRINT '"The following progra
m will ask  for the parameters re
quired and then plot your message
."
 230 GO SUB 8000
 235 IF INKEY$<>"" THEN  GO TO 23
5
 240 IF INKEY$="" THEN  GO TO 240
 242 CLS : BORDER 4
 245 PLOT 0,121: DRAW 255,0: DRAW
0,-73: DRAW -255,0: DRAW 0,73
 250 PRINT AT 8,0;"HEIGHT  1-22 ?
    _","WIDTH   1-32 ?    _","X
```

```
 axis 0-255 ?      ","Y axis 0-1
75 ?      ","MESSAGE ?",,"_____
_____INK
  0-9 ?",,
 255 LET z$="
                 "
 257 LET v$="
                 "
 260 PRINT  OVER 1;AT 8,0;z$
 262 INPUT h: PRINT AT 8,18;h;" "
; OVER 1;AT 8,0;v$
 265 PRINT  OVER 1;AT 9,0;z$: INP
UT w: PRINT AT 9,18;w;" ": OVER 1
;AT 9,0;v$
 270 PRINT  OVER 1;AT 10,0;z$: IN
PUT x: PRINT AT 10,18;x;"  "; OVE
R 1;AT 10,0;v$
 272 PRINT  OVER 1;AT 11,0;z$: IN
PUT y: PRINT AT 11,18;y;"  "; OVE
R 1;AT 11,0;v$
 273 PRINT  OVER 1;AT 12,0;z$;AT
13,0;z$: INPUT a$: PRINT AT 13,0;
a$;: FOR k=LEN a$ TO 31: PRINT "
";: NEXT k: PRINT  OVER 1;AT 12,0
;v$; OVER 1;AT 13,0;v$
 275 PRINT  OVER 1;AT 14,0;z$: IN
PUT i: PRINT AT 14,0; INK i; OVER
 1;v$
 280 PAUSE 50
 290 CLS : INK I: RANDOMIZE USR 3
2393: INK 0
 300 PRINT #0;AT 0,0;"PRESS Q TO
STOP";AT 1,0;"ANY OTHER KEY FOR A
NOTHER GO"
 310 PAUSE 0: IF INKEY$="q" OR IN
KEY$="Q" THEN  STOP
 320 CLS : GO TO 245
8000 LET h=1: LET w=2: LET x=24:
LET y=15: LET a$="PRESS ANY KEY":
 INK 2: RANDOMIZE USR 32393: INK
0
8010 RETURN
9000 STOP
9800 CLEAR 32334: LOAD ""CODE : G
O TO 5
9900 SAVE "PLOTDEMO" LINE 9800
9950 SAVE "LARGE"CODE 32335,265
org 23760 32335
FIND
32335 2A 4B 5C     ld hl,(23627)
L2
32338 3A B0 5C     ld a,(23728)
32341 BE           cp (hl)
32342 C8           ret z
32343 CB 6E        bit 5,(hl)
32345 20 08        jr nz,L1
32347 23           inc hl
32348 5E           ld e,(hl)
32349 23           inc hl
32350 56           ld d,(hl)
32351 19           add hl,de
32352 23           inc hl
32353 18 EF        jr L2
L1
32355 CB 76        bit 6,(hl)
32357 20 0C        jr nz,L3
32359 23           inc hl

32360 7E           ld a,(hl)
32361 CB 7F        bit 7,a
32363 28 FA        jr z,-6
32365 11 06 00     ld de,6
32368 19           add hl,de
32369 18 DF        jr L2
L3
32371 CB 7E        bit 7,(hl)
32373 28 F6        jr z,-10
32375 11 13 00     ld de,19
32378 19           add hl,de
32379 18 D5        jr L2
SET
32381 32 B0 5C     ld (23728),a
32384 CD 4F 7E     call FIND
32387 23           inc hl
32388 23           inc hl
32389 23           inc hl
32390 7E           ld a,(hl)
32391 02           ld (bc),a
32392 C9           ret

START
32393 01 00 5B     ld bc,23296
32396 3E 78        ld a,120
32398 CD 7D 7E     call SET
32401 03           inc bc
32402 3E 79        ld a,121
32404 CD 7D 7E     call SET
32407 03           inc bc
32408 3E 68        ld a,104
32410 CD 7D 7E     call SET
32413 03           inc bc
32414 3E 77        ld a,119
32416 CD 7D 7E     call SET
32419 3E 41        ld a,65
32421 32 B0 5C     ld (23728),a
32424 CD 4F 7E     call FIND
32427 23           inc hl
32428 5E           ld e,(hl)
32429 23           inc hl
32430 56           ld d,(hl)
32431 ED 53 04 5B  ld (23300),de

32435 D5           push de
32436 C1           pop bc
32437 23           inc hl
32438 11 05 5B     ld de,23301
32441 ED B0        ldir
32443 2A 00 5B     ld hl,(23296)
32446 AF           xor a
32447 7C           ld a,h
32448 DE B0        sbc a,176
32450 38 04        jr c,+4
32452 67           ld h,a
32453 22 00 5B     ld (23296),hl
```

```
32456 22 B0 5C     ld (23728),hl
32459 21 05 5B     ld hl,23301
LP5
32462 E5           push hl
32463 7E           ld a,(hl)
32464 26 00        ld h,0
32466 6F           ld l,a
32467 29           add hl,hl
32468 29           add hl,hl
32469 29           add hl,hl
32470 11 00 3C     ld de,15360
32473 19           add hl,de
32474 06 08        ld b,8
LP4
32476 C5           push bc
32477 ED 4B 01 5B  ld bc,(23297)
LP3
32481 7E           ld a,(hl)
32482 E5           push hl
32483 C5           push bc
32484 06 08        ld b,8
LP2
32486 C5           push bc
32487 17           rla
32488 F5           push af
32489 DA F9 7E     jp c,PLOT
32492 2A 03 5B     ld hl,(23299)
32495 3A B0 5C     ld a,(23728)
32498 B5           add a,l
32499 32 B0 5C     ld (23728),a

32502 C3 0F 7F     jp SKIP
PLOT
32505 ED 4B B0 5C  ld bc,(23728)
LP1
32509 C5           push bc
32510 ED 4B B0 5C  ld bc,(23728)
32514 C5           push bc
32515 CD E5 22     call 8933
32518 C1           pop bc
32519 0C           inc c
32520 ED 43 B0 5C  ld (23728),bc
32524 C1           pop bc
32525 10 EE        djnz LP1
SKIP
```

```
32527 F1           pop af
32528 C1           pop bc
32529 10 D3        djnz LP2
32531 3A 00 5B     ld a,(23296)
32534 21 B0 5C     ld hl,23728
32537 77           ld (hl),a
32538 23           inc hl

32539 AF           xor a
32540 7E           ld a,(hl)
32541 DE B0        sbc a,176
32543 38 03        jr c,+3
32545 77           ld (hl),a
32546 18 08        jr +8
32548 7E           ld a,(hl)
32549 FE 00        cp 0
32551 20 02        jr nz,+2
32553 36 B0        ld (hl),176
32555 35           dec (hl)
32556 C1           pop bc
32557 E1           pop hl
32558 10 B1        djnz LP3
32560 23           inc hl
32561 C1           pop bc
32562 10 A8        djnz LP4
32564 3A 03 5B     ld a,(23299)
32567 87           add a,a
32568 87           add a,a
32569 87           add a,a

32570 6F           ld l,a
32571 3A B0 5C     ld a,(23728)
32574 85           add a,l
32575 32 00 5B     ld (23296),a
32578 32 B0 5C     ld (23728),a
32581 3A 01 5B     ld a,(23297)
32584 32 B1 5C     ld (23729),a
32587 E1           pop hl
32588 23           inc hl
32589 3A 04 5B     ld a,(23300)
32592 3D           dec a
32593 C8           ret z
32594 32 04 5B     ld (23300),a
32597 C3 CE 7E     jp LP5
```

Program 2.6

The machine code in Program 2.6 starts at 32393. The first routine, from 32393 to 32418, initializes the BC register as a pointer to the printer buffer and calls the SET subroutine to set the code of the variable being located into address 23728. The SET routine in turn calls the FIND routine to locate the variables code. The value of the variable (0–255) is then stored in the printer buffer address pointed to by the BC register. So variables x,y,h, and w are found and stored consecutively. The routine from 32419 to 32442 finds the code of variable a$, the length (0–255) is then stored and finally the string copied. The routine from 32443 to 32458 checks the value of y

(and if it is greater than 175 sets it to y − 176) and then stores the values x and y back into 23296/7 and also 23728/9.

The remaining machine code is an extension of the character plot routine with the additional loops to PLOT the pixel 'width w' times for 'h lines', a check being made after each 'line' to ensure that the next PLOT position stays on the screen. The routine from 32540 to 32554 checks the next PLOT position and gives a wrap-around effect if it is off the bottom of the screen.

Without going too deeply at this stage into the CALCULATOR routines we can look at a program that makes use of PLOT at entry point 8924.

Program 2.7 shows how a sine wave can be plotted using CALCULATOR to manipulate the formula:

88 + 80 * SIN (A/128 * PI)

```
1000 FOR A=0 TO 255
1010 PLOT A,88+80*SIN (A/128*PI)
1020 NEXT A



org 23760
LET A=0

23760 AF            xor a
LOOP
STORE A
23761 F5            push af
STACK A
23762 CD 28 2D      call 11560
23765 3E 58         ld a,88
23767 CD 28 2D      call 11560
23770 3E 50         ld a,80
23772 CD 28 2D      call 11560
23775 F1            pop af
23776 F5            push af
23777 CD 28 2D      call 11560
23780 3E 80         ld a,128
23782 CD 28 2D      call 11560

STACK 88 80 A 128



USE CALCULATOR

23785 EF            rst 40
Divide top 2 values (A/128)
defb 5
Stack PI/2
defb 163
Duplicate top values
defb 49
Add top 2 values (PI)
defb 15
Multiply top 2 values
(A/128*PI)
defb 4
SIN top value SIN (A/128*PI)
defb 31
Multiply top 2 values
80*SIN (A/128*PI)
defb 4
Add top 2 values
88+80*SIN (A/128*PI)


defb 15
End calculator routine
Top 2 values are
A and 88+80*SIN (A/128*PI)
defb 56
CALL PLOT
23795 CD DC 22      call 8924
Get value A
23798 F1            pop af
23799 3C            inc a
Check not zero (256)
23800 FE 00         cp 0
23802 20 D5         jr nz,LOOP
23804 C9            ret
```

Program 2.7

The CALCULATOR routine can be made to perform complex arithmetic by the use of *literals*. These are in fact ROM calls to perform calculations involving, usually, the top two values on the calculator stack, but may also be applied to string handling. For

instance, if the top two values were 1234 and 2, and Literal 4 were called from within the CALCULATOR routine, then these two values would be removed from the stack, multiplied, and their product put back on top of the stack; the stack would therefore be reduced by one value and the top value would be 2468.

Positive integer numbers can be placed on the stack by means of:

STACK VAL A – CALL 11560 OR STACK VAL BC – CALL – 11563.

In Program 2.7 I have used STACK VAL A to place in order, 'variable A', 88, 80, 'variable A', and 128.

The USE CALCULATOR routine is then called by the RST 40 instruction. The CALCULATOR routine works through the bytes following RST 40 and acts on each one calling further subroutines as required. In our program the next byte is 5, and Literal 5 means 'GOSUB DIVIDE'. The top two values on the stack are then taken, the top one divided into the one underneath and the answer placed back on the stack. The next byte in the routine is Literal 163; this tells the calculator to 'STACK PI/2'.

Literal 49 is DUPLICATE TOP VALUE

Literal 15 is ADD TOP TWO VALUES – thus restacking the sum

Literal 4 is MULTIPLY TOP TWO VALUES

Literal 32 is SINE OF TOP VALUE – thus replacing top value with its sine

There are many more literals that can be used in games programs and these will be discussed in future Chapters.

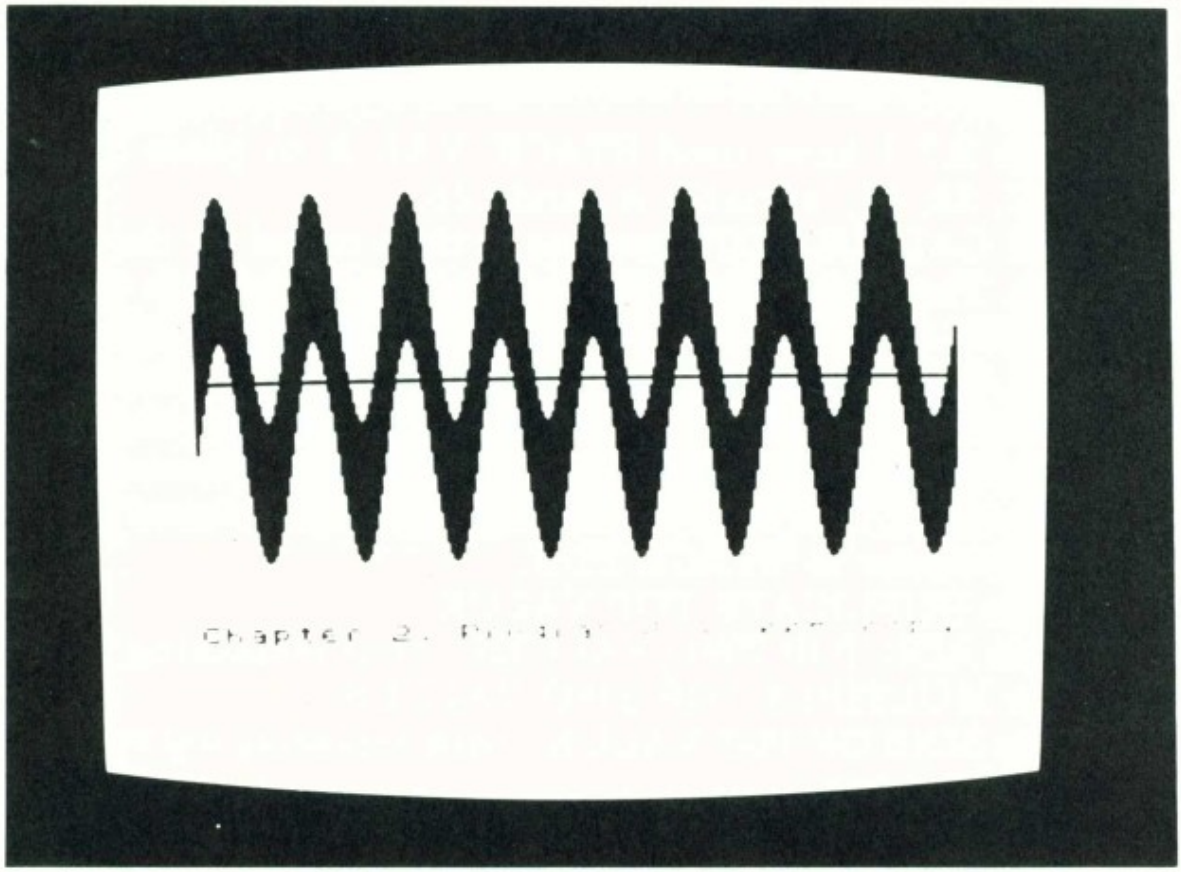
The last Literal 56 is 'END CALCULATOR ROUTINE CALL' which *must* be used to return to your machine code program. One other important point to bear in mind when using the CALCULATOR routine is that, before a 'safe' return to BASIC can be made, the stack must be cleared of all values previously stacked.

At the end of our CALCULATOR routine we are left with two values on the calculator stack, the top value being '88+80 * SIN (A/128 * P1) and the other value 'A'. The PLOT call 8924 then takes these two values, thus resetting the stack, and PLOTs the pixel. The value 'A' is then incremented and the LOOP repeated until 'A' = 256 (that is, 'A' is reset to 0).

You can see from this program that the CALCULATOR's literals are very useful and that a fairly complex formula has been dealt with in just eight bytes. In fact it takes more bytes to set up the stack than to perform the calculations.

DRAW

Again there are two entry points in ROM for the DRAW x, y command. The first point call 9402 requires the ABS value of x to be in the C register and the ABS value of y in the B register. The DE register is used to hold the SGN of x and y; the D register holding SGN x (1 if positive, 255 if negative) and the E register holding SGN y. Program 2.8 is a modified version of Program 2.7 to demonstrate the DRAW command.



```
5 PLOT 0,95: DRAW 255,0
10 FOR a=0 TO 255
20 PLOT a,120+40*SIN (a/16*PI)
DRAW 0,-50
30 NEXT a
```

```
org 23760
Plot 0,95
23760 06 5F       ld b,95
23762 0E 00       ld c,0
23764 CD E5 22    call 8933
Store H'L'
23767 D9          exx
23768 E5          push hl
23769 D9          exx
Draw 255,0
23770 06 00       ld b,0
23772 0E FF       ld c,255
23774 16 01       ld d,1
23776 1E 01       ld e,1
23778 CD BA 24    call 9402
Restore H'L'
23781 D9          exx
23782 E1          pop hl
23783 D9          exx
23784 AF          xor a
L1
23785 F5          push af
23786 CD 28 2D    call 11560
23789 3E 78       ld a,120
23791 CD 28 2D    call 11560
23794 3E 28       ld a,40
23796 CD 28 2D    call 11560
23799 F1          pop af
23800 F5          push af
23801 CD 28 2D    call 11560
23804 3E 10       ld a,16
23806 CD 28 2D    call 11560
23809 EF          rst 40
defb 5 163 49 15 4 31 4 15 56
```

```
23819 CD DC 22     call 8924
Store H'L'
23822 D9           exx
23823 E5           push hl
23824 D9           exx
DRAW 0,-50
23825 06 32        ld b,50


23827 0E 00        ld c,0
23829 16 FF        ld d,255
23831 1E 01        ld e,1
23833 CD BA 24     call 9402
Restore H'L'
23836 D9           exx
23837 E1           pop hl
23838 D9           exx
23839 F1           pop af
23840 3C           inc a
23841 FE 00        cp 0
23843 20 C4        jr nz,L1
23845 C9           ret
```

Program 2.8

Note that before DRAW is called the HL prime register must be saved (in this instance by pushing it onto the stack) because it is used in the DRAW routine.

The value of the HL prime register must *not* be corrupted during a user-written machine code routine or the program will crash on returning to BASIC. The HL prime register value is restored after the DRAW command. DRAW OVER and INVERSE are set in exactly the same way as PLOT OVER/INVERSE.

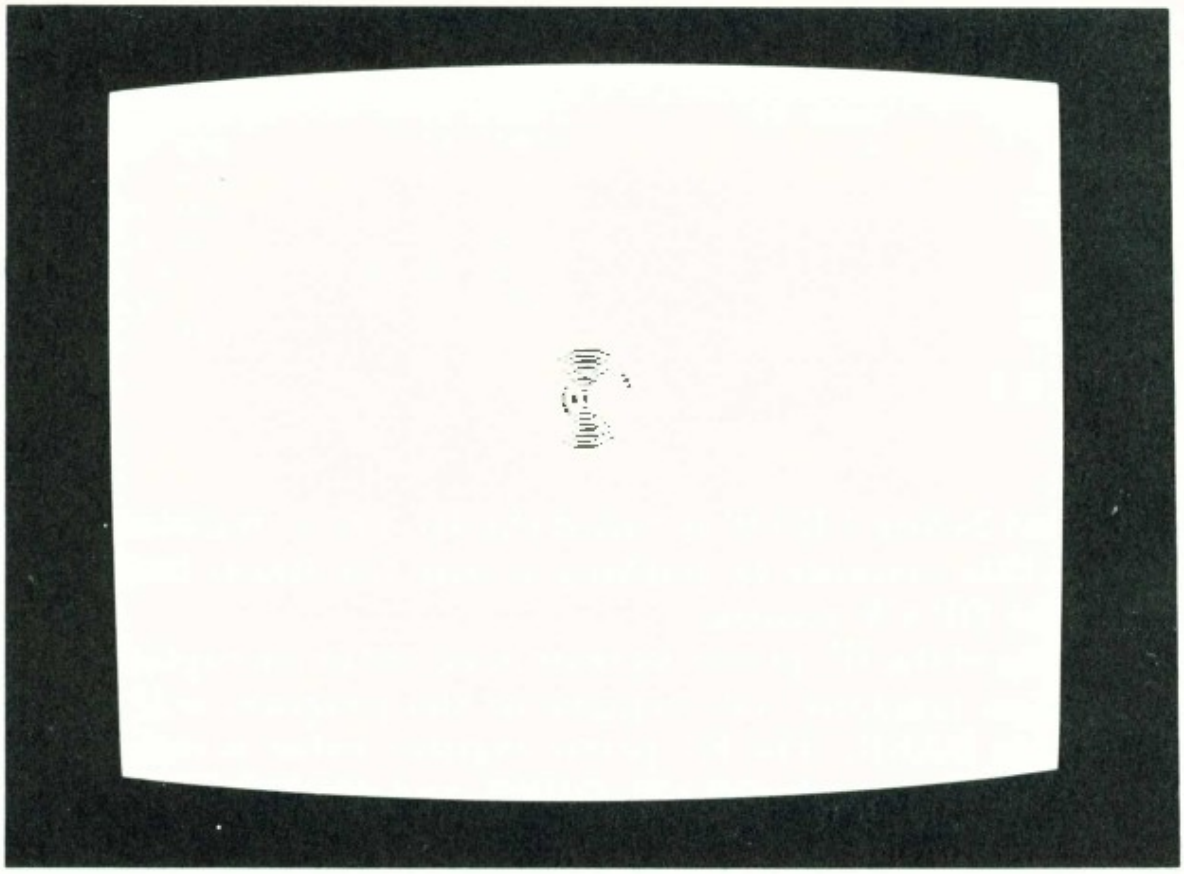
The second entry point for DRAW x,y requires the top two values on the calculator stack to have values x and y, again y being the top value – CALL 9335. Should you wish to use this second entry point then you will need to read Chapter 7 to acquaint yourself with the Spectrum method of storing five-byte *negative* numbers on the calculator stack.

DRAW x,y,a

The entry point for this BASIC command is 9108 and requires the value of x, y, and a to be placed on the calculator stack (in that order, that is, 'a' on top). Again Chapter 7 will explain how negative numbers are stacked. Again the HL prime register must not be corrupted.

CIRCLE x,y,r

The entry point for this BASIC command is 9005 and requires the values x, y, and r to be the top values on the calculator stack. The HL prime register is saved during the CIRCLE call. Program 2.9 demonstrates a method of drawing concentric circles to give a ripple effect.



```
10 REM Circle x,y,r
20 FOR B=1 TO 2
30 FOR A=1 TO 21 STEP 2
40 CIRCLE OVER 1;128,88,A
50 NEXT A
60 NEXT B


org 23760
For B=1 TO 2

23760 06 02          ld b,2
L2
23762 C5             push bc

For A=1 TO 21

23763 3E 01          ld a,1
L1
23765 F5             push af

Set OVER 1

23766 FD 36 57 03 ld (iy+87),3

Stack DATA

23770 3E 80          ld a,128


23772 CD 28 2D       call 11560
23775 3E 58          ld a,88
23777 CD 28 2D       call 11560
23780 F1             pop af
23781 F5             push af
23782 CD 28 2D       call 11560
Store H'L' (IMPORTANT !)

23785 D9             exx
23786 E5             push hl
23787 D9             exx

Call CIRCLE

23788 CD 2D 23       call 9005

Restore H'L'

23791 D9             exx
23792 E1             pop hl
23793 D9             exx


23794 F1             pop af
STEP 2
23795 3C             inc a
23796 3C             inc a
23797 FE 17          cp 23
23799 20 DC          jr nz,L1
23801 C1             pop bc
23802 10 D6          djnz L2

Reset OVER 0

23804 FD 36 57 00 ld (iy+87),0
23808 C9             ret
```

Program 2.9

You will notice that the program is almost as slow as the BASIC. This is because the ROM CIRCLE routine is quite lengthy. If a circle is required in your machine code program it would be quicker to hold the plot points as DATA and to use a loop to plot each pixel.

3 COUNTING

Most games programs and many 'serious' ones require some form of counting. With games programs this is mainly used to keep an account of the score, lives lost, time taken, etc. I know three methods of counting and displaying the result on the screen. The first is so memory consuming and unsightly that only a brief outline of the method will be given. This method involves the setting up of the MAX number allowed as DATA. For instance if you were counting from 0 to 999999 then six bytes of DATA would be reserved and initialized to 000000. A print string routine would then be required to print all six zeros on the screen. When the counter is increased by one it would then be necessary to start at the units byte, check that it is not nine, add the one to the units and then print string. If the units were nine they would be reset to zero and the tens column checked for a nine, and so on. After printing the string a check must be made to see whether all six bytes are set at nine and if so the count ends. Counting up or down in steps greater than one would involve placing the 'increase by one' counter in a loop.

The second method is used for counting up or down within the range 0 to 65535 and is demonstrated in Program 3.1.

```
org 23760
Set counter to zero

23760 01 00 00     ld bc,0
L1
23763 ED 43 B0 5C ld (23728),bc

Stack value

23767 CD 2B 2D     call 11563

Open channel 2

23770 3E 02        ld a,2
23772 CD 01 16     call 5633

Set PRINT AT 11,16

23775 3E 16        ld a,22
23777 D7           rst 16

23778 3E 0B        ld a,11
23780 D7           rst 16

23781 3E 10        ld a,16
23783 D7           rst 16

Call PRINT VALUE ON STACK

23784 CD E3 2D     call 11747

Get value and add 1
23787 ED 4B B0 5C ld bc,(23728)
23791 03           inc bc

Return if zero

23792 78           ld a,b
23793 B1           or c
23794 C8           ret z
Check for key press

23795 FD CB 01 6E bit 5,(iy+1)

23799 28 DA        jr z,L1
23801 C9           ret
```

Program 3.1

In this program use is made of a ROM routine that prints the value on top of the calculator stack: call 11747. The spare bytes in the systems variables 23728/9 are used to hold the value of the counter; hence the range 0 to 65535. All we need to do is then fetch the current value and add one, put the new value back into the COUNTER, STACK the value, set the PRINT AT parameters and call PRINT VALUE ON STACK. If the value in BC becomes zero (that is, 65536) a return to BASIC is made.

I have also included an EXIT routine from address 23795 to 23800 so that a key press will also return to BASIC. This is advisable as we would otherwise be stuck in the LOOP until the counter had reached 65535 and that would take several minutes.

The third form of counting again involves the use of the calculator. Up to now we have regarded the calculator stack as just a method of storing values without going into too much detail about how they are stored. The values are actually stored on the stack in their five-byte form, that is, it takes five bytes of information to define any number that the computer can cope with. This is discussed in more detail in Chapter 7. In Program 3.2 we make use of this fact to count from 0 upwards in steps of 250 with no upper limit. In fact, however, once 99 999 999 has been reached the PRINT STACK VALUE routine will change to printing the value in its E form (1E + 9 etc.), but one hundred million is probably high enough for any games scoring.

```
org 23760
Use CALCULATOR

23760 EF            rst 40

LITERAL STACK 0
defb 160

End use CALCULATOR
defb 56

HL set to STACKEND-5
after defb 56 instruction

L1
Copy value into PRINTER BUFFER

23763 11 00 5B      ld de,23296
23766 01 05 00      ld bc,5
23769 ED B0         ldir



Open channel 2

23771 3E 02         ld a,2
23773 CD 01 16      call 5633
```

```
Set PRINT AT 11,16
23776 3E 16         ld a,22
23778 D7            rst 16
23779 3E 0B         ld a,11
23781 D7            rst 16
23782 3E 10         ld a,16
23784 D7            rst 16

Call PRINT VALUE ON STACK

23785 CD E3 2D      call 11747

STACK 250

23788 3E FA         ld a,250

23790 CD 28 2D      call 11560

STACK VALUE
23793 21 00 5B      ld hl,23296
23796 ED 5B 65 5C   ld de,(23653)
23800 01 05 00      ld bc,5
23803 ED B0         ldir
23805 ED 53 65 5C   ld (23653),de

Use CALCULATOR
```

```
23809 EF          rst 40

LITERAL ADD
defb 15
End use CALCULATOR
defb 56


Check for key press

23812 FD CB 01 6E bit 5,(iy+1)
23816 28 C9       jr z,L1

Remove last value from STACK

23818 2A 65 5C    ld hl,(23653)
23821 2B          dec hl
23822 2B          dec hl
23823 2B          dec hl
23824 2B          dec hl
23825 2B          dec hl
23826 22 65 5C    ld (23653),hl
23829 C9          ret
```

Program 3.2

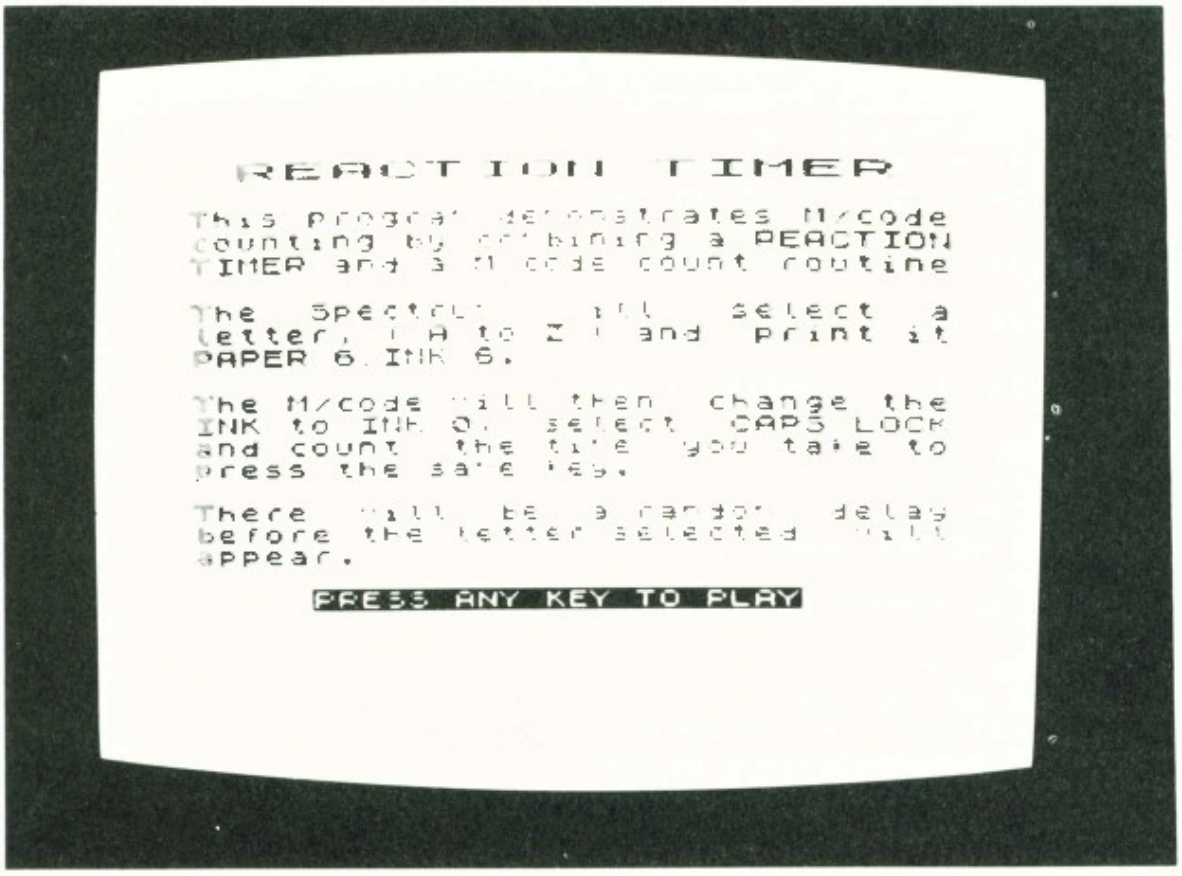
The program has several important routines that require explaining. The setting up of the value 0 is carried out on the calculator stack by defb 160, which is the literal STACK 0, the five bytes on top of the stack are then taken and copied into the printer buffer to be used as a store. This is carried out by an LDIR instruction; the value of HL is set for us by the calculator routine as (STACKEND − 5). The initial value is printed at 11, 16; by the PRINT VALUE routine and the stack is thus cleared.

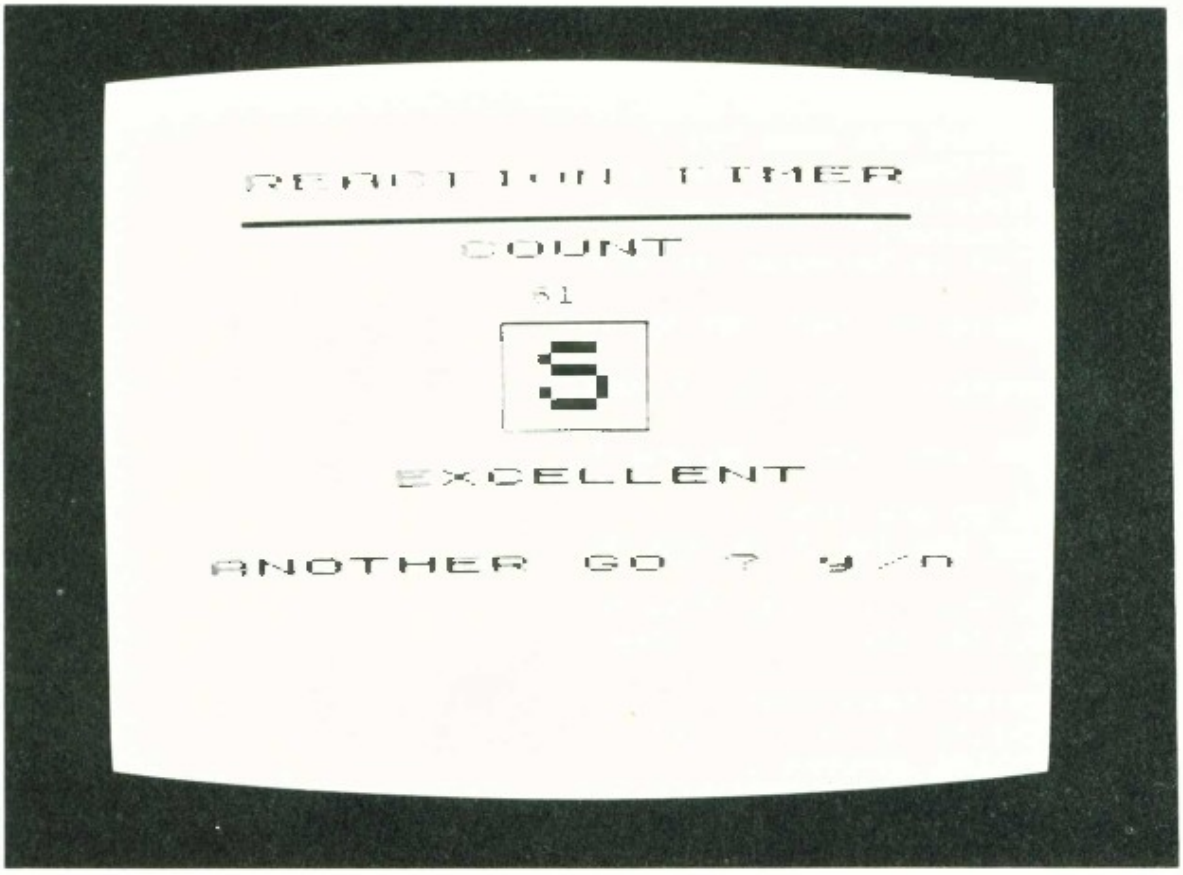
And so to the ADD 250 routine. This requires the value of 250 to be placed on the stack by means of STACK VAL A, and then the 'stored' value placed on the stack. This is carried out using LDIR. The HL register is set to the start of the stored value; the DE register is set to STACKEND. After the LDIR instruction the new address of STACKEND must be put back into the systems variable 23653. The calculator is used to add these two values together and to repeat the STORE and PRINT VALUE routines. Again a key press routine is added to allow exit from the counting, but note that the stack is reset by removing the last value before a return to BASIC is made.

Counting down would require the start value to be placed on the stack (See Chapter 7 for numbers greater than 65535) and the Literal 3 SUBTRACT used. Note that in subtracting, the 'top' value is taken away from the one underneath. At the end of each count a check would be required to see whether the 'store' bytes had all been set to zero and, if so, the count ended (or if the second byte has bit 7 set the number is negative). In counting down it is also necessary to clear the screen of the existing number before printing the new one because, if a change is made from say 1000 to 999, the 'units zero' from 1000 would remain on the screen and the number would appear to be 9990.

The COUNTDEMO program, available on the tape, shows how the counter routine can be used for reaction timing.

The BASIC program is self-explanatory and is mainly involved with the printing of instructions. The DATA statements are used to hold parameters of x, y, h, w, and a$ for LARGE printing as discussed in Chapter 2.





```
  12>PAPER 6:CLS
  15 DATA 87,143,1,2,"COUNT"
  20 DATA 95,63,1,2,"SLOW"
  30 DATA 71,63,1,2,"AVERAGE"
  40 DATA 95,63,1,2,"GOOD"
  50 DATA 63,63,1,2,"VERY GOOD"
  60 DATA 63,63,1,2,"EXCELLENT"
  80 DATA 47,63,1,2,"NOT TRYING"
  90 DATA 0,31,1,2,"ANOTHER GO ?
y/n"
  95 DATA 55,125,5,2,"THANK YOU"
  96 DATA 103,79,3,2,"for"
  97 DATA 71,50,5,2,"PLAYING"
 100 DATA 24,79,5,2,"STOP THE TAP
E"
 105 DATA 15,167,1,2,"REACTION TI
MER"
 110 DATA 15,164,2,2,"__________
___"
 120 DATA 24,15,1,2,"PRESS ANY KE
Y"
 125 RESTORE 100
 130 FOR a=1 TO 4
 140 PAUSE 25
 160 INK 2: GO SUB 9000
 170 NEXT a
 180 PAUSE 0: BORDER 5: PAPER 6:
INK 0: CLS
 190 RESTORE 105
 220 INK 0: GO SUB 9000
 250 PRINT AT 3,0;"This program d
emonstrates M/codecounting by com
bining a REACTIONTIMER and a M/co
de count routine"
 260 PRINT '"The  Spectrum  will
   select  aletter, ( A to Z ) an
d  print itPAPER 6:INK 6."
 270 PRINT '"The M/code will then
  change theINK to INK 0,  select
  CAPS LOCKand count  the time  y
ou take topress the same key."
 280 PRINT '"There  will  be  a r
andom  delaybefore the letter sel
ected  willappear."
 290 PRINT AT 20,5;"PRESS ANY KEY
  TO PLAY"
 300 IF INKEY$<>"" THEN  GO TO 30
0
 302 IF INKEY$="" THEN  GO TO 302
 305 CLS
 310 RESTORE 105: INK 1: GO SUB 9
000
 320 INK 5: GO SUB 9000
 330 RESTORE 15: INK 2: GO SUB 90
00
 350 INK 0: PLOT 102,114: DRAW 50
,0: DRAW 0,-38: DRAW -50,0: DRAW
0,38
 380 LET z=INT (RND*26+65)
 390 LET x=111: LET y=111: LET h=
4: LET w=4: LET a$=CHR$ z
 400 INK 6: LET c=USR 32393
 410 FOR a=1 TO RND*200+50: NEXT
a
```

```
 420 INK 0
 430 LET c=USR 23760
 440 LET a=PEEK 23728+256*PEEK 23
729
 450 IF a>=140 OR a=0 THEN  RESTO
RE 80
 460 IF a<140 THEN  RESTORE 20
 470 IF a<120 THEN  RESTORE 30
 480 IF a<100 THEN  RESTORE 40
 490 IF a<85 THEN  RESTORE 50
 500 IF a<70 THEN  RESTORE 60
 510 GO SUB 9000
7000 RESTORE 90: INK 1: GO SUB 90
00
7010 IF INKEY$<>"" THEN  GO TO 70
10
7020 IF INKEY$="" THEN  GO TO 702
0
7030 LET d$=INKEY$
7040 IF d$<>"y" THEN  GO TO 8000
7050 LET c=USR 23842: GO TO 350
8000 RESTORE 95
8005 POKE 23843,20
8010 LET c=USR 23842
8015 POKE 23843,18
8030 FOR a=1 TO 3
8040 GO SUB 9000
8050 NEXT a
8060 STOP
9000 READ x,y,h,w,a$
9010 LET c=USR 32393
9020 RETURN
9800 CLEAR 32334: LOAD ""CODE : G
O TO 5
9900 SAVE "REACTION" LINE 9800
9950 SAVE "LARGE"CODE 32335,265
  10 REM >z? \ STEP )^ CLEAR  THE
N 0 OVER !?X^ RETURN 6 ?60£! RETU
RN (  NEXT ??? OR  STEP +=>? STEP
 ?                          BEEP >
 BEEP >?>LEN (? CLEAR  THEN ?n( O
UT $? \PEEK   VERIFY  GO SUB CVAL
 \ CLEAR  THEN 0o<>

org 23760
Find variable z

23760 3E 7A        ld a,122
Store in 23681
23762 01 81 5C     ld bc,23681
23765 CD 7D 7E     call 32381

Set CAPS LOCK
23768 FD CB 30 DE  set 3,(iy+48)

Attribute colour swap

23772 21 00 58     ld hl,22528
L1
23775 7E           ld a,(hl)
23776 FE 36        cp 54
PAPER 6 INK 6
23778 20 02        jr nz,L2
23780 36 30        ld (hl),48
```

```
Replace PAPER 6 INK 0
.L2
23782 23          inc hl
23783 7C          ld a,h
23784 FE 5B       cp 91
End of ATTRIBUTES ?
23786 20 F3       jr nz,L1

Start counting

23788 01 00 00    ld bc,0
Store count on stack
.L3
23791 C5          push bc
Place count on CALCULATOR
23792 CD 2B 2D    call 11563

Set PRINT AT 6,14
23795 3E 02       ld a,2
23797 CD 01 16    call 5633
23800 3E 16       ld a,22


23802 D7          rst 16
23803 3E 06       ld a,6
23805 D7          rst 16
23806 3E 0E       ld a,14
23808 D7          rst 16

Print count
23809 CD E3 2D    call 11747

Set count and add 1
23812 C1          pop bc
23813 03          inc bc

Check count < 65535
23814 78          ld a,b
23815 B1          or c
23816 28 0F       jr z,END

Check key pressed

23818 FD CB 01 6E bit 5,(iy+1)


23822 28 DF       jr z,L3
Find INKEY$
23824 3A 08 5C    ld a,(23560)
Compare a$
23827 21 81 5C    ld hl,23681
23830 BE          cp (hl)
23831 20 D6       jr nz,L3
END
Store count
23833 ED 43 B0 5C ld (23728),bc
Restore lower case
23837 FD CB 30 9E res 3,(iy+48)
23841 C9          ret
Clear bottom 18 lines
23842 06 12       ld b,18
23844 CD 44 0E    call 3652
23847 C9          ret
```

Program 3.3

4 RANDOM NUMBERS

Random numbers are an essential part of most games programs such as the random delay and random choice of letter in the REACTION TIMER program (Program 3.3) of Chapter 3. The setting up of a random number in machine code is actually very easy and, depending on the 'random/range' of the number, can be tackled in one of two ways.

The first method, which does not actually produce a true random number, but is good enough for many games, is to use the FRAMES and SEED variables in a way in which they were not intended to be used. That is, if the random number range is 0–1, 0–3, 0–7, 0–15, 0–31, 0–63, 0–127, or 0–255 then this method is worth considering. The routine requires the HL register to be loaded with the value of SEED (23670) the DE register to be loaded with SEED high byte/FRAMES low byte (23671), the two register values added together, and the sum stored back into the SEED variable for the next 'random number'. The A register is then loaded with either H or L and an 'AND a' carried out to mask out the unwanted bits; hence the random number range as above. Program 4.1 for instance gives an exampie of INT(RND * 32) as it will mask out bits 7 – 5 of the value in the A register and so leave numbers from 0 to 31.

```
org 23760
10 Random numbers
23760 06 0A       ld b,10
L1
23762 C5          push bc
Load HL,(SEED)
23763 2A 76 5C    ld hl,(23670)
23766 ED 5B 77 5C ld de,(23671)
23770 19          add hl,de

Modified SEED for next number
23771 22 76 5C    ld (23670),hl

Mask BITS 7-5
23774 7D          ld a,l
23775 E6 1F       and 31

Store Random number
23777 F5          push af
Set PRINT AT b,10
23778 3E 02       ld a,2
23780 CD 01 16    call 5633
23783 3E 16       ld a,22
23785 D7          rst 16
23786 78          ld a,b
23787 D7          rst 16
23788 3E 0A       ld a,10
23790 D7          rst 16

Get random number and put
on CALCULATOR STACK
23791 F1          pop af
23792 CD 28 2D    call 11560
23795 CD E3 2D    call 11747
Print it

Get number count
23798 C1          pop bc

repeat until 10 numbers
23799 10 D9       djnz L1
23801 C9          ret
```

Program 4.1

```
PROGRAM 1 SAMPLE PRINT OUT
        6
        22
        23
        8
        9
        25
        24
        5
        1
        10
```

As previously stated this is useful if a 'not so random number' is required in one of the above ranges. It can be taken a stage further to evaluate, for example, INT (RND * 23) by:

```
LD A, H
AND 15
LD H, A
LD A, L
AND 7
ADD A, H
```

You will notice in Program 4.1 that the B register is used to hold the loop count (ten times) and that this value is also used for the PRINT AT b, 10; routine. The sample print out shows the randomness of the routine.

To produce a random number in the same way as the BASIC command INT (RND * n) we will need to use the RND ROM routine, but unfortunately this is not available with a call RND instruction as the routine has no return after it has been evaluated. The routine occupies ROM address 9725 to 9765 and uses the calculator, yet again, to modify the value of SEED. It starts by getting the existing value from SEED, and ends with the new value duplicated on top of the stack. The top value is removed and used to update SEED. The remaining value is modified further to give a value from 0 to 1 (but not 1) which is used for RND. To use this routine it is necessary to copy it into RAM and call it from your program as a subroutine. Program 4.2 shows this method used to produce INT (RND * 12345) and print 44 answers using CHR$ CODE 6 to print in two columns.

```
INT (RND*12345)

org 23760
CLS

23760 3E 02       ld a,2
23762 CD 01 16    call 5633
23765 CD 6B 0D    call 3435

44 Random numbers

23768 06 2C       ld b,44
L1
23770 C5          push bc

COPY of ROM 9725 to 9765

23771 ED 4B 76 5C ld bc,(23670)
23775 CD 2B 2D    call 11563
```

```
23778 EF            rst 40
STACK (1)
defb 161


+
defb 15
STACK (75)
defb 52 55 22
*
defb 4
STACK (65537)
defb 52 128 65 0 0 128
LITERALS
defb 50 2
STACK (1)
defb 161
-
defb 3
Duplicate
defb 49
End CALC ROUTINE
defb 56
Put top value into BC
REGISTER (INT 0-65535)
23797 CD A2 2D     call 11682


Store new SEED
23800 ED 43 76 5C ld (23670),bc
Manipulate EXPONENT BYTE
23804 7E           ld a,(hl)
23805 A7           and a
23806 28 03        jr z,L2
23808 D6 10        sub 16
23810 77           ld (hl),a
L2
STACK 12345
23811 01 39 30     ld bc,12345
23814 CD 2B 2D     call 11563
23817 EF           rst 40
*
defb 4
LITERAL 'INTEGER'
defb 39
End CALC ROUTINE
defb 56
Print value on STACK
23821 3E 02        ld a,2


23823 CD 01 16     call 5633
23826 CD E3 2D     call 11747
PRINT ,
23829 3E 06        ld a,6
23831 D7           rst 16

Get count

23832 C1           pop bc
23833 10 BF        djnz L1
23835 C9           ret
```

Program 4.2

```
SAMPLE PRINT OUT OF ABOVE PROG.

1857          3558
7666          7091
1037          3758
10296         6834
6415          12044
3058          7178
7727          11711
3057          7150
2940          10693
```

The RND routine uses several new literals which may be of use in other routines:

LITERAL 161 is STACK NUMBER 1
LITERAL 52 is STACK DATA (this is normally a number expressed in its compressed form – see Chapter 7)
LITERAL 50 is n – mod –m
LITERAL 2 is DELETE (the quotient)

The last two literals are probably of little use for games programs. The routine – CALL 11682 – is used by the ROM to remove the top value on the stack and to place the integer value in the BC register. The integer value is in this case rounded up or down as necessary to

the nearest whole number. There is also a similar routine – CALL 11733 which places the top value in the A register in a similar manner. The copied ROM routine ends at 23810.

The routine from 23811 to 23820 further modifies the RND value on the stack. The value 12345 is stacked and then multiplied by the RND value. A new literal is then used, literal 39; this removes any decimal value from the result of 12345 RND rounding *down* the value (as in BASIC RND), and so leaves INT (RND * 12345) as the top value on the stack. The PRINT VALUE routine is then used to print 44 values in two columns and the results show that these values are truly random.

Demonstration Program 4.3 shows how RND is actually used. In this case RND is used to print random-height skyscrapers in random characters of random colours and could be used in the 'city bomb' type of program. All the UDGs for a complete program are already set up and you may like to develop this program. The tape program 'RNDDEMO' uses the BASIC program to produce the first screen display; this is held on the screen for a few seconds, and then the machine code routine is used to print the next display demonstrating the speed of Machine Code as well as the RND function.

One point to remember when using BASIC RND with machine code USR calls is to use LET 'variable' = USR 'address' to call the machine code as RANDOMIZE USR 'address' will affect the random number generator. You may also use PRINT USR address if you don't mind the value held in the BC register being printed on return to BASIC. In the machine code routine the PAPER and INK colours are set up using LD (IY + 83), 47 instead of LD A, 47 : LD (IY + 83) A, as in previous examples, thus saving memory and showing the usefulness of the IY register as a pointer. This is further demonstrated later in the program where 1Y is set to 23296, the start of the printer buffer, and used to LD (23296), 22 (AT) and LD (23299), 16 (INK),. When altering the value held in IY, however, care must be taken that, if a ROM call is made that uses the IY register, the value should be reset to 23610 before the call is made or the ROM routine will be corrupted and may cause a crash.

Before the random number routine is called the A register is loaded with the RND * n number and this then stored at address 23681 (an unused address in the systems variables). This number is then picked up in the RND routine and used to obtain INT (RND * n), the value being placed in the A register by call 11733 before a return from the routine is made. The printer buffer is used to hold the PRINT information in order: AT (22), x, y, INK (16), b$, a$.

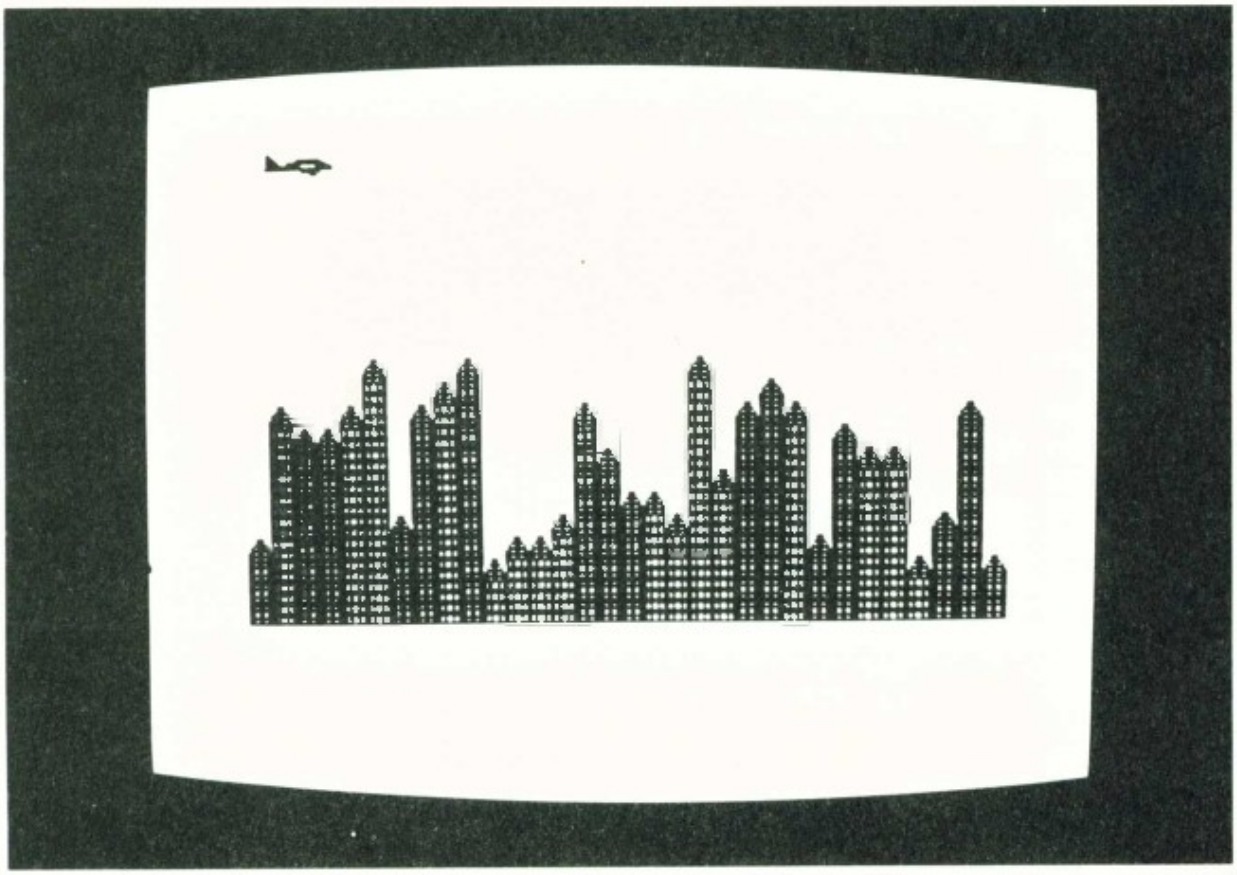
```
   1 REM >? STEP &" CLEAR 65/>?
STEP ?
  10 BORDER 0: PAPER 5: INK 7: C
LS
  20 FOR c=31 TO 0 STEP -1
  30 LET l=19-INT (RND*10)
  40 LET a$=CHR$ INT (RND*2+145)
  45 LET b$=CHR$ INT (RND*4)
  50 PRINT AT l-1,c;"▲"
  60 FOR a=l TO 20
  70 PRINT AT a,c;CHR$ 16+b$+a$
  80 NEXT a
  90 PRINT AT a,c;"■"
 100 NEXT c
 110 LET x=0: LET y=0: LET a$="
➡"
 130 PRINT AT x,y;a$
 140 PRINT #0;"■ fUEL▌10000 ■ BOMBS▌
100 ■ SHOTS▌ 100 ■"
 150 RETURN
 500 DATA 24,79,5,2,"STOP THE TA
PE"
 510 DATA 15,167,1,2,"RANDOM NUM
BERS"
 520 DATA 15,164,1,2,"__________
_____"
 525 DATA 24,15,1,2,"PRESS ANY K
EY"
 530 DATA 47,164,2,4,"BASIC"
 540 DATA 31,164,3,2,"MACHINE CO
DE"
 600 BORDER 4: PAPER 6: INK 0: C
LS
 605 RESTORE 500
 610 FOR a=1 TO 4
 620 INK a: GO SUB 8000
 630 PAUSE 50: NEXT a
 640 PAUSE 0: CLS
 645 PRINT INK 0;AT 8,0,"This  P
rogram  demonstrates  theRND rou
tine in Machine code  andcompare
s the speed of both BASICand Mac
hine code versions."
 650 RESTORE 525
 655 PAUSE 100
 660 FLASH 1: INK 2: PAPER 7: GO
SUB 8000: FLASH 0
 670 PAUSE 0: CLS
1000 LET z=1
1010 GO SUB 2000
1020 GO SUB 10
1025 LET z=z+1
1030 GO SUB 2000
1040 GO SUB 3000
1045 LET z=z+1
1050 GO TO 1010
2000 FOR a=1 TO 400: NEXT a: CLS

2010 PAPER 8: INK 0: RESTORE 530
+(10*(z/2=INT (z/2))): GO SUB 80
00
2020 FOR a=1 TO 200: NEXT a: RET
URN
3000 LET c=USR 23760: GO TO 110
8000 READ x,y,h,w,a$
8010 LET c=USR 32393
8020 RETURN
9998 CLEAR 32334: LOAD "udg"CODE
 USR "a": LOAD ""CODE : GO TO 50
0
9999 SAVE "RNDDEMO" LINE 9998: S
AVE "udg"CODE USR "a",168: SAVE
"LARGE"CODE 32335,255


org 23760

BORDER 0
```

```
23760 3E 00        ld a,0
23762 CD 9B 22     call 8859

PAPER 5 INK 7

23765 FD 36 53 2F ld (iy+83),47

CLS

23769 3E 02        ld a,2
23771 CD 01 16     call 5633
23774 CD 6B 0D     call 3435

Set IY as POINTER

23777 FD 21 00 5B ld iy,23296


23781 FD 36 00 16 ld (iy+0),22
23785 FD 36 03 10 ld (iy+3),16

Reset IY
23789 FD 21 3A 5C ld iy,23610

Column Count

23793 3E 1F        ld a,31
L1
23795 32 02 5B     ld (23298),a

19-INT (RND*10)

23798 3E 0A        ld a,10
23800 32 81 5C     ld (23681),a
23803 CD 61 5D     call RND
23806 6F           ld l,a
23807 3E 13        ld a,19
23809 95           sub l
23810 32 01 5B     ld (23297),a


INT (RND*2+148)

23813 3E 02        ld a,2
23815 32 81 5C     ld (23681),a
23818 CD 61 5D     call RND
23821 C6 94        add a,148
23823 32 05 5B     ld (23301),a


INT (RND*4)

23826 3E 04        ld a,4
23828 32 81 5C     ld (23681),a
23831 CD 61 5D     call RND
23834 32 04 5B     ld (23300),a


PRINT AT x-1,y CHR$ 147

23837 3E 02        ld a,2
23839 CD 01 16     call 5633
23842 3E 16        ld a,22
```

```
23844 D7          rst 16
23845 3A 01 5B    ld a,(23297)
23848 3D          dec a
23849 D7          rst 16
23850 3A 02 5B    ld a,(23298)
23853 D7          rst 16
23854 3E 93       ld a,147
23856 D7          rst 16
L2

FOR a=x TO 20
PRINT AT a,y CHR$ 16+b$+a$
23857 11 00 5B    ld de,23296
23860 01 06 00    ld bc,6
23863 CD 3C 20    call 8252
23866 3A 01 5B    ld a,(23297)
23869 3C          inc a
23870 32 01 5B    ld (23297),a
23873 FE 15       cp 21
NEXT a
23875 20 EC       jr nz,L2


PRINT AT a,y CHR$ 153

23877 3E 99       ld a,153
23879 32 05 5B    ld (23301),a
23882 3E 07       ld a,7
23884 32 04 5B    ld (23300),a
23887 11 00 5B    ld de,23296
23890 01 06 00    ld bc,6
23893 CD 3C 20    call 8252
23896 3A 02 5B    ld a,(23298)
23899 3D          dec a
23900 FE FF       cp 255

NEXT COLUMN

23902 20 93       jr nz,L1
23904 C9          ret

ROM RND ROUTINE


RND
23905 ED 4B 76 5C ld bc,(23670)
23909 CD 2B 2D    call 11563
23912 EF          rst 40
defb 161 15 52 55 22 4 52 128
defb 65 0 0 128 50 2 161 3 49 56
23931 CD A2 2D    call 11682
23934 ED 43 76 5C ld (23670),bc
23938 7E          ld a,(hl)
23939 A7          and a
23940 28 03       jr z,L3
23942 D6 10       sub 16
23944 77          ld (hl),a

INT (RND*PEEK (23681))

L3
23945 3A 81 5C    ld a,(23681)
```

```
23948 CD 20 2D     call 11560
23951 EF           rst 40
defb 4 39 56


VALUE to A

23955 CD D5 2D     call 11733
23958 C9           ret
```

Program 4.3



5 THE KEYBOARD

In machine code there are two methods of reading the keyboard. Both of them are useful but the method chosen depends on the type of program.

Using the LAST KEY variable

The Spectrum ROM contains a KEYSCAN and DECODE routine which is automatically called 50 times every second. The routine also updates the FRAMES count.

The character code of the last key pressed is stored in the variable LAST KEY (23560) and if it is a new key then bit 5, (IY + 1) will be set. Incidentally the HALT command waits for the next KEYSCAN call to be made before continuing with the machine code routine.

With the above information we can write a program the equivalent of PAUSE 0.

```
org 23760

WAIT FOR KEY PRESS

L1
23760 FD CB 01 6E bit 5,(iy+1)
23764 28 FA       jr z,L1
23766 FD CB 01 AE res 5,(iy+1)

CONTINUE WITH PROGRAM

23770 C9          ret
```

Program 5.1

You can see that in Program 5.1 bit 5, (IY + 1) is continually checked to see whether it is set and only when it is (indicating a new key press) will the program continue. Note that it is necessary to reset bit 5, (IY + 1) afterwards, otherwise if a similar PAUSE routine is used before the next KEYSCAN call bit 5 would still appear set and the PAUSE will be skipped.

Using IN A, (C)

This is identical to the BASIC IN command, reading the half row

specified by the value held in the BC register, and is discussed in the Spectrum manual. The value returned in A indicates which keys are pressed in that half row. Each half row contains five keys, and bits 4 – 0 of A hold the state of these keys (bits 7 – 5 are normally set) bit 0 is used to indicate the state of the 'outside key' in the half row and bit 4 the state of the 'inside key'.

With no keys pressed the bits are set and A will hold 255. If a key is pressed its bit will be reset. For example if key 0 were pressed then bit 0 would be reset and A would hold value 254. You can see that with this method we have the ability to read more than one key being pressed at the same time by either checking the value of A or the individual bits of A. This would be useful in a game for two or more players or for moving things in two directions (for example upwards and forwards) at the same time. Program 5.2 demonstrates the IN command used to wait until key 0 is pressed.

```
org 23760

READ HALF ROW 6-0

L1
23760 01 FE EF      ld bc,61438
23763 ED 78         in a,(c)

CHECK KEY 0 PRESSED

23765 CB 47         bit 0,a
23767 C8            ret z
23768 18 F6         jr L1
```

Program 5.2

The ROM KEYSCAN call is made 50 times every second *even during our own machine code program* and, in doing so, slows down the program. We can stop this interruption to our program if we need extra speed, for example in pixel-scrolling, by the use of the DI instruction. However this will mean that while the interrupt is disabled we are unable to use the routine LAST KEY to read the keyboard (unless we call the ROM routine ourselves) and must resort to using the IN instruction. Program 5.3 shows the DI instruction being used.

```
org 23760

DISSABLE

23760 F3            di

READ HALF ROW 6-0

L1
23761 01 FE EF      ld bc,61438
23764 ED 78         in a,(c)

CHECK KEY 0 PRESSED

23766 CB 47         bit 0,a
23768 20 F7         jr nz,L1

ENABLE

23770 FB            ei

23771 C9            ret
```

Program 5.3

Note that the EI instruction *must* be used before a return to BASIC or the keyboard will be useless. Try the program without the EI instruction and see what happens. No lasting damage will occur, but the Spectrum will have to be switched off then on again to make the keyboard function.

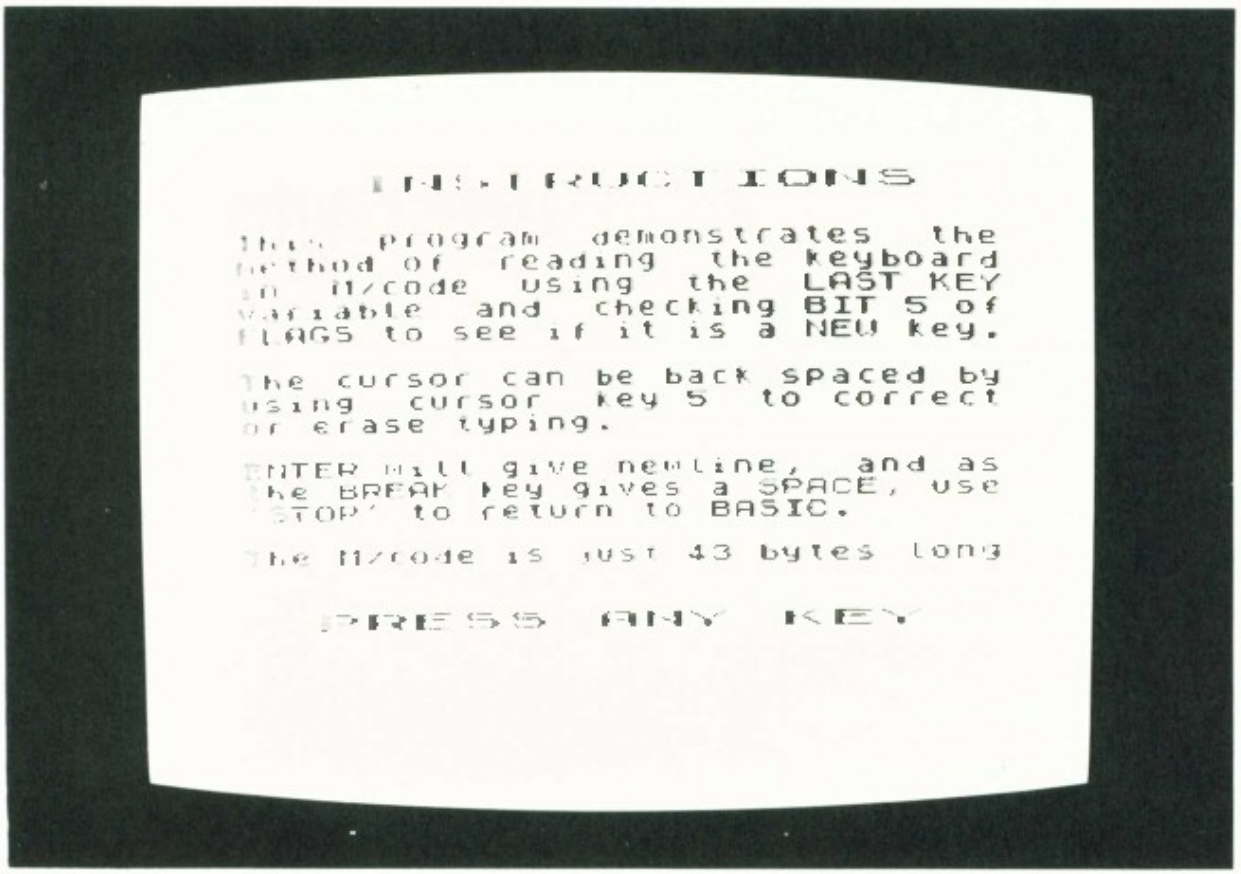
Program 5.4 shows the method of producing PAUSE n to give a timed delay or, as in the BASIC, continue if a key is pressed. The program uses the fact that the keyscans occur every 0.02 seconds and that HALT waits for a keyscan.

```
org 23760

SET 10 SECOND DELAY

23760 01 F4 01      ld bc,500
L1
PAUSE LOOP
23763 76            halt
CHECK KEY PRESS

23764 FD CB 01 6E bit 5,(iy+1)
23768 20 05         jr nz,L2
REDUCE COUNTER
23770 0B            dec bc
23771 78            ld a,b
23772 B1            or c
23773 20 F4         jr nz,L1
L2
23775 FD CB 01 AE res 5,(iy+1)

23779 C9            ret
```

Program 5.4

Program 5.5 is available on tape 'KEYDEMO' and makes use of the LAST KEY method of reading the keyboard to produce a simple typewriter program that allows erasure and modification of type.

The current print position is indicated by a flashing cursor. Note that CAPS SHIFT and '2' moves the print position to the next



PRINT COMMA TAB; CAPS SHIFT and '5' gives a backspace (but note the ROM error that you cannot backspace from the beginning of line 1 to the end of line 0) and ENTER gives a new line. In machine code the BREAK key is inoperable and so I have used 'STOP' to return to BASIC.

As with BASIC INKEY$, neither the double-shifted keys nor the graphics mode keys are read. Should you wish to check for, or print, double-shifted keys then you will need to set up a DATA table of unshifted characters and their double-shifted equivalents. Then if LD A,(LAST KEY) returns value 14 in A, indicating both shift keys pressed, a routine to read the next key press and convert its unshifted character to its double-shifted one, by means of the DATA table, will be required.

```
  10 REM >? STEP ?
  20>DATA 24.79,5,2,"STOP THE TAP
E"
  30 DATA 7,170,2,3,"TYPEWRITER"
  40 DATA 7,150,2,3,"__________"
  50 DATA 24.15,1,2,"PRESS ANY KE
Y"
  60 DATA 39.170,1,2,"INSTRUCTION
S"
  65 RESTORE
  70 BORDER 4: PAPER 6: CLS
  80 FOR A=1 TO 4
  85 PAUSE 20
  90 INK A: PAPER 8: GO SUB 8000
 100 NEXT A
 110 PAUSE 0: PAPER 7: CLS
 120 INK 2: PAPER 0: GO SUB 8000
 130 INK 0: PRINT AT 3,0;"This  p
rogram  demonstrates  themethod o
f  reading  the keyboardin  M/cod
e  using  the  LAST KEYvariable
and  checking BIT 5 ofFLAGS to se
e if it is a NEW key."
 140 PRINT '"The cursor can be ba
ck spaced byusing  cursor  key 5
 to corrector erase typing."
 150 PRINT '"ENTER will give newl
ine.  and asthe BREAK key gives a
 SPACE, use"STOP" to return to BA
SIC."
 160 PRINT '"The M/code is just 4
7 bytes long"
 200 RESTORE 50: INK 2: GO SUB 80
00
 210 PAUSE 0: BRIGHT 1: CLS
 220 INK 0: RANDOMIZE USR 23760
 230 STOP
8000 READ x,y,h,w,a$
8010 RANDOMIZE USR 32393
8020 RETURN
9990 CLEAR 32334: LOAD ""CODE : G
O TO 20
9999 SAVE "KEYDEMO" LINE 9990: SA
VE "LARGE"CODE 32335,265
```

```
org 23760

Open channel 2

23760 3E 02       ld a,2
23762 CD 01 16    call 5633

SET OVER 1

L1
23765 FD 36 57 03 ld (iy+87),3

FLASH CURSOR IN WAIT LOOP

23769 3E 8F       ld a,143
23771 D7          rst 16
23772 3E 08       ld a,8
23774 D7          rst 16
23775 3E 8F       ld a,143
23777 D7          rst 16


23778 3E 08       ld a,8
23780 D7          rst 16

WAIT FOR KEY PRESS

23781 FD CB 01 6E bit 5,(iy+1)
23785 28 EA       jr z,L1
23787 FD CB 01 AE res 5,(iy+1)

SET OVER 0

23791 FD 36 57 00 ld (iy+87),0

GET LAST KEY

23795 3A 08 5C    ld a,(23560)

CHECK FOR 'STOP'

23798 FE E2       cp 226
23800 C8          ret z


PRINT CHR$

23801 D7          rst 16
23802 18 D9       jr L1
```

Program 5.5

6 MOVEMENT

Now that we are able to print our display and read the keyboard we can look at methods of animation. This of course is an essential part of any 'real time' games program. In this Chapter we will cover methods of giving the impression of movement by:

1. Moving the foreground – ships, aliens, people, etc.
2. Moving the background – stars, planets, skyscrapers, etc.
3. Moving both 1 and 2.

The type of movement used by most software writers is 'character square'; this allows faster games and use of all colours. The screen is divided into 24 rows of 32 columns, and, when a character is moved, it travels from its present position to the adjacent row/column; this movement is fairly coarse but not jerky. If pixel movement is used then, especially with foreground movement, the characters require replotting. If you have used the BASIC PLOT command you will realize that this would normally restrict us to the use of two colours (PAPER and INK).

Foreground movement one character square

The first step is to define (or initialize) the character start position then, using either of the methods discussed in Chapter 5, to read the keyboard, and update the character position accordingly. The updating of the character position is usually carried out on a 'duplicate set' of start position data. When the updating is complete we will have two sets of data: the first holding the actual screen position and the second the new position. Any checks, for example, to see whether the new position is still on the screen, are carried out and the new data amended. To give the impression of flicker-free movement we remove the existing character and reprint it *immediately* in its new position. The method I generally use is to set OVER 1 and REPRINT the character in the *old* position, thus removing it, and, still using OVER 1 reprint in the *new* position. This will allow the character to be moved over background without erasing it.

```
org 23760
DISSABLE KEYBOARD

23760 F3          di
23761 18 18       jr START
UDG DATA

DATA1
CHR$ 144
defb 0 0 15 24 49 226 225 224
CHR$ 145
defb 24 60 255 255 153 255 231
defb 60
CHR$ 146
defb 0 0 240 24 140 71 135 7
START

SET UP UDG's

23787 ED 5B 7B 5C ld de,(23675)

23791 21 D3 5C    ld hl,DATA1
23794 01 18 00    ld bc,24
23797 ED B0       ldir
23799 18 0A       jr BEGIN

Print CHR$ DATA
AT x,y INK 8 PAPER 8
CHR$ 144 145 146

DATA2
defb 22 0 0 16 8 17 8
defb 144 145 146
BEGIN

BORDER 5
23811 FD 36 0E 28 ld (iy+14),40

PAPER 1 INK 7
23815 FD 36 53 0F ld (iy+83),15
CLS
23819 3E 02       ld a,2

23821 CD 01 16    call 5633
23824 CD 6B 0D    call 3435

PRINT STRING

23827 3E 02       ld a,2
23829 CD 01 16    call 5633
23832 11 F9 5C    ld de,DATA2
23835 01 0A 00    ld bc,10
23838 CD 3C 20    call 8252
L7

TRANSFER DATA2 TO STORE

23841 11 00 5B    ld de,23296
23844 21 F9 5C    ld hl,DATA2
23847 01 0A 00    ld bc,10
23850 ED B0       ldir

GET x,y FROM STORE

23852 2A 01 5B    ld hl,(23297)

CHECK KEY PRESSED

23855 01 FE EF    ld bc,61438
23858 ED 78       in a,(c)
23860 CB 47       bit 0,a
23862 20 01       jr nz,L1
23864 24          inc h
L1
23865 CB 4F       bit 1,a
23867 20 01       jr nz,L2
23869 25          dec h
L2
23870 01 FE F7    ld bc,63486
23873 ED 78       in a,(c)
23875 CB 47       bit 0,a
23877 20 01       jr nz,L3
23879 2D          dec l
L3
23880 01 FE FB    ld bc,64510

23883 ED 78       in a,(c)
23885 CB 47       bit 0,a
23887 20 01       jr nz,L4
23889 2C          inc l
L4

CHECK STILL ON SCREEN

23890 7D          ld a,l
23891 FE 16       cp 22
23893 20 03       jr nz,L5
23895 2D          dec l
23896 18 05       jr L6
L5
23898 FE FF       cp 255
23900 20 01       jr nz,L6
23902 2C          inc l
L6
23903 7C          ld a,h
23904 FE 1E       cp 30
23906 20 03       jr nz,L8

23908 25          dec h
23909 18 05       jr L9
L8
23911 FE FF       cp 255
23913 20 01       jr nz,L9
23915 24          inc h
L9

CHECK NO MOVE

23916 ED 5B 01 5B ld de,(23297)
23920 AF          xor a
23921 E5          push hl
23922 ED 52       sbc hl,de
23924 E1          pop hl
IF NO MOVE THEN SKIP
PRINT OVER 1
23925 28 2C       jr z,L12

STORE NEW x,y PARAMETERS
```

```
23927 22 01 5B     ld (23297),hl

SET OVER 1

23930 FD 36 57 03 ld (iy+87),3

ERASE OLD POSITION

23934 11 F9 5C     ld de,DATA2
23937 01 0A 00     ld bc,10
23940 CD 3C 20     call 8252

REPRINT IN NEW POSITION

23943 11 00 5B     ld de,23296
23946 01 0A 00     ld bc,10
23949 CD 3C 20     call 8252

UPDATE DATA2 FOR NEXT TIME

23952 11 F9 5C     ld de,DATA2

23955 21 00 5B     ld hl,23296
23958 01 0A 00     ld bc,10
23961 ED B0        ldir

DELAY LOOP

23963 21 88 13     ld hl,5000
L11
23966 2B           dec hl
23967 7C           ld a,h
23968 B5           or l
23969 20 FB        jr nz,L11

CHECK 'SPACE' PRESSED

L12
23971 01 FE 7F     ld bc,32766
23974 ED 78        in a,(c)
23976 CB 47        bit 0,a
23978 C2 21 5D     jp nz,L7


RESET OVER 0

23981 FD 36 57 00 ld (iy+87),0

MAKE KEY BOARD ACTIVE

23985 FB           ei
23986 C9           ret
```

Program 6.1A

Program 6.1A demonstrates the principle as outlined above. A spaceship-like character is moved around the screen using keys 9/0 for left/right and 1/Q for up/down. 'Space' will return to BASIC. The spaceship is able to move in two directions at once and can fly around the screen without disturbing any background that you may care to set up. The character is printed INK 8; PAPER 8; and so will take on the colours of the squares as defined by the attribute of that square. The speed of movement is governed by the delay loop, and a check is made to see whether the ship is stationary. If it is, then the reprint routine is missed out as this would cause the ship to flash by being continually erased and reprinted at the same place. You can modify the program to enable the ship to fly off the screen and reappear on the other side by resetting 'y' if the ship exceeds the screen parameters.

Multiple character movement is basically the same as above with each character having its own set of PRINT AT DATA. The machine code routine is very fast as can be demonstrated by using LD HL, 1 for the delay loop, when the TV will not have the chance to print all the positions as the character moves. You will find that most programs need some sort of delay loop to hold the picture for a moment before moving on.

Background movement one character square

Whereas foreground movement requires the character position to

be held in memory and movements tracked, background movement usually requires the shifting of the entire screen display (or blocks of it) in a known direction without keeping track of exactly where everything is.

This movement is normally in one of four directions – up, down, left, and right – and usually involves both the characters and their attributes. If a screen background is shifted by one character position we have a further choice concerning the characters shifted off the screen. We can either lose them and print spaces in the row/column created on the other side of the screen, or we can store them with their attributes and reprint them in their corresponding place on the other side of the screen thus giving a wrap-around effect which is most useful in games programs.

The following Programs 6.1B to 6.16 demonstrate ROLL and SCROLL in all four directions; firstly the attributes and then the screen characters. These programs are easily modified to ROLL or SCROLL parts of the screen leaving the rest stationary. Note the peculiar layout of the screen display which is split up into three blocks of eight rows. Each row is further divided into eight lines of 32 bytes per line. The memory map starts at row 1 line 1 and 'maps' the 32 bytes of that line, then moves to row 2 line 1, row 3 line 1 and so on up to row 8 line 1 thus mapping 256 bytes. We then jump back to row 1 line 2, row 2 line 2, row 3 line 2, etc., and end up with row 8 line 8, thus mapping 2K bytes.

We then move to the middle eight rows which are dealt with in the same way, and finally to the last eight rows, again mapped in the same way. This does make the character rolling and scrolling a little complicated and requires moving 6K bytes.

```
org 23760
23760 11 00 58     ld de,22528
23763 21 20 58     ld hl,22560
23766 01 E0 02     ld bc,736
23769 ED B0        ldir
23771 06 20        ld b,32
23773 3A 8D 5C     ld a,(23693)
L2
23776 12           ld (de),a
23777 13           inc de
23778 10 FC        djnz L2
23780 C9           ret
```

Program 6.1B

```
org 23760
23760 11 FF 5A     ld de,23295
23763 21 DF 5A     ld hl,23263
23766 01 E0 02     ld bc,736
23769 ED B8        lddr
23771 06 20        ld b,32
23773 3A 8D 5C     ld a,(23693)
L7
23776 12           ld (de),a
23777 13           inc de
23778 10 FC        djnz L7
23780 C9           ret
```

Program 6.2

```
org 23760
23760 06 18       ld b,24
23762 21 00 58    ld hl,22528
L12
23765 E5          push hl
23766 D1          pop de
23767 C5          push bc
23768 23          inc hl
23769 01 1F 00    ld bc,31
23772 ED B0       ldir
23774 3A 8D 5C    ld a,(23693)
23777 12          ld (de),a
23778 C1          pop bc
23779 10 F0       djnz L12
23781 C9          ret
```

Program 6.3

```
org 23760
23760 06 18       ld b,24
23762 21 FF 5A    ld hl,23295
L14
23765 E5          push hl
23766 D1          pop de
23767 C5          push bc
23768 2B          dec hl
23769 01 1F 00    ld bc,31
23772 ED B8       lddr
23774 3A 8D 5C    ld a,(23693)
23777 12          ld (de),a
23778 C1          pop bc
23779 10 F0       djnz L14
23781 C9          ret
```

Program 6.4

```
org 23760
23760 21 00 58    ld hl,22528
23763 E5          push hl
23764 D1          pop de
23765 06 20       ld b,32
L16
23767 7E          ld a,(hl)
23768 F5          push af
23769 23          inc hl
23770 10 FB       djnz L16
23772 01 E0 02    ld bc,736
23775 ED B0       ldir
23777 06 20       ld b,32
L17
23779 F1          pop af
23780 2B          dec hl
23781 77          ld (hl),a
23782 10 FB       djnz L17
23784 C9          ret
```

Program 6.5

```
org 23760
23760 21 FF 5A    ld hl,23295
23763 E5          push hl
23764 D1          pop de
23765 06 20       ld b,32
L24
23767 7E          ld a,(hl)
23768 F5          push af
23769 2B          dec hl
23770 10 FB       djnz L24
23772 01 E0 02    ld bc,736
23775 ED B8       lddr
23777 06 20       ld b,32
L25
23779 F1          pop af
23780 23          inc hl
23781 77          ld (hl),a
23782 10 FB       djnz L25
23784 C9          ret
```

Program 6.6

```
org 23760
23760 06 18       ld b,24
23762 21 00 58    ld hl,22528
L32
23765 E5          push hl
23766 D1          pop de
23767 C5          push bc
23768 7E          ld a,(hl)
23769 23          inc hl
23770 01 1F 00    ld bc,31
23773 ED B0       ldir
23775 12          ld (de),a
23776 C1          pop bc
23777 10 F2       djnz L32
23779 C9          ret
```

Program 6.7

```
org 23760
23760 06 18       ld b,24
23762 21 FF 5A    ld hl,23295
L33
23765 E5          push hl
23766 D1          pop de
23767 C5          push bc
23768 7E          ld a,(hl)
23769 2B          dec hl
23770 01 1F 00    ld bc,31
23773 ED B8       lddr
23775 12          ld (de),a
23776 C1          pop bc
23777 10 F2       djnz L33
23779 C9          ret
```

Program 6.8

```
org 23760
23760 06 C0       ld b,192
23762 21 00 40    ld hl,16384
L1
23765 E5          push hl
23766 D1          pop de
23767 C5          push bc
23768 7E          ld a,(hl)
23769 23          inc hl
23770 01 1F 00    ld bc,31
23773 ED B0       ldir
23775 12          ld (de),a
23776 C1          pop bc
23777 10 F2       djnz L1
23779 C9          ret
```

Program 6.9

```
org 23760
23760 06 C0       ld b,192
23762 21 FF 57    ld hl,22527
L1
23765 E5          push hl
23766 D1          pop de
23767 C5          push bc
23768 7E          ld a,(hl)
23769 2B          dec hl
23770 01 1F 00    ld bc,31
23773 ED B8       lddr
23775 12          ld (de),a
23776 C1          pop bc
23777 10 F2       djnz L1
23779 C9          ret
```

Program 6.10

```
org 23760
23760 21 00 40    ld hl,16384
23763 AF          xor a
23764 06 C0       ld b,192
L13
23766 C5          push bc
23767 E5          push hl
23768 D1          pop de
23769 23          inc hl
23770 01 1F 00    ld bc,31
23773 ED B0       ldir
23775 12          ld (de),a
23776 C1          pop bc
23777 10 F3       djnz L13
23779 C9          ret
```

Program 6.11

```
org 23760
L2
23760 21 00 40     ld hl,16384
23763 11 20 00     ld de,32
23766 06 C0        ld b,192
L1
23768 36 00        ld (hl),0
23770 19           add hl,de
23771 10 FB        djnz L1
23773 21 01 40     ld hl,16385
23776 11 00 40     ld de,16384
23779 01 FF 17     ld bc,6143
23782 ED B0        ldir
23784 EB           ex de,hl
23785 36 00        ld (hl),0
23787 C9           ret
```

Program 6.11A

```
org 23760
23760 21 FF 57    ld hl,22527
23763 AF          xor a
23764 06 C0       ld b,192
L14
23766 C5          push bc
23767 E5          push hl
23768 D1          pop de
23769 2B          dec hl
23770 01 1F 00    ld bc,31
23773 ED B8       lddr
23775 12          ld (de),a
23776 C1          pop bc
23777 10 F3       djnz L14
23779 C9          ret
```

Program 6.12

```
org 23760
23760 11 00 40     ld de,16384
23763 21 20 40     ld hl,16416
23766 01 E0 07     ld bc,2016
23769 ED B0        ldir
23771 06 08        ld b,8
23773 21 00 48     ld hl,18432
23776 11 E0 40     ld de,16608
L3
23779 C5           push bc
23780 E5           push hl
23781 D5           push de
23782 01 20 00     ld bc,32
23785 ED B0        ldir
23787 D1           pop de
23788 E1           pop hl
23789 C1           pop bc
23790 14           inc d
23791 24           inc h
23792 10 F1        djnz L3

23794 11 00 48     ld de,18432
23797 21 20 48     ld hl,18464
23800 01 E0 07     ld bc,2016
23803 ED B0        ldir
23805 06 08        ld b,8
23807 21 00 50     ld hl,20480
23810 11 E0 48     ld de,18656
L4
23813 C5           push bc
23814 E5           push hl
23815 D5           push de
23816 01 20 00     ld bc,32
23819 ED B0        ldir
23821 D1           pop de
23822 E1           pop hl
23823 C1           pop bc
23824 14           inc d
23825 24           inc h
23826 10 F1        djnz L4
23828 11 00 50     ld de,20480
23831 21 20 50     ld hl,20512

23834 01 E0 07     ld bc,2016
23837 ED B0        ldir
23839 06 08        ld b,8
23841 21 E0 50     ld hl,20704
L5
23844 C5           push bc
23845 E5           push hl
23846 06 20        ld b,32
L6
23848 36 00        ld (hl),0
23850 23           inc hl
23851 10 FB        djnz L6
23853 E1           pop hl
23854 C1           pop bc
23855 24           inc h
23856 10 F2        djnz L5
23858 C9           ret
```

Program 6.13

```
org 23760
23760 21 00 40     ld hl,16384
L18
23763 06 20        ld b,32
L19
23765 7E           ld a,(hl)
23766 F5           push af
23767 23           inc hl
23768 10 FB        djnz L19
23770 AF           xor a
23771 6F           ld l,a
23772 24           inc h
23773 7C           ld a,h
23774 FE 48        cp 72
23776 20 F1        jr nz,L18
23778 11 00 40     ld de,16384
23781 21 20 40     ld hl,16416
23784 01 E0 07     ld bc,2016
23787 ED B0        ldir
23789 06 08        ld b,8

23791 21 00 48     ld hl,18432
23794 11 E0 40     ld de,16608
L20
23797 C5           push bc
23798 E5           push hl
23799 D5           push de
23800 01 20 00     ld bc,32
23803 ED B0        ldir
23805 D1           pop de
23806 E1           pop hl
23807 C1           pop bc
23808 14           inc d
23809 24           inc h
23810 10 F1        djnz L20
23812 11 00 48     ld de,18432
23815 21 20 48     ld hl,18464
23818 01 E0 07     ld bc,2016
23821 ED B0        ldir
23823 06 08        ld b,8
23825 21 00 50     ld hl,20480
23828 11 E0 48     ld de,18656

L21
23831 C5           push bc
23832 E5           push hl
23833 D5           push de
23834 01 20 00     ld bc,32
23837 ED B0        ldir
23839 D1           pop de
23840 E1           pop hl
23841 C1           pop bc
23842 14           inc d
23843 24           inc h
23844 10 F1        djnz L21
23846 11 00 50     ld de,20480
23849 21 20 50     ld hl,20512
23852 01 E0 07     ld bc,2016
```

```
23855 ED B0       ldir
23857 21 FF 57    ld hl,22527
L22
23860 06 20       ld b,32
L23
23862 F1          pop af


23863 77          ld (hl),a
```

```
23864 2B          dec hl
23865 10 FB       djnz L23
23867 3E FF       ld a,255
23869 6F          ld l,a
23870 25          dec h
23871 7C          ld a,h
23872 FE 4F       cp 79
23874 20 F0       jr nz,L22
23876 C9          ret
```

Program 6.14

```
org 23760
23760 11 FF 57    ld de,22527
23763 21 DF 57    ld hl,22495
23766 01 E0 07    ld bc,2016
23769 ED B8       lddr
23771 06 08       ld b,8
23773 21 E0 48    ld hl,18656
23776 11 00 50    ld de,20480
L8
23779 C5          push bc
23780 E5          push hl
23781 D5          push de
23782 01 20 00    ld bc,32
23785 ED B0       ldir
23787 D1          pop de
23788 E1          pop hl
23789 C1          pop bc
23790 14          inc d
23791 24          inc h
23792 10 F1       djnz L8


23794 11 FF 4F    ld de,20479
23797 21 DF 4F    ld hl,20447
23800 01 E0 07    ld bc,2016
23803 ED B8       lddr
23805 06 08       ld b,8
23807 21 E0 40    ld hl,16608
23810 11 00 48    ld de,18432
L9
23813 C5          push bc
```

```
23814 E5          push hl
23815 D5          push de
23816 01 20 00    ld bc,32
23819 ED B0       ldir
23821 D1          pop de
23822 E1          pop hl
23823 C1          pop bc
23824 14          inc d
23825 24          inc h
23826 10 F1       djnz L9
23828 11 FF 47    ld de,18431
23831 21 DF 47    ld hl,18399


23834 01 E0 07    ld bc,2016
23837 ED B8       lddr
23839 21 00 40    ld hl,16384
L10
23842 06 20       ld b,32
L11
23844 36 00       ld (hl),0
23846 23          inc hl
23847 10 FB       djnz L11
23849 AF          xor a
23850 6F          ld l,a
23851 24          inc h
23852 7C          ld a,h
23853 FE 48       cp 72
23855 20 F1       jr nz,L10
23857 C9          ret
```

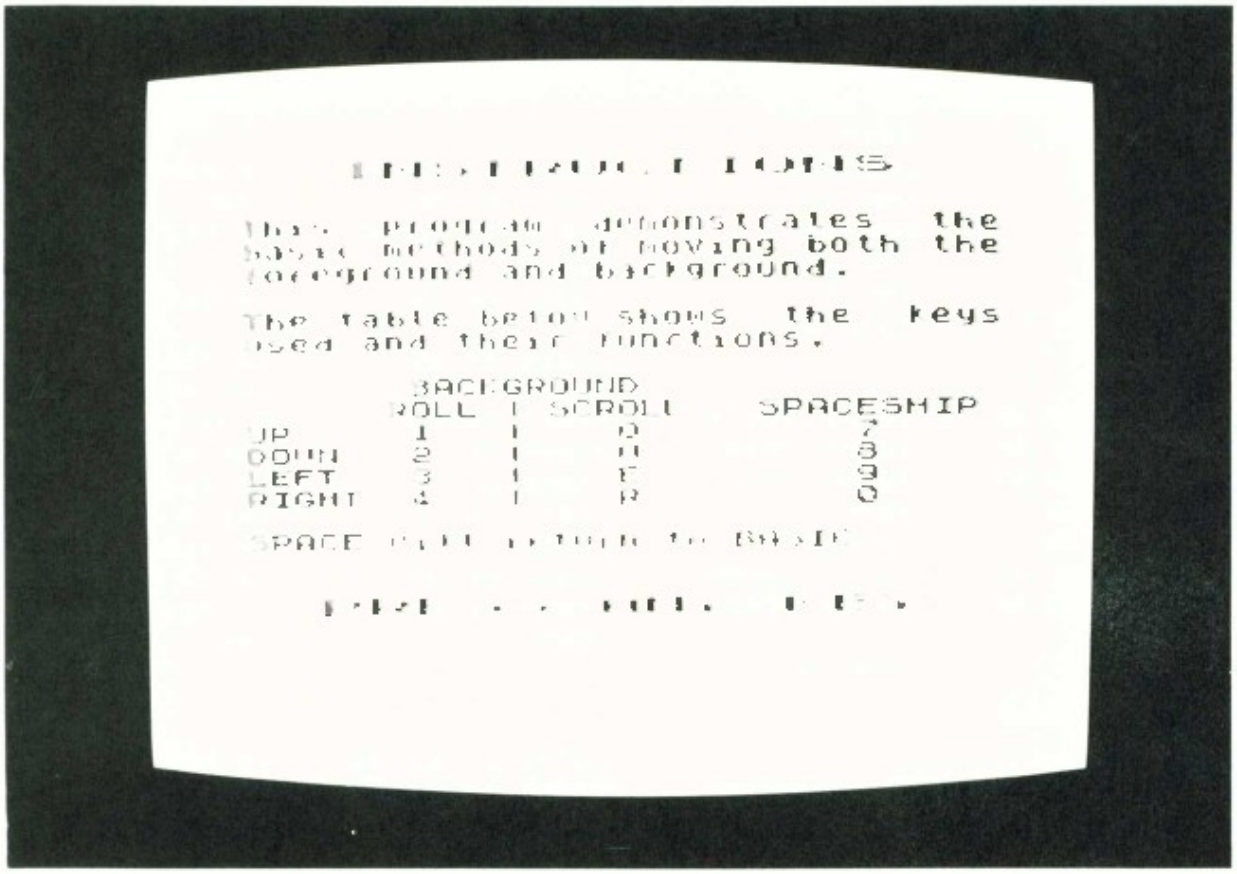
Program 6.15

```
org 23760
23760 21 FF 57    ld hl,22527
L26
23763 06 20       ld b,32
L27
23765 7E          ld a,(hl)
23766 F5          push af
23767 2B          dec hl
23768 10 FB       djnz L27
23770 3E FF       ld a,255
23772 6F          ld l,a
23773 25          dec h
23774 7C          ld a,h
23775 FE 4F       cp 79
23777 20 F0       jr nz,L26
23779 11 FF 57    ld de,22527
23782 21 DF 57    ld hl,22495
23785 01 E0 07    ld bc,2016
23788 ED B8       lddr
23790 06 08       ld b,8
```

```
23792 21 E0 48    ld hl,18656
23795 11 00 50    ld de,20480
L28
23798 C5          push bc
23799 E5          push hl
23800 D5          push de
23801 01 20 00    ld bc,32
23804 ED B0       ldir
23806 D1          pop de
23807 E1          pop hl
23808 C1          pop bc
23809 14          inc d
23810 24          inc h
23811 10 F1       djnz L28
23813 11 FF 4F    ld de,20479
23816 21 DF 4F    ld hl,20447
23819 01 E0 07    ld bc,2016
23822 ED B8       lddr
23824 06 08       ld b,8
23826 21 E0 40    ld hl,16608
```

```
23829 11 00 48     ld de,18432

L29
23832 C5           push bc
23833 E5           push hl
23834 D5           push de
23835 01 20 00     ld bc,32
23838 ED B0        ldir
23840 D1           pop de
23841 E1           pop hl
23842 C1           pop bc
23843 14           inc d
23844 24           inc h
23845 10 F1        djnz L29
23847 11 FF 47     ld de,18431
23850 21 DF 47     ld hl,18399
23853 01 E0 07     ld bc,2016
23856 ED B8        lddr
23858 21 00 40     ld hl,16384
L30
23861 06 20        ld b,32
L31
23863 F1           pop af

23864 77           ld (hl),a
23865 23           inc hl
23866 10 FB        djnz L31
23868 AF           xor a
23869 6F           ld l,a
23870 24           inc h
23871 7C           ld a,h
23872 FE 48        cp 72
23874 20 F1        jr nz,L30
23876 C9           ret
```

Program 6.16




```
   1 REM >? STEP £" CLEAR 65/>?
STEP ?
  500>DATA 24,79,5,2,"STOP THE TAP
E"
  510 DATA 0,167,6,4,"MOVEMENT"
  520 DATA 0,130,2,4,"________"
  525 DATA 24,15,1,2,"PRESS ANY KE
Y"
  550 DATA 31,170,1,2,"INSTRUCTION
S"
  600 BORDER 4: PAPER 6: INK 0: CL
S
  605 RESTORE 500
  610 FOR a=1 TO 4
  620 INK a: GO SUB 8000
```

```
 630 PAUSE 50: NEXT a
 640 PAUSE 0: CLS
 642 INK 2: GO SUB 8000
 645 PRINT  INK 0;AT 3,0;"This  p
rogram  demonstrates  thebasic me
thods of moving both theforegroun
d and background."
 646 PRINT '"The table below show
s  the  keysused and their functi
ons."
 647 PRINT
 650 PRINT "        BACKGROUND"
 655 PRINT "       ROLL  |  SCROLL
 SPACESHIP"
 660 PRINT "UP      1    |     0
     7"
 670 PRINT "DOWN    2    |     W
     8"
 680 RRINT "LEFT    3    |     E
     9"
 690 PRINT "RIGHT   4    |     R
     0"
 695 PRINT '"SPACE will return to
 BASIC"
 700 RESTORE 525: INK 2: GO SUB 8
000
 705 IF INKEY$<>"" THEN  GO TO 70
5
 710 IF INKEY$="" THEN  GO TO 710
 715 POKE 30046,0: POKE 30047,0
 720 RANDOMIZE USR 30001
 725 CLS : RESTORE 730: PAPER 8:
INK 0: GO SUB 8000
 730 DATA 0,80,3,1,"ENTER 'GOTO 7
5' for another go."
 740 STOP
8000 READ x,y,h,w,a$
8010 LET c=USR 32393
8020 RETURN
9998 CLEAR 30000: LOAD "udg"CODE
USR "a": LOAD ""CODE : GO TO 500
9999 SAVE "MOVEDEMO" LINE 9998: S
AVE "udg"CODE USR "a",168: SAVE "
M/code"CODE 30001,2767
```

Program 6.17

```
org 40000 30001
30001 F3          di
30002 CD D0 5C    call 23760
30005 18 18       jr START
DATA1
defb 0 0 15 24 49 226 225 224
defb 24 60 255 255 153 255 231
defb 60 0 0 240 24 140 71 135 7
START
30031 ED 5B 7B 5C ld de,(23675)
30035 21 37 75    ld hl,DATA1
30038 01 18 00    ld bc,24
30041 ED B0       ldir
30043 18 0A       jr BEGIN
DATA2
defb 22 0 0 16 8 17 8 144 145
defb 146
BEGIN
30055 11 5D 75    ld de,DATA2
30058 01 0A 00    ld bc,10

30061 CD 3C 20    call 8252
30064 11 00 5B    ld de,23296
30067 21 5D 75    ld hl,DATA2
30070 01 0A 00    ld bc,10
30073 ED B0       ldir
MOVE
30075 2A 01 5B    ld hl,(23297)
30078 01 FE EF    ld bc,61438
30081 ED 78       in a,(c)
30083 FE FF       cp 255
30085 28 5D       jr z,LP12
30087 CB 47       bit 0,a
```

```
30089 20 01        jr nz,LP1
30091 24           inc h
LP1
30092 CB 4F        bit 1,a
30094 20 01        jr nz,LP2
30096 25           dec h
LP2
30097 CB 57        bit 2,a
30099 20 01        jr nz,LP3


30101 2C           inc l
LP3
30102 CB 5F        bit 3,a
30104 20 01        jr nz,LP4
30106 2D           dec l
LP4
30107 7D           ld a,l
30108 FE 16        cp 22
30110 20 03        jr nz,LP5
30112 2D           dec l
30113 18 05        jr LP6
LP5
30115 FE FF        cp 255
30117 20 01        jr nz,LP6
30119 2C           inc l
LP6
30120 7C           ld a,h
30121 FE 1E        cp 30
30123 20 03        jr nz,LP7
30125 25           dec h
30126 18 05        jr LP8


LP7
30128 FE FF        cp 255
30130 20 01        jr nz,LP8
30132 24           inc h
LP8
30133 ED 5B 01 5B  ld de,(23297)
30137 AF           xor a
30138 E5           push hl
30139 ED 52        sbc hl,de
30141 E1           pop hl
30142 28 24        jr z,LP12
30144 22 01 5B     ld (23297),hl
OVER1
30147 FD 36 57 03  ld (iy+87),3
30151 11 5D 75     ld de,DATA2
30154 01 0A 00     ld bc,10
30157 CD 3C 20     call 8252
30160 11 00 5B     ld de,23296
30163 01 0A 00     ld bc,10
30166 CD 3C 20     call 8252
30169 11 5D 75     ld de,DATA2


30172 21 00 5B     ld hl,23296
30175 01 0A 00     ld bc,10
30178 ED B0        ldir
LP12
30180 01 FE F7     ld bc,63486
30183 ED 78        in a,(c)
30185 E6 0F        and 15
30187 28 3E        jr z,SCR
30189 FE 03        cp 3
30191 28 3A        jr z,SCR
30193 FE 0C        cp 12
30195 28 36        jr z,SCR
30197 FE 0F        cp 15
30199 28 32        jr z,SCR
30201 F5           push af
30202 FD 36 57 03  ld (iy+87),3
30206 11 5D 75     ld de,DATA2
30209 01 0A 00     ld bc,10
30212 CD 3C 20     call 8252
30215 F1           pop af
30216 CB 47        bit 0,a


30218 F5           push af
30219 CC C9 77     call z,UROLL
30222 F1           pop af
30223 CB 4F        bit 1,a
30225 F5           push af
30226 CC 56 78     call z,DROLL
30229 F1           pop af
30230 CB 57        bit 2,a
30232 F5           push af
30233 CC E3 78     call z,LROLL
30236 F1           pop af
30237 CB 5F        bit 3,a
30239 CC F7 78     call z,RROLL
30242 11 5D 75     ld de,DATA2
30245 01 0A 00     ld bc,10
30248 CD 3C 20     call 8252
SCR
30251 01 FE FD     ld bc,64510
30254 ED 78        in a,(c)
30256 E6 0F        and 15
30258 28 3E        jr z,DELAY


30260 FE 03        cp 3
30262 28 3A        jr z,DELAY
30264 FE 0C        cp 12
30266 28 36        jr z,DELAY
30268 FE 0F        cp 15
30270 28 32        jr z,DELAY
30272 F5           push af
30273 FD 36 57 03  ld (iy+87),3
30277 11 5D 75     ld de,DATA2
30280 01 0A 00     ld bc,10
30283 CD 3C 20     call 8252
30286 F1           pop af
30287 CB 47        bit 0,a
30289 F5           push af
30290 CC 8A 76     call z,USCR
30293 F1           pop af
30294 CB 4F        bit 1,a
30296 F5           push af
30297 CC 01 77     call z,DSCR
30300 F1           pop af
30301 CB 57        bit 2,a


30303 F5           push af
30304 CC 77 77     call z,LSCR
```

```
30307 F1          pop af
30308 CB 5F       bit 3,a
30310 CC A0 77    call z,RSCR
30313 11 5D 75    ld de,DATA2
30316 01 0A 00    ld bc,10
30319 CD 3C 20    call 8252
DELAY
30322 21 10 27    ld hl,10000
L1
30325 2B          dec hl
30326 7C          ld a,h
30327 B5          or l
30328 20 FB       jr nz,L1
30330 01 FE 7F    ld bc,32766
30333 ED 78       in a,(c)
30335 CB 47       bit 0,a
30337 C2 7B 75    jp nz,MOVE
30340 FD 36 57 00 ld (iy+87),0
30344 FB          ei

30345 C9          ret
USCR
30346 11 00 58    ld de,22528
30349 21 20 58    ld hl,22560
30352 01 E0 02    ld bc,736
30355 ED B0       ldir
30357 06 20       ld b,32
30359 3A 8D 5C    ld a,(23693)
L2
30362 12          ld (de),a
30363 13          inc de
30364 10 FC       djnz L2
30366 11 00 40    ld de,16384
30369 21 20 40    ld hl,16416
30372 01 E0 07    ld bc,2016
30375 ED B0       ldir
30377 06 08       ld b,8
30379 21 00 48    ld hl,18432
30382 11 E0 40    ld de,16608
L3
30385 C5          push bc

30386 E5          push hl
30387 D5          push de
30388 01 20 00    ld bc,32
30391 ED B0       ldir
30393 D1          pop de
30394 E1          pop hl
30395 C1          pop bc
30396 14          inc d
30397 24          inc h
30398 10 F1       djnz L3
30400 11 00 48    ld de,18432
30403 21 20 48    ld hl,18464
30406 01 E0 07    ld bc,2016
30409 ED B0       ldir
30411 06 08       ld b,8
30413 21 00 50    ld hl,20480
30416 11 E0 48    ld de,18656
L4
30419 C5          push bc
30420 E5          push hl

30421 D5          push de

30422 01 20 00    ld bc,32
30425 ED B0       ldir
30427 D1          pop de
30428 E1          pop hl
30429 C1          pop bc
30430 14          inc d
30431 24          inc h
30432 10 F1       djnz L4
30434 11 00 50    ld de,20480
30437 21 20 50    ld hl,20512
30440 01 E0 07    ld bc,2016
30443 ED B0       ldir
30445 06 08       ld b,8
30447 21 E0 50    ld hl,20704
L5
30450 C5          push bc
30451 E5          push hl
30452 06 20       ld b,32
L6
30454 36 00       ld (hl),0
30456 23          inc hl

30457 10 FB       djnz L6
30459 E1          pop hl
30460 C1          pop bc
30461 24          inc h
30462 10 F2       djnz L5
30464 C9          ret
DSCR
30465 11 FF 5A    ld de,23295
30468 21 DF 5A    ld hl,23263
30471 01 E0 02    ld bc,736
30474 ED B8       lddr
30476 06 20       ld b,32
30478 3A 8D 5C    ld a,(23693)
L7
30481 12          ld (de),a
30482 13          inc de
30483 10 FC       djnz L7
30485 11 FF 57    ld de,22527
30488 21 DF 57    ld hl,22495
30491 01 E0 07    ld bc,2016
30494 ED B8       lddr

30496 06 08       ld b,8
30498 21 E0 48    ld hl,18656
30501 11 00 50    ld de,20480
L8
30504 C5          push bc
30505 E5          push hl
30506 D5          push de
30507 01 20 00    ld bc,32
30510 ED B0       ldir
30512 D1          pop de
30513 E1          pop hl
30514 C1          pop bc
30515 14          inc d
30516 24          inc h
30517 10 F1       djnz L8
```

```
30519 11 FF 4F     ld de,20479
30522 21 DF 4F     ld hl,20447
30525 01 E0 07     ld bc,2016
30528 ED B8        lddr
30530 06 08        ld b,8
30532 21 E0 40     ld hl,16608

30535 11 00 48     ld de,18432
L9
30538 C5           push bc
30539 E5           push hl
30540 D5           push de
30541 01 20 00     ld bc,32
30544 ED B0        ldir
30546 D1           pop de
30547 E1           pop hl
30548 C1           pop bc
30549 14           inc d
30550 24           inc h
30551 10 F1        djnz L9
30553 11 FF 47     ld de,18431
30556 21 DF 47     ld hl,18399
30559 01 E0 07     ld bc,2016
30562 ED B8        lddr
30564 21 00 40     ld hl,16384
L10
30567 06 20        ld b,32
L11

30569 36 00        ld (hl),0
30571 23           inc hl
30572 10 FB        djnz L11
30574 AF           xor a
30575 6F           ld l,a
30576 24           inc h
30577 7C           ld a,h
30578 FE 48        cp 72
30580 20 F1        jr nz,L10
30582 C9           ret
LSCR
30583 06 18        ld b,24
30585 21 00 58     ld hl,22528
L12
30588 E5           push hl
30589 D1           pop de
30590 C5           push bc
30591 23           inc hl
30592 01 1F 00     ld bc,31
30595 ED B0        ldir
30597 3A 8D 5C     ld a,(23693)

30600 12           ld (de),a
30601 C1           pop bc
30602 10 F0        djnz L12
30604 21 00 40     ld hl,16384
30607 AF           xor a
30608 06 C0        ld b,192
L13
30610 C5           push bc
30611 E5           push hl
30612 D1           pop de
30613 23           inc hl
30614 01 1F 00     ld bc,31
30617 ED B0        ldir
30619 12           ld (de),a
30620 C1           pop bc
30621 10 F3        djnz L13
30623 C9           ret
RSCR
30624 06 18        ld b,24
30626 21 FF 5A     ld hl,23295
L14

30629 E5           push hl
30630 D1           pop de
30631 C5           push bc
30632 2B           dec hl
30633 01 1F 00     ld bc,31
30636 ED B8        lddr
30638 3A 8D 5C     ld a,(23693)
30641 12           ld (de),a
30642 C1           pop bc
30643 10 F6        djnz L14
30645 21 FF 57     ld hl,22527
30648 AF           xor a
30649 06 C0        ld b,192
L14
30651 C5           push bc
30652 E5           push hl
30653 D1           pop de
30654 2B           dec hl
30655 01 1F 00     ld bc,31
30658 ED B8        lddr
30660 12           ld (de),a

30661 C1           pop bc
30662 10 DD        djnz L14
30664 C9           ret
UROLL
30665 21 00 58     ld hl,22528
30668 E5           push hl
30669 D1           pop de
30670 06 20        ld b,32
L16
30672 7E           ld a,(hl)
30673 F5           push af
30674 23           inc hl
30675 10 FB        djnz L16
30677 01 E0 02     ld bc,736
30680 ED B0        ldir
30682 06 20        ld b,32
L17
30684 F1           pop af
30685 2B           dec hl
30686 77           ld (hl),a
30687 10 FB        djnz L17

30689 21 00 40     ld hl,16384
L18
30692 06 20        ld b,32
L19
```

```
30694 7E          ld a,(hl)
30695 F5          push af
30696 23          inc hl
30697 10 FB       djnz L19
30699 AF          xor a
30700 6F          ld l,a
30701 24          inc h
30702 7C          ld a,h
30703 FE 48       cp 72
30705 20 F1       jr nz,L18
30707 11 00 40    ld de,16384
30710 21 20 40    ld hl,16416
30713 01 E0 07    ld bc,2016
30716 ED B0       ldir
30718 06 08       ld b,8
30720 21 0C 48    ld hl,18432
30723 11 E0 40    ld de,16608

L20
30726 C5          push bc
30727 E5          push hl
30728 D5          push de
30729 01 20 00    ld bc,32
30732 ED B0       ldir
30734 D1          pop de
30735 E1          pop hl
30736 C1          pop bc
30737 14          inc d
30738 24          inc h
30739 10 F1       djnz L20
30741 11 00 48    ld de,18432
30744 21 20 48    ld hl,18464
30747 01 E0 07    ld bc,2016
30750 ED B0       ldir
30752 06 08       ld b,8
30754 21 00 50    ld hl,20480
30757 11 E0 48    ld de,18656
L21
30760 C5          push bc

30761 E5          push hl
30762 D5          push de
30763 01 20 00    ld bc,32
30766 ED B0       ldir
30768 D1          pop de
30769 E1          pop hl
30770 C1          pop bc
30771 14          inc d
30772 24          inc h
30773 10 F1       djnz L21
30775 11 00 50    ld de,20480
30778 21 20 50    ld hl,20512
30781 01 E0 07    ld bc,2016
30784 ED B0       ldir
30786 21 FF 57    ld hl,22527
L22
30789 06 20       ld b,32
L23
30791 F1          pop af
30792 77          ld (hl),a
30793 2B          dec hl
30794 10 FB       djnz L23
30796 3E FF       ld a,255
30798 6F          ld l,a
30799 25          dec h
30800 7C          ld a,h
30801 FE 4F       cp 79
30803 20 F0       jr nz,L22
30805 C9          ret
DROLL
30806 21 FF 5A    ld hl,23295
30809 E5          push hl
30810 D1          pop de
30811 06 20       ld b,32
L24
30813 7E          ld a,(hl)
30814 F5          push af
30815 2B          dec hl
30816 10 FB       djnz L24
30818 01 E0 02    ld bc,736
30821 ED B8       lddr
30823 06 20       ld b,32

L25
30825 F1          pop af
30826 23          inc hl
30827 77          ld (hl),a
30828 10 FB       djnz L25
30830 21 FF 57    ld hl,22527
L26
30833 06 20       ld b,32
L27
30835 7E          ld a,(hl)
30836 F5          push af
30837 2B          dec hl
30838 10 FB       djnz L27
30840 3E FF       ld a,255
30842 6F          ld l,a
30843 25          dec h
30844 7C          ld a,h
30845 FE 4F       cp 79
30847 20 F0       jr nz,L26
30849 11 FF 57    ld de,22527
30852 21 DF 57    ld hl,22495

30855 01 E0 07    ld bc,2016
30858 ED B8       lddr
30860 06 08       ld b,8
30862 21 E0 48    ld hl,18656
30865 11 00 50    ld de,20480
L28
30868 C5          push bc
30869 E5          push hl
30870 D5          push de
30871 01 20 00    ld bc,32
30874 ED B0       ldir
30876 D1          pop de
30877 E1          pop hl
30878 C1          pop bc
30879 14          inc d
30880 24          inc h
30881 10 F1       djnz L28
```

```
30883 11 FF 4F     ld de,20479
30886 21 DF 4F     ld hl,20447
30889 01 E0 07     ld bc,2016
30892 ED B8        lddr

30894 06 08        ld b,8
30896 21 E0 40     ld hl,16608
30899 11 00 48     ld de,18432
L29
30902 C5           push bc
30903 E5           push hl
30904 D5           push de
30905 01 20 00     ld bc,32
30908 ED B0        ldir
30910 D1           pop de
30911 E1           pop hl
30912 C1           pop bc
30913 14           inc d
30914 24           inc h
30915 10 F1        djnz L29
30917 11 FF 47     ld de,18431
30920 21 DF 47     ld hl,18399
30923 01 E0 07     ld bc,2016
30926 ED B8        lddr
30928 21 00 40     ld hl,16384
L30

30931 06 20        ld b,32
L31
30933 F1           pop af
30934 77           ld (hl),a
30935 23           inc hl
30936 10 FB        djnz L31
30938 AF           xor a
30939 6F           ld l,a
30940 24           inc h
30941 7C           ld a,h
30942 FE 48        cp 72
30944 20 F1        jr nz,L30
30946 C9           ret
LROLL
30947 06 D8        ld b,216
30949 21 00 40     ld hl,16384
L32
30952 E5           push hl
30953 D1           pop de
30954 C5           push bc
30955 7E           ld a,(hl)

30956 23           inc hl
30957 01 1F 00     ld bc,31
30960 ED B0        ldir
30962 12           ld (de),a
30963 C1           pop bc
30964 10 F2        djnz L32
30966 C9           ret
RROLL
30967 06 D8        ld b,216
30969 21 FF 5A     ld hl,23295
L33
30972 E5           push hl
30973 D1           pop de
30974 C5           push bc
30975 7E           ld a,(hl)
30976 2B           dec hl
30977 01 1F 00     ld bc,31
30980 ED B8        lddr
30982 12           ld (de),a
30983 C1           pop bc
30984 10 F2        djnz L33


30986 C9           ret
```

Program 6.18

Note that in these routines extensive use is made of the block transfer instructions LDIR and LDDR and that after such instructions the DE and HL registers hold the finish address +1 (LDIR) or −1 (LDDR). Use is made of this fact to save reloading HL or DE with specific a address for further program routines. The ATTR. UP SCROLL (Program 6.1B) for example uses the fact that after LDIR the DE register holds the address of the 'START of LINE 24' attribute and so it is unnecessary to reload DE with this address. The existing line 24 attributes are replaced with the permanent screen attributes held in the systems variable ATTR P (23693).

To demonstrate each type of movement I have written Program 6.17 which is available on tape 'MOVEDEMO'. Since the program is almost 1000 bytes long it is not practical to hold it all in a REM statement (this would be more than a screenful) so I have written it for use above RAMTOP with start at address 30001 (Program 6.18). The machine code in the REM statement is taken from the program

on random numbers (Program 4.1) and is used to set up the background. The program is self-explanatory and calls the various routines depending on the keys pressed. The attributes are moved at the same time as the display characters. You can move the background and the ship diagonally and if two opposing keys are pressed then the routine is skipped. A return to BASIC is made by pressing 'SPACE'. Note that the vertical movement is rather jerky and not really suitable in this form owing to the transition from one screen zone to another. The programs, in fact, momentarily put line 1 into line 8 before scrolling line 9 into line 8.

The screen UP/DOWN – SCROLL and ROLL programs (Programs 6.13 to 6.16) were written in a form that should have been easy for you to follow with no subroutines to make them position dependent. To give a smoother movement these routines should be tackled in a different way, that is, scrolling one row at a time, rather than the top line of each row then the second line of each row etc. as at present. To show how this is achieved I have rewritten the SCREEN UP SCROLL program (Program 6.19A). As you can see it involves one subroutine and a sub -subroutine and is rather more complicated. Perhaps you would like to rewrite the SCREEN DOWN SCROLL routine in the same form as an exercise to make sure that you fully understand its workings.

```
org 23760
23760 21 00 40    ld hl,16384
23763 CD 01 5D    call SECT
23766 EB          ex de,hl
23767 21 00 48    ld hl,18432
23770 E5          push hl
23771 CD 15 5D    call UP
23774 E1          pop hl
23775 CD 01 5D    call SECT
23778 EB          ex de,hl
23779 21 00 50    ld hl,20480
23782 E5          push hl
23783 CD 15 5D    call UP
23786 E1          pop hl
23787 CD 01 5D    call SECT
23790 21 E0 50    ld hl,20704
L4
23793 E5          push hl
23794 06 20       ld b,32
L3

23796 36 00       ld (hl),0
23798 23          inc hl
23799 10 FB       djnz L3
23801 E1          pop hl
23802 24          inc h
23803 7C          ld a,h
23804 FE 58       cp 88
23806 20 F1       jr nz,L4
23808 C9          ret
SECT
23809 06 07       ld b,7
L1
23811 C5          push bc
23812 01 20 00    ld bc,32
23815 E5          push hl
23816 D1          pop de
23817 09          add hl,bc
23818 E5          push hl
23819 D5          push de
23820 CD 15 5D    call UP
23823 D1          pop de

23824 E1          pop hl
23825 C1          pop bc
23826 10 EF       djnz L1
23828 C9          ret
UP
23829 06 08       ld b,8
L2
23831 C5          push bc
23832 E5          push hl
23833 D5          push de
23834 01 20 00    ld bc,32
23837 ED B0       ldir
23839 D1          pop de
23840 E1          pop hl
```

```
23841 C1          pop bc
23842 14          inc d
23843 24          inc h
23844 10 F1       djnz L2
23846 C9          ret
```

Program 6.19A

If you compare Programs 6.13 and 6.19A you will see that we have reduced the memory required from 99 bytes to 87 bytes but even this is not as compact as it could be. To show how we can reduce the memory and running time still further *and* give an extra useful feature we will consider the UP ROLL Program 6.14 which as it stands takes 117 bytes. At present the program handles each character row, line by line and has the 'fault' of temporarily transferring row 1 to row 8 and row 9 to row 17. We could rewrite it on the lines of Program 6.21 to overcome this problem but let us consider an entirely different approach that will give a program only 76 bytes long.

Instead of handling the screen one row at a time, we could write a program that rolls one column at a time. The routine would then be repeated for 32 columns. This would give a feature of being able to select which columns you require rolling either in blocks or singly, and what is more, would not require 256 bytes of memory to store the top row of the screen as Program 6.14 does but rather only eight bytes for the single top column character. Program 6.19B shows how this reduction in memory is achieved.

```
org 23760
CHAPTER 6
PROGRAM 19B

SCREEN UP ROLL 'n' COLUMNS

EXAMPLE

ROLL COLUMNS 5 TO 14 INC

23760 AF          xor a

LD DE,16383+START COLUMN

1st COLUMN = 1

23761 11 04 40    ld de,16388

LD B,No. of columns


23764 06 0A       ld b,10
L5
23766 D5          push de
23767 C5          push bc

STORE TOP LINE CHR ON STACK

23768 D5          push de
23769 E1          pop hl
23770 06 08       ld b,8
L6
23772 7E          ld a,(hl)
23773 F5          push af
23774 24          inc h
23775 10 FB       djnz L6

TRANSFER 7 LINES

L4
23777 06 07       ld b,7
L2

23779 C5          push bc
23780 21 20 00    ld hl,32
23783 19          add hl,de
23784 E5          push hl

TRANSFER 8 BYTES

23785 06 08       ld b,8
L1
23787 7E          ld a,(hl)
23788 12          ld (de),a
23789 24          inc h
```

```
23790 14          inc d
23791 10 FA       djnz L1
23793 D1          pop de
23794 C1          pop bc
23795 10 EE       djnz L2

SCREEN ZONE TRANSFER

23797 21 20 07    ld hl,1824


23800 19          add hl,de
23801 7C          ld a,h

CHECK FOR OUT OF SCREEN
i.e  START OF ATTRIBUTES

23802 FE 58       cp 88
23804 28 0C       jr z,END
23806 E5          push hl
23807 06 08       ld b,8
L3
23809 7E          ld a,(hl)
23810 12          ld (de),a
23811 24          inc h
23812 14          inc d
23813 10 FA       djnz L3
23815 D1          pop de
23816 18 D7       jr L4

REMOVE CHR FROM STACK
AND PLACE IN BOTTOM SCREEN ROW


END
23818 11 20 00    ld de,32
23821 ED 52       sbc hl,de
23823 06 08       ld b,8
L7
23825 F1          pop af
23826 77          ld (hl),a
23827 25          dec h
23828 10 FB       djnz L7

MOVE TO NEXT COLUMN AND REPEAT

23830 C1          pop bc
23831 D1          pop de
23832 13          inc de
23833 10 BB       djnz L5
23835 C9          ret
```

Program 6.19B

You will note that we start Program 6.19B with the DE register pair holding the address of the top byte of the start column and the B register holding the number of columns to be rolled. As listed, the program is completely self-contained and can be positioned anywhere in memory.

Even this is not the end of the memory saving. Would you believe that is was possible to reduce Program 6.19B to just 58 bytes *and* add an extra facility of being able to define the rows required, thus giving a roll window routine? Well, Program 6.19C does just that.

The memory saving is achieved by checking for the end of a screen zone using the BIT 0,H instruction. If BIT 0,H is not zero then we have come to the end of a zone and, instead of adding 32d to DE to move up one line within a zone, we add 1824 to move to the 'first' line in the next zone. Using this method we can define how many rows require rolling by the number of times loop L4 is repeated. The start ROW/COLUMN is defined by the display address held in the DE register pair (23671/3). To calculate this start address use the following formula:

16384 + (1824 * INT (ROW/8)) = ((ROW − INT (ROW/8)) * 32) + COLUMN

In this formula the Spectrum ROW/COLUMN numbers apply, that is 1st row = 0 1st column = 0.

Example: ROW 17 COLUMN 5

= 16384 + (1824 * 2) + ((17 − 6) * 32) + 5

= 16384 + 3648 + 32 + 5

= 20069

```
org 23760
CHAPTER 6
PROGRAM 19C

UP ROLL WINDOW

EXAMPLE
COLUMNS 4 TO 10
ROWS 5 TO 18

23760 AF            xor a

LD DE,SCREEN START ADDRESS
+ COLUMN/ROW START ADDRESS

23761 11 83 40      ld de,16515

LD B,No of columns

23764 06 07         ld b,7


L6
23766 D5            push de
23767 C5            push bc
23768 D5            push de
23769 E1            pop hl
23770 06 08         ld b,8
L1
23772 7E            ld a,(hl)
23773 F5            push af
23774 24            inc h
23775 10 FB         djnz L1

LD B,No of rows-1!

23777 06 0D         ld b,13
L4
23779 C5            push bc
23780 21 20 00      ld hl,32
23783 19            add hl,de

CHECK SCREEN ZONE CHANGE


23784 CB 44         bit 0,h
23786 28 04         jr z,L2
23788 21 20 07      ld hl,1824
23791 19            add hl,de
L2
23792 E5            push hl
23793 06 08         ld b,8
L3
23795 7E            ld a,(hl)
23796 12            ld (de),a
23797 14            inc d
23798 24            inc h
23799 10 FA         djnz L3
23801 D1            pop de
23802 C1            pop bc
23803 10 E6         djnz L4
23805 06 08         ld b,8
L5
23807 25            dec h
23808 F1            pop af


23809 77            ld (hl),a
23810 10 FB         djnz L5
23812 C1            pop bc
23813 D1            pop de
23814 D1            pop de
23815 13            inc de
23816 10 CC         djnz L6
23818 C9            ret
```

Program 6.19C

To roll the whole screen DE should contain 16384, the B register (before L6) should contain 32 and the B register (before L4) should contain 23. This program is easily adapted to produce UP/DOWN SCROLL and DOWN ROLL routines.

Pixel movement

This type of movement for foreground characters is not really suitable for games programs as it does tend to be rather slow. The movement is reduced by a factor of eight and if you are checking for, say, a character hitting an obstacle then each bit of the character shape must be checked using the machine code equivalent of POINT

x,y to see whether its new position is clear before replotting. So if a character is 16 × 16 pixels in size then even if the outside pixel positions only are checked this would mean perhaps 100 calls to the POINT routine before moving the character. This all takes time and that means that speed of movement is drastically reduced. Background movement, however, is possible one pixel at a time as long as the attributes remain fixed (these cannot be moved one pixel).

Demonstration program 'PIXEL DEMO' is available on tape and is our first arcade games program. This demonstrates the slowness of pixel movement and also the fact that there is a great deal of flicker due to the background movement. The balloon must be removed from the screen during background movement and a POINT check made before replotting it. This time delay is noticeable but has been kept as short as possible by the choice of balloon in which only the outline is necessary, thus reducing the number of POINT checks and PLOT calls to a minimum. The principles are the same as in character square movement in that the x,y PLOT positions are stored as data, a duplicate set of data updated and checked, and the balloon erased using OVER 1 and replotted using the duplicate data. Note that the balloon is able to move off the left and right sides of the screen in a wrap-around way. In fact this is necessary to escape the arrows on the bottom line.

For those of you with colour sets, the program is in black and white mainly because if more than two colours were used the balloon would change colour as it moved from one attribute square to another and perhaps become indistinct but also because it looks equally good on a black and white set.

The program demonstrates the principles behind left and right screen roll in that each character byte is rotated left RLA or right RRA and, if a bit is transferred into CARRY, it is picked up by the adjacent character byte. This will be discussed more in Chapter 9.

To demonstrate pixel down roll the following program (Program 6.20) will plot a sine wave and draw a line on the top of the screen then down roll it until we end up with a very smooth moving black wavy 'road'. This could be used in a motor-racing type of program. It also demonstrates the method of putting non-integer steps into a loop (see Chapter 7).

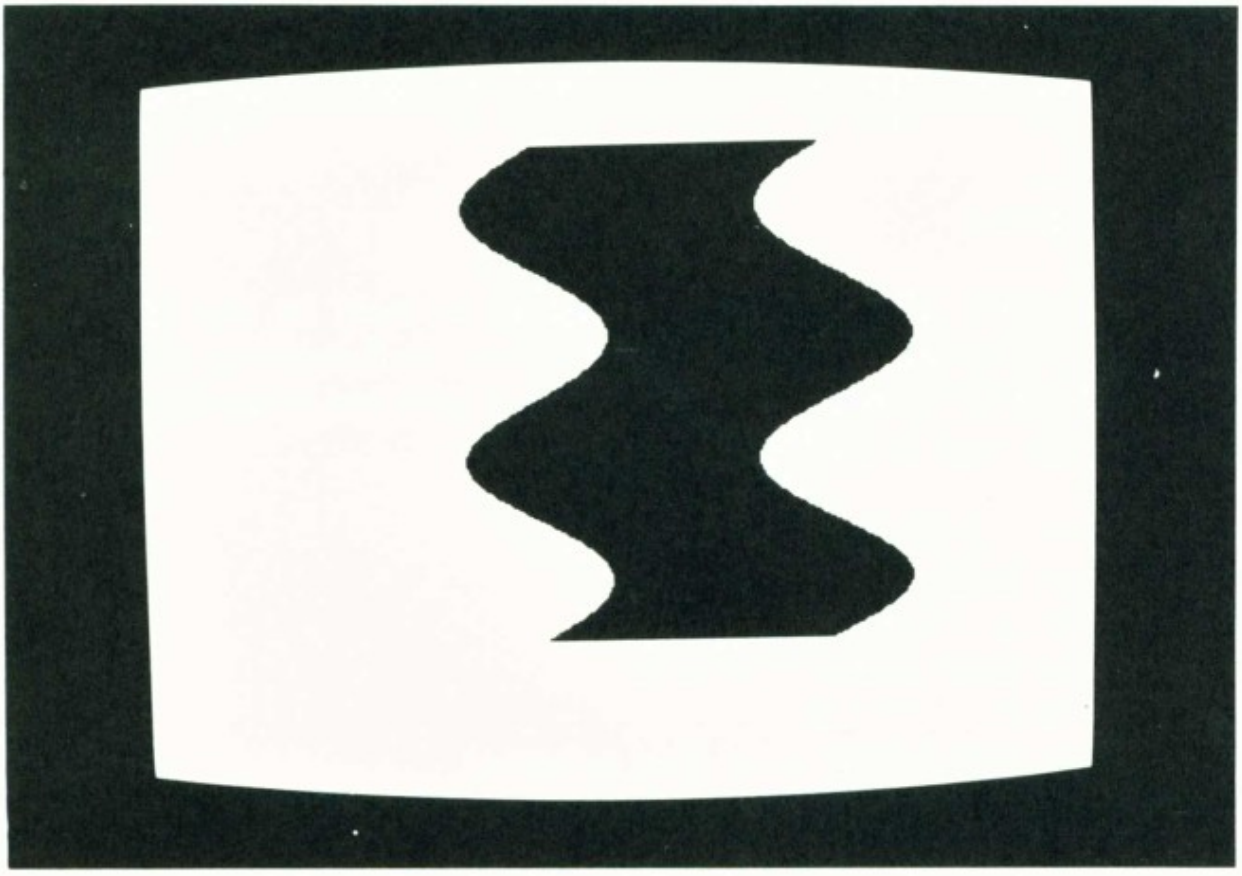
```
10 FOR a=0 TO 4*PI STEP PI/44
PLOT 100+SIN a*25,175: DRAW
100,0
30 REM CALL ONE PIXEL DOWN ROL
L
40 NEXT a
```

```
org 23760

SET a=0 ( on calculator )

23760 EF            rst 40
defb 160 56
```

```
STORE value a in DATA

L1
23763 11 35 5D     ld de,DATA
23766 01 05 00     ld bc,5
23769 ED B0        ldir

STACK 4*PI ( on calc )
23771 EF           rst 40
defb 163 56
23774 34           inc (hl)
23775 34           inc (hl)
23776 34           inc (hl)

SUB a-4*PI

23777 EF           rst 40
defb 3 56

CHECK 1st MANTISSA BYTE
FOR -ve ANSWER

23780 23           inc hl
23781 7E           ld a,(hl)
23782 CB 7F        bit 7,a
23784 20 04        jr nz,L2

CLEAR CALCULATOR if -ve

23786 CD F1 2B     call 11249

RETURN TO BASIC

23789 C9           ret

CLEAR CALCULATOR

L2
23790 CD F1 2B     call 11249
23793 CD 3A 5D     call ROLL

STACK DATA a

23796 CD 24 5D     call STACK

100+SIN a*25=x

23799 EF           rst 40
sine
defb 31
stack 25
defb 52 53 72
mult
defb 4
stack 100

defb 52 55 72
add
defb 15
stack 175 (=y)
defb 52 56 47 56

CALL PLOT x,y

23813 CD DC 22     call 8924

SAVE H'L'

23816 D9           exx
23817 E5           push hl
23818 D9           exx

LD B,0  LD C,100

23819 01 64 00     ld bc,100

LD DE, +ve +ve

23822 11 01 01     ld de,257

CALL DRAW

23825 CD BA 24     call 9402

RESTORE H'L'

23828 D9           exx
23829 E1           pop hl
23830 D9           exx

STACK DATA a

23831 CD 24 5D     call STACK

a+PI/44
23834 EF           rst 40
stack PI/2
defb 163

stack 22
defb 52 53 48
divide
defb 5
add
defb 15
end calc routine
defb 56
23842 18 AF        jr L1

STACK a SUB

STACK
23844 21 35 5D     ld hl,DATA
23847 ED 5B 65 5C  ld de,(23653)
23851 01 05 00     ld bc,5
23854 ED B0        ldir
23856 ED 53 65 5C  ld (23653),de
23860 C9           ret

DATA a STORE

DATA
defb 0 0 0 0 0

DOWN ROLL

ROLL
23866 06 20        ld b,32
23868 21 A0 57     ld hl,22432
```

```
L3
23871 7E          ld a,(hl)
23872 F5          push af
23873 23          inc hl
23874 10 FB       djnz L3
23876 21 BF 56    ld hl,22207
23879 11 BF 57    ld de,22463
23882 06 06       ld b,6
23884 CD 86 5D    call DOWN
23887 21 E0 4F    ld hl,20448
23890 11 00 50    ld de,20480
23893 01 20 00    ld bc,32

23896 ED B0       ldir
23898 21 FF 4E    ld hl,20223
23901 11 FF 4F    ld de,20479
23904 06 08       ld b,8
23906 CD 86 5D    call DOWN
23909 21 E0 47    ld hl,18400
23912 11 00 48    ld de,18432
23915 01 20 00    ld bc,32
23918 ED B0       ldir
23920 21 FF 46    ld hl,18175
23923 11 FF 47    ld de,18431
23926 06 08       ld b,8
23928 CD 86 5D    call DOWN
23931 06 20       ld b,32
23933 21 1F 40    ld hl,16415
L4
23936 F1          pop af
23937 77          ld (hl),a
23938 2B          dec hl
23939 10 FB       djnz L4
23941 C9          ret

DOWN
23942 C5          push bc
23943 06 07       ld b,7
L5
23945 C5          push bc
23946 E5          push hl
23947 E5          push hl
23948 01 20 00    ld bc,32
23951 ED B8       lddr
23953 D1          pop de
23954 E1          pop hl
23955 25          dec h
23956 C1          pop bc
23957 10 F2       djnz L5
23959 7C          ld a,h
23960 C6 08       add a,8
23962 67          ld h,a
23963 7D          ld a,l
23964 D6 20       sub 32
23966 6F          ld l,a
23967 E5          push hl

23968 E5          push hl
23969 01 20 00    ld bc,32
23972 ED B8       lddr
23974 E1          pop hl
23975 D1          pop de
23976 25          dec h
23977 C1          pop bc
23978 10 DA       djnz DOWN
23980 C9          ret
```

Program 6.20



The PIXEL DOWN ROLL routine at the end of Program 6.20 has again been written so that it should be easy for you to see the procedure necessary. This can be rewritten on the lines of Program 6.19C to pixel down roll a window, at the same time making it 'position independent' *and* using less memory. In its present form it takes 115 bytes (+ 32 bytes to store the bottom line) but rewritten as Program 6.20A takes just 44 bytes (+ 1 to store the bottom column byte).

```
org 23760
CHAPTER 6
PROGRAM 20A

DOWN ROLL WINDOW

EXAMPLE

COLUMNS 4 TO 10
LINES 4 TO 39

REM LINE 1/COLUMN 1=TOP LH.

23760 11 B3 46     ld de,18051

LD B,Columns

23763 06 07        ld b,7
L2
23765 C5           push bc

23766 D5           push de
23767 1A           ld a,(de)
23768 F5           push af
23769 D5           push de
23770 E1           pop hl
23771 25           dec h

LD B,Lines-1 !
23772 06 23        ld b,35
L1
23774 E5           push hl
23775 7E           ld a,(hl)
23776 12           ld (de),a
23777 D1           pop de
23778 7C           ld a,h
23779 25           dec h
23780 E6 07        and 7
23782 20 0A        jr nz,L3
23784 7D           ld a,l
23785 D6 20        sub 32

23787 6F           ld l,a
23788 38 04        jr c,L3
23790 7C           ld a,h
23791 C6 08        add a,8
23793 67           ld h,a
L3
23794 10 EA        djnz L1
23796 F1           pop af
23797 12           ld (de),a
23798 D1           pop de
23799 C1           pop bc
23800 13           inc de
23801 10 DA        djnz L2
23803 C9           ret
```

Program 6.20A

The number of columns to be rolled is held in the B register (before L2) and the number of lines − 1 in the B register (before L1). The DE register is loaded with the screen address of the first column bottom byte and is calculated using:

LET A = LINE (0 is first line)
LET B = INT (A/64)
LET C = A − (b * 64)
LET D = INT (C/8)
LET E = C − (D * 8)
LET F = COLUMN (0 is first column)
ADDRESS = 16384 + (1824 * B) + (256 * E) + (32 * (D − 1)) + F
EXAMPLE LINE 38 : COLUMN 3

A = 38 : B = 0 : C = 38 : D = 3 : E = 6 : F = 3
ADDRESS = 16384 + (1824 * 0) + (256 * 6) + (32 * 4) + 3 = 18051

As this formula is rather lengthy you could write a machine code program to do the calculation for you. Start with the HL register pair holding the LINE/COLUMN number and end with this converted to the screen address in DE so that you may go straight into the ROLL routine (or alternatively have a table showing the individual addresses of the lines/columns for the screen memory map.

Why not try to write such a routine? It could be useful in many programs, for example, to POKE characters directly onto the screen. If you get stuck, then Program 6.20B gives one method and takes just 29 bytes (this would be 28 bytes if LINE/COLUMN were placed in HL using LD HL, 034Fh). I have attached the program to Program 6.20A.

Study this program until you are confident that you know how it works as it will give you a better understanding of the display file.

```
org 23760
CHAPTER 6
PROGRAM 20B

DOWN ROLL WINDOW

EXAMPLE

COLUMNS 3 TO 9
LINES 56 TO 79

REM LINE 0/COLUMN 0=TOP LH.

LD H,Line

23760 26 4F        ld h,79

LD L,Column

23762 2E 03        ld l,3

23764 11 00 40     ld de,16384
23767 7C           ld a,h
23768 E6 07        and 7
23770 B2           or d
23771 57           ld d,a
23772 7C           ld a,h
23773 E6 C0        and 192
23775 1F           rra
23776 1F           rra
23777 1F           rra
23778 B2           add a,d
23779 57           ld d,a
23780 7C           ld a,h
23781 E6 38        and 56
23783 17           rla
23784 17           rla
23785 5F           ld e,a
23786 7D           ld a,l
23787 83           add a,e
23788 5F           ld e,a

LD B,Columns

23789 06 07        ld b,7
L2
23791 C5           push bc
23792 D5           push de
23793 1A           ld a,(de)
23794 F5           push af
23795 D5           push de
23796 E1           pop hl
23797 25           dec h

LD B,Lines-1 !

23798 06 17        ld b,23
L1
23800 E5           push hl
23801 7E           ld a,(hl)
23802 12           ld (de),a
23803 D1           pop de
23804 7C           ld a,h

23805 25           dec h
23806 E6 07        and 7
23808 20 0A        jr nz,L3
23810 7D           ld a,l
23811 D6 20        sub 32
23813 6F           ld l,a
23814 38 04        jr c,L3
23816 7C           ld a,h
```

```
23817 C6 08        add a,8
23819 67           ld h,a
L3
23820 10 EA        djnz L1
23822 F1           pop af
23823 12           ld (de),a
23824 D1           pop de
23825 C1           pop bc
23826 13           inc de
23827 10 DA        djnz L2
23829 C9           ret
```

Program 6.20B

These two programs for pixel movement (Programs 6.20A and 6.20B) show methods of rolling the background left/right and down. I will leave it to you to produce programs to UP ROLL and SCROLL. It must be remembered that in machine code there is no correct method. Each person will have his or her own personal way of doing things, choosing registers, and deciding whether to push/pop, or store value etc. and as long as the program works to the individual's satisfaction then all is well. Many of the programs discussed so far may well be rewritten to save memory or to reduce running time but in doing so they may not be so easy to follow for someone beginning programming.

There is one more useful ROM routine that is not available from BASIC and that is SCROLL n lines with attributes, where n must be greater or equal to two (but not greater than 24 of course).

Program 6.21 shows the routine being used to clear lines 16 to 24 inclusive (nine lines) by calling the routine nine times. Note that the number of lines to be scrolled are counted from line 24. This routine could be used instead of our user-written one in the 'MOVEDEMO' program. The B register holds the number of lines to be scrolled −1 and then a call to 3584 is made. The bottom line is overprinted with spaces using colours from ATTR P.

```
org 23760
23760 06 09        ld b,9
L1
23762 C5           push bc
23763 06 08        ld b,8
23765 CD 00 0E     call 3584
23768 C1           pop bc
23769 10 F7        djnz L1
23771 C9           ret
```

Program 6.21

Finally, here is a routine to roll a screen left (or right) by half a character at a time. This program, although short, is rather more difficult to understand and makes use of the rotate left decimal (or rotate right decimal) instruction. This instruction involves the nibble-handling of the A register and the contents of the address in

the HL register pair. RLD transfers bits 0 to 3, (HL) into bits 7 to 4, (HL); bits 7 to 4, (HL) into bits 0 to 3, A; and bits 0 to 3, A into bits 0 to 3, (HL). Incidentally it affects none of the 'flags'. You can see from Program 6.22 that this instruction is used on each screen line using the A register to store the right-hand nibble and to place it into the next character left-hand nibble. The first character left-hand nibble is blanked out because the A register holds 0 at the start of each line. At the end of each line the A register holds the left-hand nibble which will be shifted off the screen. This is used to add to the line start byte to give a wrap-around effect. If you required a continually changing background you could hold the replacement right-hand nibble in data form to be added to the right-hand byte instead of using the nibble shifted off the screen as above. I will leave the RIGHT ROLL routine for you to write (one tip – start at the beginning of the display file).

```
org 23760
CHAPTER 6
PROGRAM 22

HALF CHARACTER SQUARE
LEFT ROLL ROUTINE

23760 F3          di

Start at end of display

23761 21 FF 57    ld hl,22527

No. of screen lines

23764 06 C4       ld b,196
L1
23766 C5          push bc

Reset a=0


23767 AF          xor a

No. of bytes/line

23768 06 20       ld b,32

Store line start

23770 E5          push hl

Rotate left a,(hl)
nibble instruction

L2
23771 ED 6F       rld
23773 2B          dec hl
23774 10 FB       djnz L2

Get line start in de


23776 D1          pop de

Store present scr. pos.

23777 EB          ex de,hl

Add LH nibble to
RH byte

23778 86          add a,(hl)
23779 77          ld (hl),a

Restore scr. pos. in hl

23780 EB          ex de,hl
23781 C1          pop bc
23782 10 EE       djnz L1
23784 FB          ei
23785 C9          ret
```

Program 6.22

7 MUSIC AND SOUND EFFECTS

In this chapter we will be looking at ways to improve your animated graphics with interesting sounds and 'music'. But firstly we must take a look at the Spectrum way of storing numbers in floating point form and also how to convert a floating point number to its compressed form. If your maths are a little rusty then do not worry too much about the theory as the Spectrum can help. Put simply, any number whether decimal, integer, positive, or negative can be expressed in a five-byte form using a set procedure to define each byte. The first byte is called the *exponent* and the remaining four bytes are called the *mantissa*.

The conversion of a 'normal' number to its five-byte form involves four stages as follows:

1. Express the number in its *binary* form.

   For example 11.375 would become 1011.011
   Remember that 0.1 binary = $\frac{1}{2}$
   0.01 binary = $\frac{1}{4}$
   etc.
2. Find the *exponent*.
   Move the decimal point either left or right until it is to the left of the first 1 in the binary number and count the number of moves taken.
   The EXPONENT will be 128 + the number of moves taken.
   If the moves are to the left then the 'moves' are positive.
   If the moves are to the right then the 'moves' are negative.
   In our example the exponent = 128 + 4 = 132
   and we are left with .1011011
3. Alter the bit to the right of the decimal point to indicate the sign of the original number.
   If the number was positive then the bit is reset.
   If the number was negative then the bit is left set.
   In our example the number was positive and becomes .0011011
4. Find the *mantissa*.
   Discard the decimal point and divide the remaining binary number into four bytes, adding zero as necessary to make up to 32 bits.

00110110 00000000 00000000 00000000

and then convert each byte back to its decimal number.

And so it can be seen that in our example

11.375 = 132 54 0 0 0

If by now you are thoroughly confused then, as I have said, the Spectrum can help. The Spectrum has a useful method (useful to us, that is) of storing simple variables in that they are stored immediately after the variables' code in their five-byte floating point form. So all we really need to do is to write a short program to ENTER a number and then PEEK at the variable store to find the five-byte form.

```
  5 GO TO 5000
 10 REM    PROGRAM TO PRINT
    FLOATING POINT FORM OF ANY
              NUMBER
 20 PRINT AT 3,0;"THE FOLLOWING
SHORT PROGRAM WILLPRINT THE FLOAT
ING POINT FORM OFANY NUMBER, DECI
MAL, INTEGER ANDNEGATIVE NUMBERS.
              INTEGER NUMBERS HA
VE THE DECIMAL0.00000000001  ADDE
D  TO CONVERTTO A FLOATING  POINT
 NUMBER  BUTNOT AFFECT ITS VALUE.
          '
 25 PRINT '''"COMPRESSED FORM NUM
BERS ARE ALSOGIVEN FOR  USE  WITH
  CALCULATORLITERAL 34H (52d).
          '
 40 RETURN
100 INPUT "NUMBER:";TAB 9;n
200 LET n$="NUMBER:"
300 LET b$="FLOATING POINT  :"
400 LET c$="COMPRESSED FORM:"
500 LET d$="□"
1003 IF N<>0 THEN  GO TO 1010
1005 PRINT n$;TAB 9;d$; PAPER 6;0
b$;TAB 9;d$;"0  ";d$;"0  ";d$;"0
  ";d$;"0  ";d$;"0"
1006 PRINT c$;TAB 9;d$;"0  ";d$;"
176";d$;"0"
1007 GO TO 100
1010 LET N=N+.00000000001
1020 PRINT n$;TAB 9;d$; PAPER 6;N
1025 PRINT b$;
1030 LET X=PEEK 23627+256*PEEK 23
628
1040 FOR A=1 TO 5
1050 PRINT TAB 5+4*a;d$;PEEK (X+A
);
1060 NEXT A
1065 PRINT '
1070 DIM a(5)
1075 LET q=0
1076 PRINT c$;
1080 FOR b=5 TO 1 STEP -1
1085 LET a(b)=PEEK ((PEEK 23627+2
56*PEEK 23628)+b)
1086 IF b=2 THEN  GO TO 1100
1090 IF q=0 AND a(b)=0 THEN  NEXT
 b
```

```
1100 LET q=q+1
1110 NEXT b
1120 LET q=q-2
1125 LET x=(a(1)-80)
1126 IF x>=64 THEN  GO TO 2000
1130 LET e=x+(q*64)
1140 PRINT TAB 9;d$;e;
1150 FOR b=1 TO q+1
1160 PRINT TAB 9+b*4;d$;a(1+b);
1170 NEXT b
1180 PRINT
1190 GO TO 100
2000 PRINT TAB 9;d$;q*64;TAB 13;d
$;a(1)-80;
2010 FOR b=1 TO q+1
2020 PRINT TAB 13+b*4;d$;a(1+b);
2030 NEXT b
2040 PRINT : GO TO 100
5000 DATA 24,79,5,2,"STOP THE TAP
E"
5100 DATA 15,167,7,4,"NUMBERS"
5200 DATA 15,130,2,4,"_______"
5250 DATA 24,15,1,2,"PRESS ANY KE
Y"
5500 DATA 31,170,1,2,"INSTRUCTION
S"
6000 BORDER 4: PAPER 6: INK 0: CL
S
6010 LET n=0
6050 RESTORE 5000
6100 FOR a=1 TO 4
6200 INK a: GO SUB 8000
6300 PAUSE 50: NEXT a
6400 PAUSE 0: CLS
6420 INK 2: GO SUB 8000
6450 INK 0: PAPER 7: GO SUB 10
7000 RESTORE 5250: INK 2: GO SUB
8000
7005 IF INKEY$<>"" THEN  GO TO 70
05
7006 IF INKEY$="" THEN  GO TO 700
6
7010 CLS : GO TO 100
8000 READ x,y,h,w,a$
8010 LET c=USR 32393
8020 RETURN
9998 CLEAR 32334: LOAD "udgs"CODE
 USR "a",168: LOAD ""CODE : GO TO
 5000
9999 SAVE "NUMBERS" LINE 9998: SA
VE "udgs"CODE USR "a",168: SAVE "
LARGE"CODE 32335,265
(336@ S.A.Nicholls
```

Program 'Numbers'

This program is available on tape with colours held as part of strings n$ b$ c$ and d$.

When RUN, the program will print the five-byte floating point *and* compressed form of any number. The compressed form will be discussed later. Note that 0 is treated as a special case in which all bytes are 0, and also that 0.5 and ½ give different results.

By now you are probably wondering what this has to do with music and sounds. The answer is that the BASIC BEEP command makes use of the calculator stack and any number stored on the stack must be in its five-byte form.

We can now look at the method of converting the BASIC command BEEP duration, pitch into machine code. This entails stacking the value of duration and then pitch in their five-byte forms on top of the calculator stack and then calling the BEEP routine from address 03F8h (1016d).

If we take, for example, BEEP .1,11, then using the NUMBERS program we can convert .1 and 11 to their five-byte form:

.1 = 125 76 204 204 204
11 = 132 48 0 0 0

We must now find a way of stacking these ten bytes consecutively on the calculator stack. One method would be to find the start address to which the DATA must be transferred by PEEKing at the system variable STACKEND and then to use an LDIR instruction as shown in Program 7.1.

```
org 23760
CHAPTER 7
PROGRAM 1

BEEP .1,11

FIND STACKEND

23760 ED 5B 65 5C ld de,(23653)
23764 21 E4 5C    ld hl,DATA
23767 01 0A 00    ld bc,10
23770 ED B0       ldir

UPDATE STACKEND
23772 ED 53 65 5C ld (23653),de

CALL BEEP

23776 CD F8 03    call 1016
23779 C9          ret
DATA
0.1 (5 byte form)
defb 125 76 204 204 204

11 (5 byte form)
defb 132 48 0 0 0
```

Program 7.1

The RESET is needed to reload STACKEND with the new address of the top of the stack. Remember that LDIR ends with HL and DE holding the *address* of the last byte transferred +1. The BEEP routine when called from address 03F8h takes the top two values from the stack and manipulates them to give the required duration and pitch. The stack is thus reset to give a safe return to BASIC.

Another method of stacking integer numbers is to use LD A,n and CALL STACK A subroutine 2D28h (11560d) for numbers 0 to 255, or LD BC,nn and CALL STACK BC subroutine 2D2Bh (11563d) for numbers 0 to 65535. Program 7.1 could then be written as Program 7.2.

```
org 23760
CHAPTER 7
PROGRAM 2


BEEP .1,11


FIND STACKEND

23760 ED 5B 65 5C ld de,(23653)
23764 21 E9 5C    ld hl,DATA
23767 01 05 00    ld bc,5
23770 ED B0       ldir

UPDATE STACKEND
23772 ED 53 65 5C ld (23653),de
23776 3E 0B       ld a,11


STACK value a

23778 CD 28 2D    call 11560

CALL BEEP

23781 CD F8 03    call 1016
23784 C9          ret
DATA
0.1 (5 byte form)
defb 125 76 204 204 204
```

Program 7.2

Lastly, for those who wish to take floating point numbers one stage further, we can convert them to their *compressed form* and use the calculator literal 34h (52d) to stack data in this compressed form.

The stages for converting five-byte floating numbers are as follows:

1. Starting from the fifth byte, remove all zero numbers until a non-zero number is reached *or* until the second byte is reached.
2. The quotient is then the number of remaining bytes *less 1*.
3. Subtract 50h (80d) from the exponent and, if the remainder is greater than or equal to 40h (64d) then go to instruction 6.
4. Change the exponent to (exponent − 80d) + (quotient * 64d).
5. Go to instruction 7.
6. The exponent becomes two bytes. The first byte is the quotient *64d; the second byte is the exponent − 80d.
7. Place the remaining bytes after the modified exponent byte(s).

To convert a compressed number back to its five-byte form then the following stages are taken:

1. Divide the first byte by 64d.
2. If there is a remainder then the exponent will be 80d + remainder.
3. If there is no remainder then the exponent will be 80d + the second byte.
4. The quotient is used to find how many extra bytes follow the exponent. The number of extra bytes is the quotient + 1.

As an example 11 = 52 48 in compressed form.
52 divided by 64 = 0 remainder 52
quotient = 0
further bytes = 1
As there was a remainder exponent = 52 + 80 = 132
1 further byte specified = 48
Make up to 5 bytes with 0 0 0
So 52 48 = 132 48 0 0 0

Again if all this is too much for you at present then the NUMBERS program will do all the converting for you. Using compressed form numbers BEEP .1,11 can be converted to machine code as shown in program 7.3.

```
org 23760
CHAPTER 7
PROGRAM 3

BEEP .1,11

USE CALCULATOR

23760 EF            rst 40

STACK 0.1 (COMP. FORM)

defb 52 237 76 204 204 204

STACK 11 (COMP. FORM)

defb 52 52 48

END CALC

defb 56

CALL BEEP

23771 CD F8 03      call 1016
23774 C9            ret
```

Program 7.3

In Program 7.3 RST 28h (40d) calls the CALCULATOR routine and defb 38h (56d) is the END CALC literal.

The FANFARE BEEP for the 'CROSS' program is a combination of all three methods, namely, holding numbers as DATA, using stack A and using literal 34h (52d) to stack compressed form numbers. In this program it is fortunate that the mantissa bytes of the compressed form of decimals .1 .8 and .05 are the same, so that the exponent byte only needed to be stored as DATA.

```
  1 REM CHAPTER 7
  2 REM PROGRAM 4
  REM FANFARE BEEP
 10 FOR a=1 TO 8
 20 READ b,c
 30 BEEP b,c
 50 NEXT a
 60 DATA .1,11,.1,11,.8,16,.05,
11,.05,16,.05,11,.05,16,1,20
```

```
org 23760
23760 06 07         ld b,7
23762 21 00 5D      ld hl,DATA
LOOP
23765 7E            ld a,(hl)
23766 32 DE 5C      ld (VALUE),a
23769 23            inc hl
23770 C5            push bc
23771 E5            push hl
23772 EF            rst 40
defb 52
VALUE
defb 0 76 204 204 204 56
23780 E1            pop hl
23781 7E            ld a,(hl)
23782 E5            push hl
23783 CD 28 2D      call 11560
23786 CD F8 03      call 1016
23789 E1            pop hl
23790 C1            pop bc
23791 23            inc hl
23792 10 E3         djnz LOOP
23794 3E 01         ld a,1
23796 CD 28 2D      call 11560
23799 3E 14         ld a,20
23801 CD 28 2D      call 11560
23804 CD F8 03      call 1016
23807 C9            ret
DATA
defb 237 11 237 11 240 16 236
defb 11 236 16 236 11 236 16
```

Program 7.4

So far I have shown you how to convert any BASIC BEEP command into machine code. This is fine for 'music' but will not produce anything like a decent sound effect. For this type of sound we will need to enter the BEEP routine at a different point, 03B5h (949d). After the values for duration and pitch have been removed from the stack they are manipulated and end up with 'pitch' in the HL register and 'duration' in the DE register. So a program could be written to give a falling tone by incrementing the value stored in HL and calling the BEEP routine repeatedly in a 'FOR/NEXT loop'. This can be achieved as shown in Program 7.5.

```
org 23760                          CALL BEEP
CHAPTER 7
PROGRAM 5                          23770 CD B5 03     call 949
                                   23773 C1           pop bc
SOUND 1                            23774 E1           pop hl
                                   23775 23           inc hl
23760 06 FF        ld b,255        23776 10 F3        djnz LOOP
23762 21 01 00     ld hl,1
LOOP
23765 11 01 00     ld de,1         23778 C9           ret
23768 E5           push hl
23769 C5           push bc
```

Program 7.5

You will notice when Program 7.5 is RUN that as the pitch gradually changes the duration also changes. This is because the duration is in fact a function of both values in HL and DE registers. To even out the duration we must decrease the value held in DE as the value in the HL register increases. So we arrive at Program 7.6.

```
org 23760                          23770 C5           push bc
CHAPTER 7                          23771 CD B5 03     call 949
PROGRAM 6                          23774 C1           pop bc
                                   23775 E1           pop hl
SOUND 2                            23776 D1           pop de
                                   23777 23           inc hl
23760 06 64        ld b,100        23778 1B           dec de
23762 21 01 00     ld hl,1         23779 10 F3        djnz LOOP
23765 11 65 00     ld de,101
LOOP
23768 D5           push de         23781 C9           ret
23769 E5           push hl
```

Program 7.6

We have one last method of producing sound from the Spectrum and that is by sending 'signals' directly to the speaker switching it high or low in the same way as the ROM routine does. There seems little point in using this method for musical notes as we would need to know the frequency of the high/low switching for each note and would in fact duplicate the ROM routine. However it does have a use in games programs for producing a 'white noise' type of sound for explosions etc.

The instruction to communicate with the speaker is OUT (254), A. This instruction controls not only the speaker but also the temporary border colour in the following way:

1. If bit 0,A is set then blue is on.
   If bit 0,A is reset then blue is off.
2. If bit 1,A is set then red is on.
   If bit 1,A is reset then red is off.
3. If bit 2,A is set then green is on.
   If bit 2,A is reset then green is off.
4. If bit 4,A is set then speaker is 'high'.
   If bit 4,A is reset then speaker is 'low'.

You can see from the above that if bit 4 were set and reset at regular intervals then a note would be produced dependent on that interval.

To produce true white noise we would need random interval switching but this would mean a lengthy routine to produce a random number and check bit 4,A each time causing a 'long' pause between switching. We must therefore find a quick method of producing 'random numbers'. This is not as hard as it sounds, for we are only interested in the state of bit 4,A and for our purposes the ROM bytes are random enough. With this in mind we can write a program to look at each ROM address in turn checking the state of bit 4 of the number held in that address and thus switch the speaker high or low accordingly.

```
org 23760
23760 21 00 00     ld hl,0
L1
23763 7E           ld a,(hl)
23764 00           nop
23765 D3 FE        out (254),a
23767 00           nop
23768 00           nop
23769 D3 FE        out (254),a
23771 00           nop
23772 00           nop
23773 D3 FE        out (254),a
23775 00           nop
23776 23           inc hl
23777 7C           ld a,h
23778 FE 3C        cp 60
23780 20 ED        jr nz,L1
23782 C9           ret
```

Program 7.7

There are several points to note in Program 7.7.

1. The three OUT (254), A instructions and NOPs give a set delay. You may like to remove or add more and hear the effect.
2. The length of sound is governed by the CP 60 instruction. If this were reduced to say CP 40 the length of sound would be similarly reduced. Anything above 60 runs into an area of ROM with not so random numbers. Try it and see what happens.
3. The border colour is also temporarily affected as bits 0 – 2 are also changed at random. To keep the border the same colour you would need to replace bits 0 – 2 with bits 3 – 5 of the value held in the systems variable BORDER.

If you want to experiment with producing music by this method then remember that the ROM interrupt routine is called 50 times

per second and will upset your frequency so you will need to disable it (DI) before your routine and enable it (EI) afterwards. This in fact is what the ROM routine does and explains why you cannot BREAK a BASIC program during execution of a BEEP command.

I leave the rest to your imagination and ingenuity in altering the values held in HL and DE registers to produce wonderful and weird effects, but to give you some idea of sounds possible using the above method the tape contains a Program SOUND which has five different sounds accessed by pressing keys 1 to 5. The flashing border does give an extra dimension to sounds 1 and 5 and is very simple to program.

One last point – do keep sound effects as short as possible since they do halt all moving graphics during their execution. The best place for sounds is in delay loops used to slow down the moving graphics.


```
  10 REM ? RETURN RUN GO SUB X P
RINT THEN G TO ?] LET PRINT THEN
 J TO ]]LET PRINT THEN W TO D]
LET PRINT THEN _ TO _] LET PRINT
 THEN g TO [] LET >? STEP £"? RE
TURN @ GO SUB X THEN G>=?<>
2 OR !d?
  25>INK 2:PAPER 7:BORDER 4:CLS
  30 LET x=16: LET y=100: LET w=2
: LET h=4: LET a$="STOP THE TAPE"
  40 PAPER 8: RANDOMIZE USR 32393
  50 PRINT #0;AT 0,3;"PRESS ANY K
EY TO START"
```

```
  60 PAUSE 0
  65 CLS
  70 LET x=8: LET y=175: LET w=5:
 LET h=15: LET a$="SOUND!"
  80 INK 2: RANDOMIZE USR 32393
  90 PRINT AT 19,2;"Press keys 1
to 5 for sounds"
 100 PRINT AT 21,3;"SPACE will re
turn to BASIC"
 110 RANDOMIZE USR 23760
 120 CLS
 130 LET x=24: LET y=100: LET h=5
: LET w=1: LET a$="To re RUN ente
r GOTO 65"
 140 RANDOMIZE USR 32393
 150 STOP
9998 CLEAR 32334: LOAD ""CODE : G
O TO 25
9999 SAVE "SOUNDS" LINE 9998: SAV
E "LARGE"CODE 32335,265: STOP
<336   @ S.A.Nicholls
```

```
org 23760
START
23760 01 FE F7     ld bc,63486
23763 ED 78        in a,(c)
23765 F5           push af
23766 CB 47        bit 0,a
23768 CC 07 5D     call z,BEEP1
23771 F1           pop af
23772 F5           push af
23773 CB 4F        bit 1,a
23775 CC 29 5D     call z,BEEP2
23778 F1           pop af
23779 F5           push af
23780 CB 57        bit 2,a
23782 CC 44 5D     call z,BEEP3
23785 F1           pop af
23786 F5           push af
23787 CB 5F        bit 3,a
23789 CC 5F 5D     call z,BEEP4
23792 F1           pop af

23793 F5           push af
23794 CB 67        bit 4,a
23796 CC 7B 5D     call z,BEEP5
23799 F1           pop af
23800 3E 07        ld a,7
23802 CD 9B 22     call 8859
23805 01 FE 7F     ld bc,32766
23808 ED 78        in a,(c)
23810 CB 47        bit 0,a
23812 C8           ret z
23813 18 C9        jr START
BEEP1
23815 06 32        ld b,50
L1
23817 C5           push bc
23818 21 64 00     ld hl,100
L2
23821 11 0A 00     ld de,10
23824 E5           push hl
23825 7D           ld a,l
23826 E6 07        and 7
```

```
23828 CD 9B 22     call 8859
23831 CD B5 03     call 949
23834 E1           pop hl
23835 11 0A 00     ld de,10
23838 AF           xor a
23839 ED 52        sbc hl,de
23841 7C           ld a,h
23842 B5           or l
23843 20 EB        jr nz,L2
23845 C1           pop bc
23846 10 E1        djnz L1
23848 C9           ret
BEEP2
23849 21 00 00     ld hl,0
L3
23852 7E           ld a,(hl)
23853 00           nop
23854 D3 FE        out (254),a
23856 00           nop
23857 00           nop
23858 D3 FE        out (254),a


23860 00           nop
23861 00           nop
23862 D3 FE        out (254),a
23864 00           nop
23865 00           nop
23866 D3 FE        out (254),a
23868 00           nop
23869 23           inc hl
23870 7C           ld a,h
23871 FE 3C        cp 60
23873 20 E9        jr nz,L3
23875 C9           ret
BEEP3
23876 06 05        ld b,5
L5
23878 C5           push bc
23879 21 32 00     ld hl,50
L4
23882 11 0A 00     ld de,10
23885 E5           push hl
23886 CD B5 03     call 949
23889 E1           pop hl
23890 11 32 00     ld de,50
23893 19           add hl,de
23894 7C           ld a,h
23895 FE 04        cp 4
23897 20 EF        jr nz,L4
23899 C1           pop bc
23900 10 E8        djnz L5
23902 C9           ret
BEEP4
23903 06 0A        ld b,10
L6
23905 C5           push bc
23906 21 00 04     ld hl,1024
L7
23909 11 01 00     ld de,1
23912 E5           push hl
23913 CD B5 03     call 949
23916 E1           pop hl
23917 AF           xor a
23918 11 10 00     ld de,16
```

```
23921 ED 52        sbc hl,de
23923 7C           ld a,h
23924 B5           or l
23925 20 EE        jr nz,L7
23927 C1           pop bc
23928 10 E7        djnz L6
23930 C9           ret
BEEP5
23931 21 01 00     ld hl,1
L8
23934 11 05 00     ld de,5
23937 E5           push hl
23938 CD B5 03     call 949
23941 E1           pop hl
23942 23           inc hl
23943 7C           ld a,h
23944 FE 02        cp 2
23946 20 F2        jr nz,L8
23948 06 FA        ld b,250
L9
23950 C5           push bc

23951 78           ld a,b
23952 E6 06        and 6
23954 CD 9B 22     call 8859
23957 21 90 01     ld hl,400
23960 11 01 00     ld de,1
23963 CD B5 03     call 949
23966 C1           pop bc
23967 10 ED        djnz L9
23969 C9           ret
```

Program 'Sound'

8 ATTRIBUTE, SCREEN$ AND POINT

As you may know if you have tried BASIC games programming, there will come a time when you will need to find the character in a particular screen position. This is useful for example if checking that a missile has hit its target or that you have landed on the moon. In BASIC there are three methods of doing this, namely:
ATTRIBUTE which checks the INK: PAPER: FLASH: BRIGHT state of a character square and returns a number from 0 to 255.
SCREEN$ which checks the character in a particular square (but only characters CODE 32 to 127; the rest returns an empty string).
POINT which checks the state of a screen pixel: 0 = unplotted 1 = plotted.
All three above methods are available in machine code by calls to the particular ROM routines.

ATTRIBUTE (line, column)

The machine code routine – call 9603 – requires the line number in the C register and the column number in the B register. The value of the ATTRIBUTE after the routine is called ends up as the top value on the calculator stack. The value of the ATTRIBUTE is made up in the following way:
Value = 128 * (FLASH number) + 64 * (BRIGHT number) + 8 *(PAPER colour) + INK colour
You can see from the above formula that the value has a range of 0 to 255, and so may easily be removed from the stack into the A register using the 'CALC VALUE TO A' routine – call 11733 – and then checked by a CP n instruction.

Program 8.1 shows the above method used to PRINT AT 0, 20; PAPER 1; INK 7; FLASH 1; CHR$ 144 (which has been redefined as a man). The program then checks each screen position, shown by a > sign, until it finds ATTR value 143 and then returns to BASIC.

```
org 23760
CHAPTER 8
PROGRAM 1

ATTRIBUTE CHECK

SET UP UDG
```

```
23760 ED 5B 7B 5C ld de,(23675)
23764 21 42 5D    ld hl,DATA3
23767 01 08 00    ld bc,8
23770 ED B0       ldir

CLEAR SCREEN
```

```
23772 3E 02       ld a,2
23774 CD 01 16    call 5633
23777 CD 6B 0D    call 3435
23780 3E 02       ld a,2
23782 CD 01 16    call 5633

PRINT UDG

23785 11 2E 5D    ld de,DATA1
23788 01 10 00    ld bc,16
23791 CD 3C 20    call 8252

SET OVER 1

23794 FD 36 57 03 ld (iy+87),3

RESET START AT 0,0

23798 AF          xor a
23799 32 40 5D    ld (COL),a

PRINT >

L1
23802 11 3E 5D    ld de,DATA2
23805 01 04 00    ld bc,4

23808 CD 3C 20    call 8252

DELAY

23811 21 FF FF    ld hl,65535
L2
23814 2B          dec hl
23815 7C          ld a,h
23816 B5          or l
23817 20 FB       jr nz,L2

REMOVE >

23819 11 3E 5D    ld de,DATA2
23822 01 04 00    ld bc,4
23825 CD 3C 20    call 8252

INC COLUMN

23828 3A 40 5D    ld a,(COL)
23831 3C          inc a
23832 32 40 5D    ld (COL),a

GET COLUMN/LINE IN BC

23835 ED 4B 3F 5D ld bc,(LINE)

CALL ATTR. &
GET VALUE IN A

23839 CD B3 25    call 9603
23842 CD D5 2D    call 11733

CHECK IF 143

23845 FE 8F       cp 143

MOVE TO NEXT POSN.

23847 20 D1       jr nz,L1

RESET OVER 0

23849 FD 36 57 00 ld (iy+87),0
23853 C9          ret

PRINT UDG DATA

DATA1
defb 22 0 20 17 1 16 7 18 1
defb 144 18 0 17 7 16 0

PRINT > DATA

DATA2
defb 22
LINE
defb 0
COL
defb 0 62

UDG DATA

DATA3
defb 24 153 126 153 24 36 36 102
```

Program 8.1

When run, Program 8.1 gives the appearance of a missile moving slowly towards a man and returns to BASIC when the man is hit. You could of course have a hit routine instead of the RETurn instruction (with sound effects). This method of checking screen positions for targets etc. is OK but a bit limiting in that all your targets must have the same ATTRIBUTE value.

SCREEN$ (line, column)

As with the ATTR routine the line number is held in the C register and the column number in the B register before call 9528 is made. The routine places the *parameters of the string* on top of the calculator stack in five-byte form. The use of the calculator stack to hold string parameters is a new idea as so far we have only used it for holding five-byte numbers. Suffice it to say that there are calculator literals for manipulating strings, but instead of putting the 'string' on the stack their 'parameters' are held in a five-byte form. To put the parameters of the string on to the stack, the BC register pair holds the length of the string and the DE register pair holds the start address of the string. For simple strings the A register holds value 0. A call to the routine – call 10929 – will place the parameters in the correct order on the stack. Similarly the routine – call 11249 – will take the last 'value' from the stack and place it into A,B,C,D, and E registers; again BC will hold the string length and DE the start address.

Program 8.2 shows the routines being used to print the character @ at SCREEN position 0, 20; and when run will end with two @s at 0, 20; and 0, 21;. Instead of the PRINT STRING – call 8252 – we could have used LD A,(DE) to check the actual character in position 0, 20; and then to take the necessary actions.

However there is one limitation in the BASIC SCREEN$ routine, and that is it will only find characters in the range CODE 32 – CODE 127; anything else will return an empty string. This in effect rules out using this method for finding UDGs and in BASIC this is a big handicap in games programs. In machine code this is no problem as there are 'quick' ways to fool the ROM and place the UDGs into the character set. The systems variable CHARS – 23606/7 usually holds the address of the start of the character set −256, that is, 15360 and is used by the SCREEN$ routine to find the character. We could set this variable to point to the start of the UDGs −256 before the SCREEN$ call is made (in effect making UDG 'A' into CODE 32, UDG 'B' into CODE 33, etc.) and then reset it to its normal value afterwards. In this way we can check through the UDGs to find the character we want.

```
org 23760
CHAPTER 8
PROGRAM 2

SCREEN$ (0,20)

CLEAR SCREEN

23760 3E 02        ld a,2
23762 CD 01 16     call 5633
23765 CD 6B 0D     call 3435
23768 3E 02        ld a,2
23770 CD 01 16     call 5633

PRINT AT 0,20 @

23773 3E 16        ld a,22
23775 D7           rst 16
```

```
23776 3E 00       ld a,0
23778 D7          rst 16
23779 3E 14       ld a,20
23781 D7          rst 16
23782 3E 40       ld a,64
23784 D7          rst 16

CALL SCREEN$

23785 06 14       ld b,20
23787 0E 00       ld c,0
23789 CD 38 25    call 9528

CALL 'VALUE TO A,B,C,D,E

23792 CD F1 2B    call 11249

CALL PRINT STRING

23795 CD 3C 20    call 8252
23798 C9          ret
```

Program 8.2

Program 8.3 is in effect the same as Program 8.1 but this time we are checking for CHR$ 144 before returning to BASIC.

```
org 23836
CHAPTER 8
PROGRAM 3

SCREEN$ FOR UDG's

23760 TO 23835
SAME AS PROG. 1

SET CHARS. TO UDG's - 256

23836 2A 7B 5C    ld hl,(23675)
23839 25          dec h
23840 22 36 5C    ld (23606),hl

CHECK SCREEN$

23843 CD 38 25    call 9528
23846 CD F1 2B    call 11249

CHECK FOR CHR$ 32
i.e. CHR$ 144 (UDG 'A')

23849 1A          ld a,(de)
23850 FE 20       cp 32

RESET CHARS. TO NORMAL

23852 21 00 3C    ld hl,15360
23855 22 36 5C    ld (23606),hl

REST OF PROGRAM
AS PROGRAM 1

23847 TO END OF DATA3
```

Program 8.3

You could of course copy the character set into RAM and keep CHARS permanently pointing to the start −256. In this way you can forget the UDGs and redefine any character you wish in the new set (leave the alphabet and numbers unchanged so that text will be unaltered). This method will allow about 50 redefinable characters if you limit yourself to using text in *upper case* only and a minimum of punctuation marks. The SCREEN$ routine will recognize these characters as they will appear in the new character set.

There is one very important point to note when using the calculator for string manipulation and that is that use is made of the workspace to hold the string and/or the result of the calculation. If this workspace is not cleared regularly then you may find that an out of memory report will suddenly appear in your program for no apparent reason or, worse still, the workspace will run into your machine code routine and your program will crash. In practice it is advisable to clear the workspace each time the SCREEN$ routine is called. The ROM routine – call 5823 – will clear the workspace for you (and also clear the calculator stack). So Program 8.3 should

have call 5823 after LD A,(DE) but remember to save the value in A before the call.

POINT

The BASIC POINT x,y, returns a value of 1 if the pixel x,y is set (that is PLOTted) or 0 if reset (PLOT OVER). The machine code routine – call 8910 – requires the x coordinate to be held in the C register and the y coordinate in the B register before the call is made. As with the previous routines the result ends up as the last value on the calculator stack, and, as this value is either 0 or 1, we can unstack it into the A register to compare it to a required value. Program 8.4 shows how this is used to check screen position 0,175, that is, the top left-hand corner. It first prints a black square at 0,0; then returns to BASIC as POINT 0,175 = 1. Use is made of this routine in the 'balloon' program to POINT each of the balloon plot positions before replotting the balloon. If the routine returns a value of 1 then the HIT routine is called.

```
org 23760
CHAPTER 8
PROGRAM 4
POINT x,y

23760 3E 02       ld a,2
23762 CD 01 16    call 5633
23765 CD 6B 0D    call 3435
23768 3E 02       ld a,2
23770 CD 01 16    call 5633
23773 3E 8F       ld a,143
23775 D7          rst 16
23776 0E 00       ld c,0
23778 06 AF       ld b,175
23780 CD CE 22    call 8910
23783 CD D5 2D    call 11733
23786 FE 01       cp 1
23788 C8          ret z
```

Program 8.4

9 THE PRINTER

Not many programs make use of the printer but it can be handy sometimes to have a copy of the screen (to prove to friends that you have achieved the highest scores etc.). So with this in mind we will look at the three BASIC commands COPY, LPRINT, and LLIST and their machine code equivalents.

COPY

Normally the COPY routine will pass the contents of the first 22 lines of the screen directly to the printer. In machine code however we can improve on this and specify how many screen lines we want, and the start line, so for instance we could copy just three lines starting from line seven.

Program 9.1 demonstrates the method used to copy all 24 lines since some games programs have the score held in the bottom two screen lines and will not be printed with a direct COPY command. You can see that before call 3762 the HL register pair holds the line start address, in our example – this is line 1, and the B register holds the number of lines required × 8 (24 × 8 = 192).

```
org 23760                    EXAMPLE 24 LINES
CHAPTER 9
PROGRAM 1                    23760 21 00 40     ld hl,16384
                             23763 06 C0        ld b,192
COPY n SCREEN LINES          23765 F3           di
                             23766 CD B2 0E     call 3762
HL=SCREEN LINE START         23769 C9           ret
 B=LINES x 8
```

Program 9.1

LPRINT

This instruction can be considered the same as PRINT with the only difference being that control characters will not work, of course, and that a different channel requires to be opened before the RST 16 instruction to send the output to the printer instead of to the screen. So to LPRINT "A", for example, first OPEN CHANNEL 3, LD A, CODE "A" then use RST 16 to LPRINT it.

Program 9.2 shows the above method used to LPRINT a string of

characters. Should you wish to tabulate your LPRINTing, the TAB number should be POKEd into systems variable PRCC 23680 before the RST 16 instruction.

```
org 23760
CHAPTER 9
PROGRAM 2

LPRINT

OPEN CHANNEL 3

23760 3E 03       ld a,3
23762 CD 01 16    call 5633
23765 11 DF 5C    ld de,DATA
23768 01 11 00    ld bc,17

LPRINT STRING

23771 CD 3C 20    call 8252
23774 C9          ret
DATA
defs This is program 2
```

Program 9.2

LLIST

Although I cannot think of any application in which a listing would be required in the middle of a program, I have included this because it is one of the printer commands and very easy to program. All that is needed is call 6133. Program 9.3 demonstrates this by assembling the BASIC program and then LLISTing it.

```
org 23760
CHAPTER 9
PROGRAM 3

LLIST

23760 CD F5 17    call 6133
23763 C9          ret

  10 REM STEP PRINT
     20 REM go
  30>REM org 23760
  40 REM !CHAPTER 9;!PROGRAM 3;!
  50 REM ! LLIST ;!
  60 REM call 6133
  70 REM ret
9000 REM finish
9010 RANDOMIZE USR 58000
9020 COPY
9030 LPRINT
9040 RANDOMIZE USR 23760
```

Program 9.3

10 PROGRAM CONVERSION

If you have managed to reach this Chapter with a clear understanding of all the previous ones then congratulations – this one should be no problem. If you are not too sure about any of the previous routines then I would advise you to reread the particular Chapter before proceeding.

In this Chapter I hope to demonstrate the method of producing a games program completely in machine code using a 'working' BASIC program as a guide.

No doubt you have your own method of producing a BASIC program. Perhaps you have an idea and develop it actually on the Spectrum adding routines as you think of them and ending with a completely unstructured, but working, program that only you can follow. This method is satisfactory but you may find that, if you try to amend the program a few weeks later, not even *you* can follow it. I find that the best method is to produce a flow diagram from the basic idea and then to add routines as necessary ending with a complete structured flow diagram from which the BASIC program can be written and perhaps refined with colour, sound, and UDGs. More importantly, however, this gives a program that is easy to convert to machine code.

The program we shall convert in this Chapter is called 'CROSS' and started out as a program to control a man past obstacles to a safe home. From this idea the flow diagram was produced. This involves the main routine to set up the variables and print instructions and the display and then a loop to check on the movement of the man and his 'new' screen position. There are two points of exit from this main loop:

1. If the man is hit we enter the HIT routine and check lives; if there are no lives left the game ends, otherwise we re-enter the main loop.
2. The HOME routine which also checks the number of homes filled and adds spiders or increases the speed before returning to the main loop.

From this flow diagram the BASIC version of 'CROSS' was produced. If you compare the actual program with the flow diagram you should be able to spot the various routines.

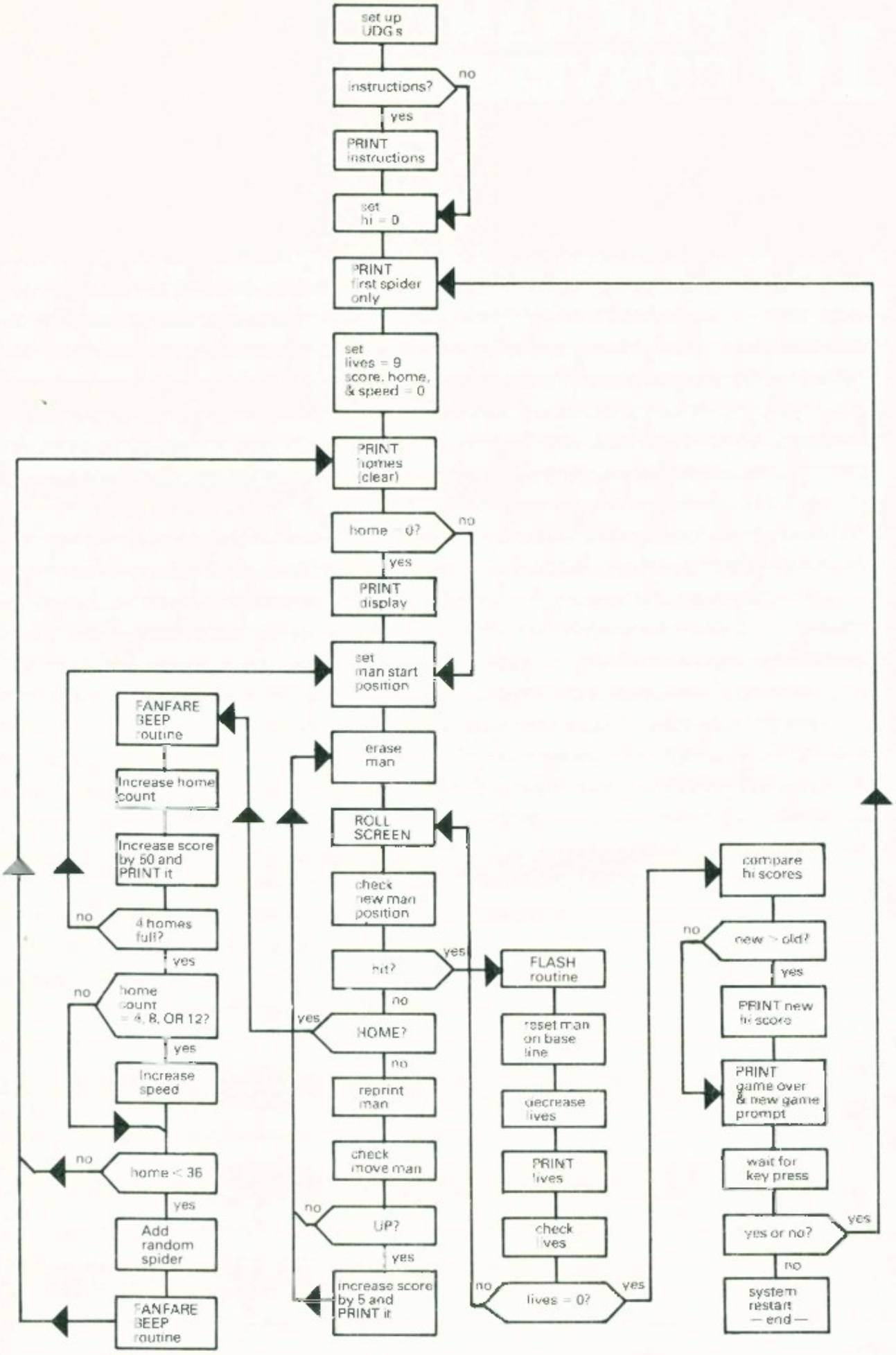


Figure 10.1 Flow diagram for 'Cross' program

The program, although very simple, is greatly improved by making full use of the UDGs, colours, and sound. It does cheat very slightly by using a machine code routine to roll screen lines left or right one pixel at a time, but a BASIC version of this would have been incredibly slow.

The machine code is POKEd into the correct memory addresses by the BASIC program. This could have been carried out using a LOAD 'machine' code XX, n instruction to load the code directly from tape.

Before continuing with this Chapter make sure that you completely understand the program workings as we will now work through it line by line converting it to machine code.

```
  20 CLEAR 32243: GO TO 40
  25 BEEP .01,b-a
  30 PRINT OVER 1; PAPER 6; INK
8;AT a,y2;"*": RETURN
  40 PRINT AT 11,5;"Please wait
a moment"
  50 FOR a=32244 TO 32494
  60 READ b: POKE a,b: NEXT a
  70 DATA 14,8,229,17,31,0,25,12
6,237,82,31,6,32,126,31,119,35,1
6,250,225,36,13,32,234,201
  80 DATA 14,8,175,229,17,31,0,2
37,82,126,25,23,6,32,126,23,119,
43,16,250,225,36,13,32,233,201
  90 DATA 33,95,64,205,13,126,33
,128,64,205,244,125,33,128,64,20
5,244,125,33,223,64,205,13,126,3
3,0,72,205,244,125,33,0,72,205,2
44,125,33,0,72,205,244,125
 100 DATA 58,121,92,0,0,0,0,0,0,
0,230,2,40,20,33,64,72,205,244,1
25,33,64,72,205,244,125,33,64,72
,205,244,125,24,18,33,95,72,205,
13,126,33,95,72,205,13,126,33,95
,72,205,13,126
 110 DATA 33,128,72,205,244,125,
33,192,72,205,244,125,33,192,72,
205,244,125,33,31,80,205,13,126,
33,31,80,205,13,126,33,95,80,205
,13,126,201
 120 DATA 33,128,72,205,244,125,
33,192,72,205,244,125,33,31,80,2
05,13,126,33,95,80,205,13,126,20
1
 130 DATA 33,95,64,205,13,126,33
,128,64,205,244,125,33,0,72,205,
244,125,201
 140 DATA 33,95,64,205,13,126,33
,223,64,205,13,126,33,128,72,205
,244,125,33,192,72,205,244,125,2
01
 150 LET a=PEEK 23675+256*PEEK 2
3676
 160 FOR b=a TO a+167
 170 READ c: POKE b,c: NEXT b
 180 DATA 15,18,34,127,255,255,4
0,16,128,64,32,254,254,255,40,16
 190 DATA 127,127,127,127,127,25
5,21,8,254,254,254,254,255,255,6
4,128
 200 DATA 0,248,196,196,254,254,
40,16,24,24,36,126,60,90,165,66
 210 DATA 56,40,148,124,56,56,40
,108,1,2,4,127,127,255,20,8
 220 DATA 240,72,68,254,255,255,
20,8,0,31,35,35,127,127,20,8
```

```
230 DATA 127,127,127,127,255,25
5,2,1,254,254,254,254,254,255,15
8,16
240 DATA 16,41,199,0,38,0,0,0,0
,68,255,68,68,255,68,0
250 DATA 0,34,65,143,151,163,16
0,0,0,68,170,241,233,197,5,0
260 DATA 16,16,16,254,63,31,15,
7,0,0,0,0,30,255,255,255
270 DATA 96,124,84,120,127,255,
254,252,0,0,3,2,15,63,255,0,6,12
,152,240,224,85,255,0
280 PRINT AT 11,3;"Do you want
instructions?",AT 13,11;"(y)es";
AT 15,11;"(n)o"
290 PAUSE 0: IF INKEY$="y" THEN
GO TO 300
295 GO TO 400
300 CLS : PRINT AT 0,11;"OBJECT
":"To guide a  across a road a
nd sriver,avoiding  
":"A  patrols the central
island."
310 PRINT ":"There are 4 HOMES
to be filled, i.e. gaps in top f
ence  "
320 PRINT :"Once all 4 HOMES ar
e filled the speed will increase
,an exta  will be added and t
he HOMES willempty."
330 PRINT ":AT 18,9;"Press any
key.": PAUSE 0
370 CLS : PRINT AT 7,11;"CONTRO
LS"
375 PRINT "        ↑
    ( )"
380 PRINT FLASH 1;AT 11,6;"1";
FLASH 0;" 2 3 4 5 6 7 8 "; FLASH
1;"9"; FLASH 0," "; FLASH 1;"0"
390 PRINT AT 18,5;"Press any ke
y to PLAY": PAUSE 0
400 BRIGHT 1  PAPER 5: BORDER 5
: CLS
410 LET h1=0
420 PRINT PAPER 4;AT 10,0;"
                "
430 LET lives=9: LET score=0: L
ET home=0
440 POKE 32425,201: POKE 32450,
201: POKE 32459,201
450 PRINT AT 0,0; PAPER 4;"
"; PAPER 7;" "; PAPER 4;"
"; PAPER 7;" "; PAPER 4;"
"; PAPER 7;" "; PAPER 4;"
"; PAPER 7;" "; PAPER 4;"
"
455 IF home<>0 THEN GO TO 660
460 PRINT PAPER 4; INK 5;"
                "
470 PRINT "
  "
480 PRINT INK 7;"
"
490 PRINT INK 2;"
  "
500 PRINT INK 7;"
"
510 PRINT INK 1;"
  "
520 PRINT INK 7;"
"
530 PRINT "
  "
540 PRINT PAPER 4;"
"
550 PRINT PAPER 0; INK 7;AT 11,
0;"
"
560 PRINT PAPER 0; INK 3;"
```

```
 570 PRINT PAPER 0; INK 7;"-----
----------------------------"
 580 PRINT PAPER 0; INK 5;"
 590 PRINT PAPER 0; INK 7;"=====
============================"
 600 PRINT PAPER 0; INK 4;"
 610 PRINT PAPER 0; INK 7;"-----
----------------------------"
 620 PRINT PAPER 0; INK 6;"
 630 PRINT PAPER 4;"################
################################"
 640 PRINT PAPER 4;"
 650 PRINT PAPER 1; INK 7;" SCOR
E ";AT 21,11;" MEN "; PAPER 5; I
NK 0;lives; PAPER 1; INK 7;" HI-
SCORE "
 660 LET x1=20: LET y1=16: LET x
2=x1: LET y2=y1
 670 PRINT PAPER 8; INK 8;AT x1,
y1;" "
 680 RANDOMIZE USR 32295
 690 IF SCREEN$ (x2,y2)=" " THEN
 GO TO 680
 700 LET a=x2: FOR b=25 TO 35: G
O SUB 25: GO SUB 25: NEXT b
 730 FOR a=x2 TO 20 STEP 2: GO S
UB 25: GO SUB 25: NEXT a
 740 LET lives=lives-1: PRINT AT
 21,16;lives
 750 LET x2=20
 760 IF lives<>0 THEN GO TO 680
 770 IF hi>score THEN GO TO 790
 780 LET hi=score: PRINT AT 21,2
7;hi
 790 PRINT FLASH 1; PAPER 7;AT 1
2,0;"            GAME  OVER
 "
 800 PRINT AT 14,0;" Another ga
me ? (y)es  (n)o "
 840 IF INKEY$="n" THEN RANDOMIZ
E USR 0
 850 IF INKEY$<>"y" THEN GO TO 8
40
 860 PRINT PAPER 5;AT 21,7;"
"  GO TO 415
 880 IF x2<>0 THEN GO TO 1050
 890 PRINT PAPER 8; INK 8;AT x1,
y1;" ": PRINT AT x2,y2;"
1020 IF SCREEN$ (10,a+1)="" THEN
 900>RESTORE 920
 910 FOR a=1 TO 8: READ b,c: BEE
P b,c: NEXT a
 920 DATA .1,11,.1,11,.8,16,.05,
11,.05,16,.05,11,.05,16,1,20
 930 LET home=home+1: LET score=
score+50: PRINT AT 21,7;score
 950 IF home/4<>INT (home/4) THE
N GO TO 660
 960 IF home=4 THEN POKE 32425,0
 970 IF home=8 THEN POKE 32450,0
 980 IF home=12 THEN POKE 32459,
0
 985 IF home>36 THEN GO TO 450
 990 LET a=RND*30
1000 LET a=a+1
1005 IF a>31 THEN LET a=0
1010 IF SCREEN$ (10,a)="" THEN G
O TO 1000
1020 IF SCREEN$ (10,a+1)="" THEN
 GO TO 1000
1030 PRINT PAPER 4;AT 10,a;"
1035 RESTORE 920: FOR a=1 TO 8:
READ b,c: BEEP b,c: NEXT a
```

```
1040 GO TO 450
1050 PRINT PAPER 8; INK 8;AT x2,
y2;"A"
1060 LET x1=x2: LET y1=y2
1070 IF INKEY$<>"1" THEN GO TO 1
100
1080 BEEP .001,33
1090 LET x2=x2-2: LET score=scor
e+5: PRINT AT 21,7;score
1100 LET y2=y2+(INKEY$="0" AND y
2<>31)-(INKEY$="9" AND y2<>0)
1110 GO TO 670
```

USER DEFINABLE GRAPHICS :

```
AB   =
CDE  =
F    =
G    =
HI   =
JKL  =
M    =
N    =
OP   =
QRS  =
TU   =
```

Program 'Cross basic'

```
org 32244
CHAPTER 10
PROGRAM >CROSS<

[ BASIC ] M/CODE


RIGHT LINE ROLL

RIGHT
32244 0E 08       ld c,8
L1
32246 E5          push hl
32247 11 1F 00    ld de,31
32250 19          add hl,de
32251 7E          ld a,(hl)
32252 ED 52       sbc hl,de
32254 1F          rra
32255 06 20       ld b,32
L2


32257 7E          ld a,(hl)
32258 1F          rra
32259 77          ld (hl),a
32260 23          inc hl
32261 10 FA       djnz L2
32263 E1          pop hl
32264 24          inc h
32265 0D          dec c
32266 20 EA       jr nz,L1
32268 C9          ret
```

```
LEFT LINE ROLL

LEFT
32269 0E 08       ld c,8
L3
32271 AF          xor a
32272 E5          push hl
32273 11 1F 00    ld de,31
32276 ED 52       sbc hl,de
32278 7E          ld a,(hl)


32279 19          add hl,de
32280 17          rla
32281 06 20       ld b,32
L4
32283 7E          ld a,(hl)
32284 17          rla
32285 77          ld (hl),a
32286 2B          dec hl
32287 10 FA       djnz L4
32289 E1          pop hl
32290 24          inc h
32291 0D          dec c
32292 20 E9       jr nz,L3
32294 C9          ret

START ROUTINE

HL holds :-
Line start for RIGHT ROLL
Line end for LEFT ROLL
```

```
SPEED 0

32295 21 5F 40     ld hl,16479
32298 CD 0D 7E     call LEFT
32301 21 80 40     ld hl,16512
32304 CD F4 7D     call RIGHT
32307 21 80 40     ld hl,16512
32310 CD F4 7D     call RIGHT
32313 21 DF 40     ld hl,16607
32316 CD 0D 7E     call LEFT
32319 21 00 48     ld hl,18432
32322 CD F4 7D     call RIGHT
32325 21 00 48     ld hl,18432
32328 CD F4 7D     call RIGHT
32331 21 00 48     ld hl,18432
32334 CD F4 7D     call RIGHT

Move SPIDER line
Uses FRAMES counter

32337 3A 79 5C     ld a,(23673)
32340 00           nop
32341 00           nop
32342 00           nop
32343 00           nop
32344 00           nop
32345 00           nop
32346 00           nop
32347 E6 02        and 2
32349 28 14        jr z,L5
32351 21 40 48     ld hl,18496
32354 CD F4 7D     call RIGHT
32357 21 40 48     ld hl,18496
32360 CD F4 7D     call RIGHT
32363 21 40 48     ld hl,18496
32366 CD F4 7D     call RIGHT
32369 18 12        jr L6
L5
32371 21 5F 48     ld hl,18527
32374 CD 0D 7E     call LEFT
32377 21 5F 48     ld hl,18527

32380 CD 0D 7E     call LEFT
32383 21 5F 48     ld hl,18527
32386 CD 0D 7E     call LEFT
L6
32389 21 80 48     ld hl,18560
32392 CD F4 7D     call RIGHT
32395 21 C0 48     ld hl,18624
32398 CD F4 7D     call RIGHT
32401 21 C0 48     ld hl,18624
32404 CD F4 7D     call RIGHT
32407 21 1F 50     ld hl,20511
32410 CD 0D 7E     call LEFT
32413 21 1F 50     ld hl,20511
32416 CD 0D 7E     call LEFT
32419 21 5F 50     ld hl,20575
32422 CD 0D 7E     call LEFT
32425 C9           ret

SPEED 1

32426 21 80 48     ld hl,18560

32429 CD F4 7D     call RIGHT
32432 21 C0 48     ld hl,18624
32435 CD F4 7D     call RIGHT
32438 21 1F 50     ld hl,20511
32441 CD 0D 7E     call LEFT
32444 21 5F 50     ld hl,20575
32447 CD 0D 7E     call LEFT
32450 C9           ret

SPEED 2

32451 21 5F 40     ld hl,16479
32454 CD 0D 7E     call LEFT
32457 21 80 40     ld hl,16512
32460 CD F4 7D     call RIGHT
32463 21 00 48     ld hl,18432
32466 CD F4 7D     call RIGHT
32469 C9           ret

SPEED 3

32470 21 5F 40     ld hl,16479
32473 CD 0D 7E     call LEFT
32476 21 DF 40     ld hl,16607
32479 CD 0D 7E     call LEFT
32482 21 80 48     ld hl,18560
32485 CD F4 7D     call RIGHT
32488 21 C0 48     ld hl,18624
32491 CD F4 7D     call RIGHT
32494 C9           ret
```

Program 'Machine Code for Cross basic'

Machine code conversion

BASIC LINE 20

This will not be necessary in the final machine code version because there will be no need to reset RAMTOP to protect the machine code.

BASIC LINES 25 AND 30

This is a subroutine used in the HIT routine and in machine code this will be placed with the HIT routine. The subroutine is placed at the start of the BASIC program to reduce the time that the Spectrum takes to find it. When a subroutine is called the Spectrum starts from the beginning of the BASIC program and works through the line numbers until the required routine is located. You can see that it would take longer to find if it had a high line number thus increasing the time taken to carry out lines 700 to 730 which call this routine at least 22 times.

BASIC LINE 40

In BASIC it takes several seconds for the Spectrum to 'LOAD' the machine code and set up the UDGs so this message is displayed during that period. In machine code, however, this is instantaneous and the message is therefore unnecessary.

BASIC LINES 50 TO 140

This is the routine to POKE the machine code 'ROLL ROUTINE' into memory addresses 32244 to 32494, and again is not required in machine code as it will automatically be correctly located along with the rest of the machine code program.

BASIC LINES 150 TO 270 SET UP UDGS

This is the first routine that will need converting. We could of course use SAVE 'UDG' CODE USR 'a', 168 : LOAD 'UDG' CODE USR 'a', 168 but this would mean saving and loading two sets of machine code routine, namely the main game and the UDGs. In order that the machine code will easily fit into the 16K Spectrum we will begin the machine code program at address 5DC1h (24001d). As with the BASIC we will hold each byte of the UDGs in DATA form and read through this DATA transferring each number to its correct place in the UDG area of memory. The simplest method as you will see is to use the LDIR instruction. The DE register pair is loaded with the address of UDG start as held in the system variable 5C7Bh (23675d) and the HL register pair holds the address of the start of DATA. Routine DATA = 5DC1h to 5E68h and machine code routine = 5E69h (24169d) to 5E73h (24180d). Note that the routine is called using RANDOMIZE USR 24169 *not* USR 24001 which is DATA start.

BASIC LINE 280

This is a simple printing statement and is easily converted to machine code using the print DATA ROM call (203Ch – 8252d) as discussed in Chapter 1. So DATA = 5E77h (24183d) to 5EA1h (24225d). This is jumped over by the instruction 'JR 5EA2h' at memory address 5E75/6h. The print DATA routine = 5EA2h(24226d) to 5EAFh.

BASIC LINE 290 AND 295 MACHINE CODE 5EB0 TO 5EBE

In this routine we wait until a new key press is registered and check the key for 'y' (the HALT command is not absolutely necessary). If the key pressed is not 'y' then we skip the instructions by jumping (NZ) to 608Ah (24714d).

BASIC LINE 300 : 1 CLS MACHINE CODE 5EBF TO 5EC6

This routine is straightforward and is discussed in Chapter 1.

BASIC LINES 300:2 TO 330

This again is carried out using DATA store and PRINT string routines. The first set of DATA is held at 5ECA to 5F72 with the PRINT DATA routine at 5F73 to 5F83. The second set of DATA is held from 5F84 to 5FF9 and the PRINT DATA routine at 5FFA to 6002. The DATA could have been lumped together with just one PRINT DATA routine.

The PAUSE 0 routine is 6003 to 600C; note that bit 5, (IY + 1) has to be reset from the previous PAUSE 0 routine. Try removing the RES 5,(IY + 1) and 'see' the result.

BASIC LINE 370:1 CLS ROUTINE 600E TO 6012

This uses the alternative methods of clearing the whole screen by POKEing zeros into all screen addresses (not affecting the ATTRIBUTES).

BASIC LINES 370:2 TO 390

DATA for print routine = 6016 to 6075
PRINT data routine = 6076 to 607E
This is followed again by the PAUSE 0 routine.

BASIC LINE 400

Using the set BORDER colour routine and set permanent attribute

colour as in Chapter 1, we can convert this line as routine 608A to 609D.
The CLS call puts the colours on the screen as in BASIC.

BASIC LINE 410

This line sets the initial value of the high score. We will assume that the value will not be greater than 65 535 and as such use the first two bytes of the printer buffer to hold its value (address 5B00/01 – 23296/7). This is easily set to zero by LD HL, 0000h and LD(5B00),HL and is shown in routine 609C to 60A1.

BASIC LINE 420

DATA for printing = 60A4 to 60C8
PRINT DATA routine = 60C9 to 60D6

BASIC LINE 430

This sets up the initial values of 'lives', 'score', and 'home'. The lives can be held as one byte, the score as two bytes, and the home as one byte. We will again use the printer buffer to hold these values. Address 5B02 holds 'lives', 5B03/4 holds 'score', and 5B05 holds 'home'. These initial values are stored using routine 60D7 to 60E5.

BASIC LINE 440

This line resets the speed to zero by replacing the RET instructions at the correct points in the LINE ROLL subroutine. Routine: 60E6 to 60F0.

BASIC LINE 450

DATA for printing = 60F4 to 6128
PRINT DATA routine = 6129 to 6136

BASIC LINE 455

A check is made to see whether home <> 0, that is whether the screen display has to be printed or left as it is just clearing the homes. We need to fetch the value stored in 'home' 5B05 and check that it is not zero using 'AND A'. If this does not set the zero flag we jump to the PRINT display routine. If zero flag is set we skip the PRINT display routine and jump straight into the game proper. Routine: 6137 to 6140.

BASIC LINES 460 TO 640

This is the longest routine in the program and demonstrates just how tedious printing a display actually is.
DATA for printing 6141 to 63D1
PRINT DATA routine 63D2 to 63DF

BASIC LINE 650

You will notice that this PRINT routine contains the variable 'lives', so before we can use our PRINT data routine, the correct value of 'lives' must be placed into the DATA for printing. This is achieved by using the routine 63E0 to 63E9 which just collects the value 'lives' from 5B02 then adds 30h (48d) to convert it to the correct ASCII value and finally 'POKEs' it into DATA, address 6401.
DATA for printing 63EA to 640F
PRINT DATA routine 6410 to 641D

BASIC LINE 660

This line sets the initial values of the man screen print position x1, y1 and the 'new' position used in the SCREEN$ routine x2, y2. Again we will use the printer buffer to hold these values

x1 = 5B06
y1 = 5B07
x2 = 5B08
y2 = 5B09

This is easily carried out in machine code by LD HL,1014h: LD(5B06), HL : LD(5B08),HL. You will notice from the above how much easier it is to use hexadecimal numbers and not decimal ones. It is quite clear that with LD HL, 1014h that H will hold 10h (16d) and L will hold 14 (20d). Routine 641E to 6426.

BASIC LINE 670

As we are printing just one character whose position is dependent on the variables x1, y1, it is easier to use LD A,n : RST 10h than a PRINT DATA routine. Routine 6427 to 6445.

BASIC LINE 680

Routine 6446 to 6448. We will leave the ROLL routine at address (32295) 7E27.

BASIC LINE 690

We will use the routine described in Chapter 8 to find SCREEN$ (x2, y2) then unstack the 'value' into the A,B,C,D,E, registers. The character can then be found by LD A,(DE) and compared to 20h (32). Remember that we must clear the workspace before continuing with the program. Routine 6449 to 645D. If the character is not a space then we jump to the HIT routine that starts at address 6548h. The BASIC main loop jumps to line 880.

BASIC LINE 880

Here we check that the man is not on the top screen line, that is, 'home'. In machine code we get the value x2 by LD A,(5B08) and compare it to 0. If it is zero we jump to the home routine at address 66A6. Routine 645E to 6465. The BASIC main loop jumps to line 1050.

BASIC LINE 1050

Because we are printing one character using two variables x2, y2, we will use LD A, n : RST 10h (as line 670). Routine 6466 to 6484.

BASIC LINE 1060

This is a case of collecting the value held in 5B08/9 and placing it in 5B06/7. Routine 6485 to 648A.

BASIC LINE 1070

At this point we will change the BASIC to improve the game. Instead of using the LAST KEY variable to read the keyboard, we will read it directly using the IN A,(C) command and so allow all keys to be read and diagonal moves made.

To read key '1' we need to read half row 1 to 5 and as described in Chapter 5 the routine required is 648B to 6493.

BASIC LINE 1080

Because the BEEP is not important in its length and pitch we need not be precise in the machine code conversion. We can use the BEEP routine call 03B5(949d) instead of using the calculator. Routine 6494 to 649C.

BASIC LINE 1090

Here we are updating the line position (x2) of the man so we collect the value in 5B08, decrease it by two, and put the new value back

into 5BØ8. The score is increased by collecting the value in 5BØ3/4, adding five and putting the result back into 5BØ3/4. Routine 649D to 64AF. To print the score we will use the STACK BC and PRINT VALUE ON STACK routines, but first we define the 'PRINT AT' parameters. Routine 64B1 to 64C8.

BASIC LINE 1100

Again using the IN A,(C) instruction we can read the keyboard and update the value of y 2 (5BØ9). Routine 64C9 to 64F1. I have added a routine to check for key '6' being pressed to give a return to BASIC facility at this point. (This is necessary to 'SAVE' the program once it is running properly.) Routine 64F2 to 64F4.

This completes the main loop but you will find that, if this program is run, it will be so fast as to make the man almost invisible as he flashes on and off between screen rolls. Because of this we need our delay loop to hold the man for a moment as suggested in Chapter 6. Instead of our normal loop we can add a traffic noise sound effect as routine 64F5 to 650B. The final JP 6427 will take us back to the beginning of the main loop (line 670).

Hit routine

BASIC LINE 700

Here we introduce another variable a = x2. We will use address 5CBØ to hold this value (an unused address in the systems variables). The FOR/NEXT loop variable 'b' can be replaced by LD B, 19h(25d). This value is then placed in address 5CB1 to be used in the next routine. Routine 6548 to 6561. The GOSUB 25 call is replaced by call 650F.

BASIC LINE 25

This is easily converted using the calculator to stack .01 . b − a is simply LD HL,(5CBØ) : LD A,H: SUBL; the values a and b being stored consecutively at 5CBØ/B1. We then use the stack value in 'A' routine 2D28 and call BEEP routine Ø3F8. Routine 650F to 6521.

BASIC LINE 30

This is another case of using LD A,n : RST 10h as there are two variables in the PRINT routine. Routine 6522 to 6547.

BASIC LINE 730

Variable a is already stored at 5CBØ, so we can set up a loop taking

this value and increasing it by two after each pass until the value reaches 14h(20d). Routine 6562 to 6573.

BASIC LINE 740

Here we get the value of 'lives' from address 5B02, reduce it by one, and return the new value to 5B02. To print this value we just set the PRINT AT parameters then get the value, add 30h(48d) to convert it to ASCII code, and print it. Routine 6574 to 658E.

BASIC LINE 750

Routine 658F to 6593. This involves resetting value x2(5B08) to 14h(20d).

BASIC LINE 760

Routine 6594 to 659A. This is quite straightforward. If 'lives' not zero we jump to 6446, that is, back into the main loop.

End game routine

BASIC LINE 770

This involves getting the value of hi score and score and checking which is greater. It is quite easily done by using SBC HL, DE and then checking the state of the carry flag. Routine 659B to 65A. If hi score is greater than score, we jump to 6611.

BASIC LINE 780

This involves transferring score 5B03/4 to hi score 5B0/01. Routine 65A7 to 65AC. To print the hi score we use the STACK VALUE IN BC and PRINT TOP VALUE ON CALCULATOR STACK routines having first set the PRINT AT parameters. Routine 65AD to 66C2.

BASIC LINES 790 TO 800

DATA for printing = 65C5 to 6610
PRINT DATA routine = 6611 to 6619

BASIC LINE 840 TO 850

Here we use LAST KEY variable to wait for a key press and take action accordingly. Routine 661A to 6632. If the key pressed is not 'y' (79h) or 'n' (6Eh) then we jump back into the WAIT loop.

BASIC LINE 860

This is carried out using LD A,n : RST 10h followed by JP 60C9 to return to the main loop reprinting the display but leaving the 'hi score' unaltered. Routine 6633 to 6655.

Home routine

BASIC LINE 890

Here we use the PRINT DATA routine but first putting the required values of x1, y1 and x2, y2 into the DATA.
DATA for PRINTING 669A to 66A5
SET value of x1,y1,x2,y2 66A6 to 66B1
PRINT DATA routine 66B2 to 66BF

BASIC LINE 900

This of course is unnecessary in machine code as the DATA start does not need to be reset.

BASIC LINES 910 TO 920

FANFARE BEEP call 666A
The routine is covered in detail in Chapter 7 and so needs no further comment. Routine 66C0 to 66C2.

BASIC LINES 930

Another set of routines to collect current values of 'home' and 'score' and update each one followed by a routine to print the score using the STACK VALUE IN BC and PRINT TOP VALUE ON STACK routines. Update routine 66C3 to 66D3. Print score routine 66D4 to 66E9.

BASIC LINE 950

This is a check to see whether all four homes are full and is easier to program in machine code than in BASIC. Routine 66EA to 66F1. You can see that we first LD A, (5B05) that is, 'home' count, then mask it with AND 03h. If we are left with a non-zero answer it will show that the original value of 'home' was not a multiple of four. If the result is not zero we jump back into the main loop JP 641E.

BASIC LINE 960 TO 980

These routines are used to increase the speed of the game when 'home' = 4,8, and 12. This is done by removing the RETURN

instructions in the ROLL subroutine allowing certain lines to be moved by an extra pixel: line 960 = 66F2 to 66FF, line 970 = 6700 to 6709, and line 980 = 670A to 6712.

BASIC LINE 985

We now check that 'home' is not greater than 36. If it is then the 'ADD EXTRA SPIDER' routine is missed and we return to the main loop. We simply subtract 37 from the value of 'home' and if the carry flag is not set (that is home =37) then we JP NC, 6129. Routine 6714 to 6718.

BASIC LINE 990

This routine is discussed in Chapter 4 and needs no further explanation except to point out that in this case we use the modified SEED value in BC and mask 1Fh (31d) : LD A,C : AND 1Fh then subtract two and check for the carry flag set. This method was chosen because a true random number was not necessary. Routine 6719 to 6740.

BASIC LINE 1000

Routine 6741
All that is required is to increment the value in 'a'.

BASIC LINE 1005

A check is made that the value of 'a' is not greater than 31, that is, off the screen; if it is then 'a' is reset to 0. Routine 6742 to 6746.

BASIC LINE 1010

A check is made that the screen position (10,a) is clear using the SCREEN$ routine. This entails placing the value 'a' into the B register and 0ah (10d) into the C register, calling STACK VALUE IN BC and SCREEN$ routines then removing the parameters from the stack into A,B,C,D,E registers and finally checking for SCREEN$ (10,a) = 20h(32d). If all is satisfactory then we get the original value of 'a' (POP AF) and continue. If the SCREEN$ routine indicates that the position is not clear then we JR 6741 thus stepping to the next screen position. Routine 6747 to 675E.

BASIC LINE 1020

This is a repeat of the previous routine except that the value of 'a' is

incremented before the SCREEN$ routine. Routine 675F to 6776. Note that the value of 'a' is saved before the SCREEN$ routine (6760 PUSH AF) to be used in the next routine.

BASIC LINE 1030

The value 'a' is POPped back into AF and decreased. This is then placed into the PRINT DATA, and the PRINT routine called. Routine 6777 to 6792.

BASIC LINE 1030

This is a repeat of the FANFARE BEEP and just requires CALL 666A. Routine 6793 to 6795.

BASIC LINE 1040

Finally we jump back into the main loop using JP 6129. Routine 6796 to 6798.

You can see from the above that it really is very simple to convert a BASIC program to machine code *as long as you take it one step at a time* and plan your program with machine code in mind.

One last point that you will no doubt have noticed is that it is better to work in hexadecimal rather than decimal as for instance many of the routines require the loading of BC with line/column parameters. Take another look at the LEFT/RIGHT ROLL subroutine. The decimal screen addresses mean very little, with no apparent pattern, but if you look at the hexadecimal equivalents you will see some sort of pattern giving a clearer indication of what is actually happening.

All that is necessary now is for you to dream up your own brilliant and original program and start converting it to machine code. I wish you good luck and hope you enjoy many happy hours of programming with not too many crashes.

```
org 42000 24001

SDC1h
defb $0f $12 $22 $7f $ff $ff $20
defb $10
defb $80 $40 $20 $fe $fe $ff $28
defb $10
defb $7f $7f $7f $7f $7f $ff $15
defb $0B
defb $ff $fe $fe $fe $ff $ff $40
defb $80
defb $00 $f8 $c4 $c4 $fe $fe $28
defb $10
defb $18 $18 $24 $7e $3c $5a $a5
defb $42
defb $38 $28 $92 $72 $38 $38 $28
defb $6c
defb $01 $02 $04 $7f $7f $ff $14
defb $08
defb $f0 $48 $44 $fe $ff $ff $14
defb $08
defb $00 $1f $23 $23 $7f $7f $14
defb $0B
defb $7f $7f $7f $7f $ff $ff $02
defb $01
defb $fe $fe $fe $fe $fe $ff $a8
defb $10
defb $10 $29 $c7 $00 $26 $00 $00
defb $00
defb $00 $44 $ff $44 $44 $ff $44
```

```
defb $00
defb $00 $22 $55 $8f $97 $a3 $a0
defb $00
defb $00 $44 $aa $f1 $e9 $c5 $05
defb $00
defb $10 $10 $10 $fe $3f $1f $0f
defb $07
defb $00 $00 $00 $00 $1e $ff $ff
defb $ff
defb $60 $7c $54 $78 $7f $ff $fe
defb $7c


defb $00 $00 $03 $02 $0f $3f $ff
defb $00
defb $06 $0c $98 $f0 $e0 $55 $ff
defb $00
```

```
5E69h
24169 ED 5B 7B 5C ld de,($5c7b)
24173 21 C1 5D    ld hl,$5dc1
24176 01 A8 00    ld bc,$00a8
24179 ED B0       ldir
24181 18 2B       jr +$2b
```

```
5E77h
defb $16 $0b $03 $44 $6f $20 $79
defb $6f
defb $75 $20 $77 $61 $6e $74 $20
defb $69


defb $6e $73 $74 $72 $75 $63 $74
defb $69
defb $6f $6e $73 $3f $16 $0d $0b
defb $28
defb $79 $29 $65 $73 $16 $0f $0b
defb $28
defb $6e $29 $6f
```

```
5EA2h
24226 3E 02       ld a,$02
24228 CD 01 16    call $1601
24231 11 77 5E    ld de,$5e77
24234 01 2B 00    ld bc,$002b
24237 CD 3C 20    call $203c
24240 76          halt
24241 FD CB 01 6E bit 5,(iy+$01
24245 28 F9       jr z,-$07
24247 3A 08 5C    ld a,($5c08)
24250 FE 79       cp $79


24252 C2 8A 60    jp nz,$608a
```

```
5EBFh
24255 3E 02       ld a,$02
24257 CD 01 16    call $1601
24260 CD 6B 0D    call $0d6b
24263 C3 73 5F    jp $5f73
```

```
5ECA
defb $16 $00 $0b $4f $42 $4a $45
defb $43
defb $54 $0d $0d $54 $6f $20 $67
defb $75
defb $69 $64 $65 $20 $61 $20 $96
defb $20
defb $61 $63 $72 $6f $73 $73 $20
defb $61


defb $20 $72 $6f $61 $64 $20 $61
defb $6e
defb $64 $20 $61 $72 $69 $76 $65
defb $72
defb $2c $61 $76 $6f $69 $64 $69
defb $6e
defb $67 $20 $90 $91 $20 $92 $93
defb $94
defb $20 $95 $20 $a0 $a1 $a1 $a2
defb $20
defb $a3 $a4 $0d $0d $41 $20 $9e
defb $9f
defb $20 $70 $61 $74 $72 $6f $6c
defb $73
defb $20 $74 $68 $65 $20 $63 $65
defb $6e
defb $74 $72 $61 $6c $20 $69 $73
defb $6c
defb $61 $6e $64 $2e $0d $0d $54
defb $68
defb $65 $72 $65 $20 $61 $72 $65


defb $20
defb $34 $20 $48 $4f $4d $45 $53
defb $20
defb $74 $6f $20 $62 $65 $20 $66
defb $69
defb $6c $6c $65 $64 $2e $20 $69
defb $2e
defb $65 $2e $20 $67 $61 $70 $73
defb $20
defb $69 $6e $20 $66 $65 $6e $63
defb $65
defb $20 $9d $9d $9d $20 $9d $9d
defb $9d $0d
```

```
5F73h
24435 3E 02       ld a,$02
24437 CD 01 16    call $1601
24440 11 CA 5E    ld de,$5eca
24443 01 A9 00    ld bc,$00a9

24446 CD 3C 20    call $203c
```

```
24449 C3 FA 5F     jp $5ffa


5F84h
defb $0d $4f $6e $63 $65 $20 $61
defb $6c
defb $6c $20 $34 $20 $48 $4f $4d
defb $45
defb $53 $20 $61 $72 $65 $20 $66
defb $69
defb $6c $6c $65 $64 $20 $74 $68
defb $65
defb $20 $73 $70 $65 $65 $64 $20
defb $77
defb $69 $6c $6c $20 $69 $6e $63
defb $72
defb $65 $61 $73 $65 $2c $20 $61
defb $6e
defb $20 $65 $78 $74 $72 $61 $20

defb $65
defb $20 $61 $64 $64 $65 $64 $20
defb $61
defb $6e $64 $20 $74 $68 $65 $20
defb $48
defb $4f $4d $45 $53 $20 $77 $69
defb $6c
defb $6c $65 $6d $70 $74 $79 $16
defb $12
defb $09 $50 $72 $65 $73 $73 $20
defb $61
defb $6e $79 $20 $6b $65 $79


5FFAh
24570 11 84 5F     ld de,$5f84
24573 01 76 00     ld bc,$0076
24576 CD 3C 20     call $203c
24579 FD CB 01 AE  res 5,(iy+$01
24583 76           halt

24584 FD CB 01 6E  bit 5,(iy+$01
24588 28 F9        jr z,-$07


6006h
defb $16 $07 $0b $43 $4f $4e $54
defb $52
defb $4f $4c $53 $0d $0d $20 $20
defb $20
defb $20 $20 $20 $5e $20 $20 $20
defb $20
defb $20 $20 $20 $20 $20 $20 $20
defb $20

defb $20 $20 $20 $3c $30 $3e $12
defb $01
defb $16 $0b $06 $31 $12 $00 $20
defb $32
defb $20 $33 $20 $34 $20 $35 $20
defb $36
defb $20 $37 $20 $38 $30 $12 $01
defb $39
defb $12 $00 $20 $12 $01 $30 $12
defb $00
defb $16 $12 $05 $50 $72 $65 $73
defb $73
defb $20 $61 $6e $79 $20 $6b $65
defb $79
defb $20 $74 $6f $20 $50 $4c $41
defb $59


6076h
24694 11 16 60     ld de,$6016


24697 01 60 00     ld bc,$0060
24700 CD 3C 20     call $203c
24703 FD CB 01 AE  res 5,(iy+$01
24707 76           halt
24708 FD CB 01 6E  bit 5,(iy+$01
24712 28 F9        jr z,-$07


608Ah
24714 3E 05        ld a,$05
24716 CD 9B 22     call $229b
24719 3E 68        ld a,$68
24721 32 BD 5C     ld ($5cbd),a
24724 3E 02        ld a,$02
24726 CD 01 16     call $1601
24729 CD 6B 0D     call $0d6b


609Ch


24732 21 00 00     ld hl,$0000
24735 22 00 5B     ld ($5b00),hl
24738 18 25        jr +$25


60A4h
defb $11 $04 $16 $0a $00 $20 $20
defb $20
defb $20 $20 $20 $20 $20 $20 $20
defb $20
defb $20 $20 $20 $20 $9e $9f $20
defb $20
```

```
defb $20 $20 $20 $20 $20 $20 $20
defb $20
defb $20 $20 $20 $20 $20
```

```
60C9h
24777 3E 02        ld a,$02

24779 CD 01 16     call $1601
24782 11 A4 60     ld de,$60a4
24785 01 25 00     ld bc,$0025
24788 CD 3C 20     call $203c
```

```
60D7h
24791 3E 09        ld a,$09
24793 32 02 5B     ld ($5b02),a
24796 21 00 00     ld hl,$0000
24799 22 03 5B     ld ($5b03),hl
24802 AF           xor a
24803 32 05 5B     ld ($5b05),a
```

```
60E6h
24806 3E C9        ld a,$c9
24808 32 A9 7E     ld ($7ea9),a
24811 32 C2 7E     ld ($7ec2),a

24814 32 D5 7E     ld ($7ed5),a
24817 C3 29 61     jp $6129
```

```
60F4h
defb $16 $00 $00 $11 $04 $9d $9d
defb $9d
defb $9d $11 $07 $20 $11 $04 $9d
defb $9d
defb $9d $9d $9d $9d $11 $07 $20
defb $11
defb $04 $9d $9d $9d $9d $9d $9d
defb $9d
defb $11 $07 $20 $11 $04 $9d $9d
defb $9d
defb $9d $9d $9d $9d $11 $07 $20
defb $11
defb $04 $9d $9d $9d $9d
```

```
6129h
24873 3E 02        ld a,$02
24875 CD 01 16     call $1601
24878 11 F4 60     ld de,$60f4
24881 01 35 00     ld bc,$0035
24884 CD 3C 20     call $203c
```

```
6137h
24887 3A 05 5B     ld a,($5b05)
24890 A7           and a
24891 C2 1E 64     jp nz,$641e
24894 C3 D2 63     jp $63d2
```

```
6141h
defb $11 $04 $10 $05 $8c $8c $8c
defb $8c
defb $8c $8c $8c $8c $8c $8c $8c
defb $8c
defb $8c $8c $8c $8c $8c $8c $8c
defb $8c
defb $8c $8c $8c $8c $8c $8c $8c
defb $8c
defb $8c $8c $8c $8c $11 $05 $10
defb $00
defb $20 $a0 $a1 $a1 $a2 $20 $20
defb $20
defb $a0 $a1 $a1 $a1 $a2 $20 $20
defb $20
defb $20 $a0 $a1 $a1 $a2 $20 $20
defb $20
defb $a0 $a1 $a1 $a2 $20 $20 $20
defb $20
defb $10 $07 $20 $20 $20 $9c $9c
defb $9c
defb $20 $20 $20 $20 $20 $9c $9c
defb $9c
defb $9c $9c $20 $20 $20 $20 $20

defb $9c
defb $9c $9c $20 $20 $20 $20 $20
defb $20
defb $9c $10 $02 $20 $20 $a3 $a4
defb $20
defb $20 $20 $20 $20 $a3 $a4 $20
defb $20
defb $20 $20 $20 $a3 $a4 $20 $20
defb $20
defb $20 $a3 $a4 $20 $20 $20 $20
defb $20
defb $20 $a3 $a4 $20 $10 $07 $9c
defb $9c
defb $20 $20 $20 $9c $20 $20 $20
defb $20
defb $20 $20 $9c $9c $9c $9c $9c
defb $20
defb $20 $20 $20 $20 $20 $20 $20
defb $9c
defb $9c $9c $20 $20 $20 $20 $10
defb $01

defb $a1 $a2 $20 $20 $20 $20 $20
defb $a0
defb $a1 $a1 $a2 $20 $20 $20 $20
defb $20
defb $20 $a0 $a1 $a1 $a1 $a1 $a2
defb $20
defb $20 $20 $20 $20 $a0 $a1 $a1
```

```
defb $a1
defb $10 $07 $20 $20 $20 $9c $9c
defb $20
defb $20 $9c $9c $9c $9c $9c $20
defb $20
defb $20 $9c $9c $20 $20 $20 $20
defb $20
defb $20 $9c $9c $9c $20 $20 $20
defb $20
defb $20 $20 $10 $00 $a4 $20 $20
defb $20
defb $20 $20 $20 $20 $20 $20 $a3
defb $a4
defb $20 $20 $20 $20 $20 $a3 $a4
defb $20
defb $20 $20 $20 $20 $20 $a3 $a4
defb $20
defb $20 $20 $20 $a3 $11 $04 $9d
defb $9d
defb $9d $9d $9d $9d $9d $9d $9d
defb $9d
defb $9d $9d $9d $9d $9d $9d $9d
defb $9d
defb $9d $9d $9d $9d $9d $9d $9d
defb $9d
defb $9d $9d $9d $9d $9d $9d $11
defb $00
defb $10 $07 $16 $0b $00 $9d $9d
defb $9d
defb $9d $9d $9d $9d $9d $9d $9d
defb $9d
defb $9d $9d $9d $9d $9d $9d $9d
defb $9d
defb $9d $9d $9d $9d $9d $9d $9d
defb $9d
```

```
defb $9d $9d $9d $9d $9d $10 $03
defb $20
defb $90 $91 $20 $95 $20 $20 $90
defb $91
defb $20 $20 $92 $93 $92 $93 $94
defb $20
defb $95 $20 $95 $20 $20 $20 $92
defb $93
defb $94 $20 $20 $20 $20 $20 $20
defb $10
defb $07 $2d $2d $2d $2d $2d $2d
defb $2d
defb $2d $2d $2d $2d $2d $2d $2d
defb $2d
defb $2d $2d $2d $2d $2d $2d $2d
defb $2d
defb $2d $2d $2d $2d $2d $2d $2d
defb $2d
defb $2d $2d $2d $2d $2d $2d $2d
defb $2d
defb $2d $10 $05 $20 $90 $91 $20
defb $20
defb $20 $20 $90 $91 $20 $20 $20
```

```
defb $20
defb $90 $91 $20 $20 $90 $91 $20
defb $20
defb $20 $20 $20 $20 $20 $20 $90
```

```
defb $91
defb $20 $20 $20 $10 $07 $3d $3d
defb $3d
defb $3d $3d $3d $3d $3d $3d $3d
defb $3d
defb $3d $3d $3d $3d $3d $3d $3d
defb $3d
defb $3d $3d $3d $3d $3d $3d $3d
defb $3d
defb $3d $3d $3d $3d $3d $10 $04
defb $98
defb $20 $20 $20 $20 $20 $97 $98
defb $20
defb $20 $20 $97 $98 $20 $20 $20
defb $20
defb $20 $20 $20 $97 $98 $20 $20
defb $20
```

```
defb $20 $20 $20 $20 $20 $20 $97
defb $10
defb $07 $2d $2d $2d $2d $2d $2d
defb $2d
defb $2d $2d $2d $2d $2d $2d $2d
defb $2d
defb $2d $2d $2d $2d $2d $2d $2d
defb $2d
defb $2d $2d $2d $2d $2d $2d $2d
defb $2d
defb $2d $10 $06 $9a $9b $20 $20
defb $20
defb $97 $98 $20 $20 $97 $98 $20
defb $95
defb $20 $20 $95 $20 $20 $99 $9a
defb $9b
defb $9a $9b $20 $20 $20 $95 $20
defb $20
defb $20 $20 $99 $11 $04 $10 $00
defb $9d
defb $9d $9d $9d $9d $9d $9d $9d
```

```
defb $9d
defb $9d $9d $9d $9d $9d $9d $9d
defb $9d
defb $9d $9d $9d $9d $9d $9d $9d
defb $9d
defb $9d $9d $9d $9d $9d $9d $9d
defb $11
defb $04 $20 $20 $20 $20 $20 $20
defb $20
defb $20 $20 $20 $20 $20 $20 $20
defb $20
defb $20 $20 $20 $20 $20 $20 $20
defb $20
defb $20 $20 $20 $20 $20 $20 $20
defb $20 $20
```

```
63D2h
25554 3E 02        ld a,$02
25556 CD 01 16     call $1601
```

```
25559 11 41 61     ld de,$6141
25562 01 91 02     ld bc,$0291
25565 CD 3C 20     call $203C
```

```
63E0h
25568 3A 02 5B     ld a,($5b02)
25571 C6 30        add a,$30
25573 32 01 64     ld ($6401),a
25576 18 26        jr +$26
```

```
63EAh
defb $11 $01 $10 $07 $20 $53 $43
defb $4f
defb $52 $45 $20 $16 $15 $0b $20
defb $4d
defb $45 $4e $20 $11 $05 $10 $00
defb $39

defb $11 $01 $10 $07 $20 $48 $49
defb $2d
defb $53 $43 $4f $52 $45 $20
```

```
6410h
25616 3E 02        ld a,$02
25618 CD 01 16     call $1601
25621 11 EA 63     ld de,$63ea
25624 01 26 00     ld bc,$0026
25627 CD 3C 20     call $203c
```

```
641Fh
25630 21 14 10     ld hl,$1014
25633 22 06 5B     ld ($5b06),hl
25636 22 08 5D     ld ($5b08),hl
```

```
6427h
25639 3E 02        ld a,$02
25641 CD 01 16     call $1601
25644 3E 11        ld a,$11
25646 D7           rst $10
25647 3E 08        ld a,$08
25649 D7           rst $10
25650 3E 10        ld a,$10
25652 D7           rst $10
25653 3E 08        ld a,$08
25655 D7           rst $10
25656 3E 16        ld a,$16
25658 D7           rst $10
25659 3A 06 5B     ld a,($5b06)
25662 D7           rst $10
25663 3A 07 5B     ld a,($5b07)
25666 D7           rst $10
```

```
25667 3E 20        ld a,$20
25669 D7           rst $10
```

```
6446h
25670 CD 27 7E     call $7e27
```

```
6449h
25673 ED 4B 08 5B  ld bc,($5b08)
25677 CD 38 25     call $2538
25680 CD F1 2B     call $2bf1
25683 1A           ld a,(de)
25684 F5           push af
25685 CD BF 16     call $16bf
25688 F1           pop af
25689 FE 20        cp $20
25691 C2 48 65     jp nz,$6548
```

```
645Eh

25694 3A 08 5B     ld a,($5b08)
25697 FE 00        cp $00
25699 CA A6 66     jp z,$66a6
```

```
6466h
25702 3E 02        ld a,$02
25704 CD 01 16     call $1601
25707 3E 11        ld a,$11
25709 D7           rst $10
25710 3E 08        ld a,$08
25712 D7           rst $10
25713 3E 10        ld a,$10
25715 D7           rst $10
25716 3E 08        ld a,$08
25718 D7           rst $10
25719 3E 16        ld a,$16
25721 D7           rst $10
25722 3A 08 5B     ld a,($5b08)
25725 D7           rst $10

25726 3A 09 5B     ld a,($5b09)
25729 D7           rst $10
25730 3E 96        ld a,$96
25732 D7           rst $10
```

```
6485h
25733 2A 08 5B     ld hl,($5b08)
25736 22 06 5B     ld ($5b06),hl
```

```
648Bh
```

```
25739 01 FE F7     ld bc,$f7fe
25742 ED 78        in a,(c)
25744 CB 47        bit 0,a
25746 20 1C        jr nz,+$1c
```

```
6494h
25748 21 32 00     ld hl,$0032
25751 11 05 00     ld de,$0005
25754 CD B5 03     call $03b5
```

```
649Dh
25757 3A 08 5B     ld a,($5b08)
25760 3D           dec a
25761 3D           dec a
25762 32 08 5B     ld ($5b08),a
25765 2A 03 5B     ld hl,($5b03)
25768 23           inc hl
25769 23           inc hl
25770 23           inc hl
25771 23           inc hl
25772 23           inc hl
25773 22 03 5B     ld ($5b03),hl
25776 00           nop
25777 3E 02'       ld a,$02

25779 CD 01 16     call $1601
25782 3E 16        ld a,$16
25784 D7           rst $10
25785 3E 15        ld a,$15
25787 D7           rst $10
25788 3E 07        ld a,$07
25790 D7           rst $10
25791 ED 4B 03 5B  ld bc,($5b03)
25795 CD 2B 2D     call $2d2b
25798 CD E3 2D     call $2de3
```

```
64C9h
25801 01 FE EF     ld bc,$effe
25804 ED 78        in a,(c)
25806 CB 47        bit 0,a
25808 20 0E        jr nz,+$0e
25810 3A 09 5B     ld a,($5b09)
25813 FE 1F        cp $1f
25815 28 01        jr z,+$01

25817 3C           inc a
25818 32 09 5B     ld ($5b09),a
25821 C3 F5 64     jp $64f5
25824 CB 4F        bit 1,a
25826 20 0E        jr nz,+$0e
25828 3A 09 5B     ld a,($5b09)
25831 FE 00        cp $00
25833 28 01        jr z,+$01
25835 3D           dec a
```

```
25836 32 09 5B     ld ($5b09),a
25839 C3 F5 64     jp $64f5
```

```
64F2h
25842 CB 67        bit 4,a
25844 C8           ret z
```

```
64F5h

25845 06 0A        ld b,$0a
25847 11 78 00     ld de,$0078
25850 21 01 00     ld hl,$0001
25853 E5           push hl
25854 D5           push de
25855 C5           push bc
25856 CD B5 03     call $03b5
25859 C1           pop bc
25860 D1           pop de
25861 E1           pop hl
25862 7D           ld a,l
25863 3C           inc a
25864 6F           ld l,a
25865 00           nop
25866 10 F1        djnz -$0f
25868 C3 27 64     jp $6427
```

```
650Fh
25871 EF           rst $28
```

```
6510h
defb $34 $ea $23 $d7 $0a $3d $3D
```

```
6517h
25879 2A B0 5C     ld hl,($5cb0)
25882 7C           ld a,h
25883 95           sub l
25884 CD 2B 2D     call $2d2b
25887 CD F8 03     call $03f8
25890 3E 02        ld a,$02
25892 CD 01 16     call $1601
25895 3E 15        ld a,$15
25897 D7           rst $10
25898 3E 01        ld a,$01
25900 D7           rst $10
25901 3E 11        ld a,$11

25903 D7           rst $10
25904 3E 08        ld a,$08
25906 D7           rst $10
25907 3E 10        ld a,$10
25909 D7           rst $10
```

```
25910 3E 08       ld a,$08
25912 D7          rst $10
25913 3E 16       ld a.$16
25915 D7          rst $10
25916 3A B0 5C    ld a,($5cb0)
25919 D7          rst $10
25920 3A 09 5B    ld a.($5b09)
25923 D7          rst $10
25924 3E 96       ld a,$96
25926 D7          rst $10
25927 C9          ret


6548h
25928 3A 08 5B    ld a,($5b08)


25931 32 B0 5C    ld ($5cb0),a
25934 06 19       ld b,$19
25936 78          ld a,b
25937 C5          push bc
25938 32 B1 5C    ld ($5cb1),a
25941 CD 0F 65    call $650f
25944 CD 0F 65    call $650f
25947 C1          pop bc
25948 04          inc b
25949 78          ld a.b
25950 FE 23       cp $23
25952 20 EF       jr nz,-$11


6562h
25954 CD 0F 65    call $650f
25957 CD 0F 65    call $650f
25960 3A D0 5C    ld a,($5cb0)
25963 3C          inc a
25964 3C          inc a


25965 32 B0 5C    ld ($5cb0),a
25968 FE 14       cp $14
25970 20 EE       jr nz,-$12


6574h
25972 3A 02 5B    ld a.($5b02)
25975 3D          dec a
25976 32 02 5B    ld ($5b02).a
25979 3E 02       ld a.$02
25981 CD 01 16    call $1601
25984 3E 16       ld a.$16
25986 D7          rst $10
25987 3E 16       ld a.$16
25989 D7          rst $10
25990 3E 10       ld a.$10
25992 D7          rst $10
25993 3A 02 5B    ld a.($5b02)
25996 C6 30       add a.$30
25998 D7          rst $10
```

```
658Fh
25999 3E 14       ld a,$14
26001 32 02 5B    ld ($5b02),a


6594h
26004 3A 02 5B    ld a,($5b02)
26007 A7          and a
26008 C2 46 64    jp nz,$6446


659Bh
26011 AF          xor a
26012 2A 03 5B    ld hl,($5b03)
26015 ED 5B 00 5B ld de,($5b00)
26019 ED 52       sbc hl,de


26021 38 6A       jr c,+$6a


65A7h
26023 2A 03 5B    ld hl,($5b03)
26026 22 00 5B    ld ($5b00),hl
26029 E5          push hl
26030 C1          pop bc
26031 CD 2B 2D    call $2d2b
26034 3E 02       ld a,$02
26036 CD 01 16    call $1601
26039 3E 16       ld a,$16
26041 D7          rst $10
26042 3E 15       ld a,$15
26044 D7          rst $10
26045 3E 1B       ld a,$1b
26047 D7          rst $10
26048 CD E3 2D    call $2de3
26051 18 4C       jr +$4c


65C5h
defb $12 $01 $11 $07 $16 $0c $00
defb $20
defb $20 $20 $20 $20 $20 $20 $20
defb $20
defb $20 $20 $47 $41 $4d $45 $20
defb $20
defb $4f $56 $45 $52 $20 $20 $20
defb $20
defb $20 $20 $20 $20 $20 $20 $20
defb $16
defb $0e $00 $12 $00 $20 $20 $41
defb $6e
defb $6f $74 $68 $65 $72 $20 $67
defb $61
defb $6d $65 $20 $3f $20 $28 $79
defb $29
defb $65 $73 $20 $20 $28 $6e $29
defb $6f
```

```
defb $20 $20 $20 $20


6611h
26129 11 C5 65     ld de,$65c5
26132 01 4C 00     ld bc,$004c
26135 CD 3C 20     call $203c


661Ah
26138 76           halt
26139 FD CB 01 6E  bit 5,(iy+$01
26143 28 F9        jr z,-$07
26145 FD CB 01 AE  res 5,(iy+$01
26149 3A 0B 5C     ld a,($5c0b)
26152 FE 6E        cp $6e
26154 20 03        jr nz,+$03
26156 CD 00 00     call $0000
26159 FE 79        cp $79


26161 20 E7        jr nz,-$19


6633h
26163 3E 02        ld a,$02
26165 CD 01 16     call $1601
26168 3E 11        ld a,$11
26170 D7           rst $10
26171 3E 05        ld a,$05
26173 D7           rst $10
26174 3E 16        ld a,$16
26176 D7           rst $10
26177 3E 15        ld a,$15
26179 D7           rst $10
26180 3E 07        ld a,$07
26182 D7           rst $10
26183 3E 20        ld a,$20
26185 D7           rst $10
26186 3E 20        ld a,$20
26188 D7           rst $10


26189 3E 20        ld a,$20
26191 D7           rst $10
26192 3E 20        ld a,$20
26194 D7           rst $10
26195 C3 C9 60     jp $60c9


6656h
defb $00 $00 $00 $00 $00 $00 $ed
defb $0b
defb $ed $0b $f0 $10 $ec $0b $ec
defb $10
defb $ec $0b $ec $10


666Ah
26218 06 07        ld b,$07
26220 21 5C 66     ld hl,$665c
26223 7E           ld a,(hl)


26224 32 78 66     ld ($6678),a
26227 23           inc hl
26228 C5           push bc
26229 E5           push hl
26230 EF           rst $28
defb $34 $ec $4c $cc $cc $cc $38
26238 E1           pop hl
26239 7E           ld a,(hl)
26240 E5           push hl
26241 CD 28 2D     call $2d28
26244 CD F8 03     call $03f8
26247 E1           pop hl
26248 C1           pop bc
26249 23           inc hl
26250 10 E3        djnz -$1d
26252 3E 01        ld a,$01
26254 CD 28 2D     call $2d28
26257 3E 14        ld a,$14
26259 CD 28 2D     call $2d28
26262 CD F8 03     call $03f8
26265 C9           ret


669Ah
defb $11 $08 $10 $0B $16 $02 $04
defb $20
defb $16 $00 $04 $96


66A6h
26278 2A 06 5B     ld hl,($5b06)
26281 22 9F 66     ld ($669f),hl
26284 2A 08 5B     ld hl,($5b08)
26287 22 A3 66     ld ($66a3),hl
26290 3E 02        ld a,$02
26292 CD 01 16     call $1601
26295 11 9A 66     ld de,$669a
26298 01 0C 00     ld bc,$000c
26301 CD 3C 20     call $203c
26304 CD 6A 66     call $666a


66C3h
26307 3A 05 5B     ld a,($5b05)
26310 3C           inc a
26311 32 05 5B     ld ($5b05),a
26314 2A 03 5B     ld hl,($5b03)
26317 11 32 00     ld de,$0032
26320 19           add hl,de
26321 22 03 5B     ld ($5b03),hl
26324 E5           push hl
26325 3E 02        ld a,$02
26327 CD 01 16     call $1601
```

```
26330 3E 16        ld a,$16
26332 D7           rst $10
26333 3E 15        ld a,$15
26335 D7           rst $10
26336 3E 07        ld a,$07
26338 D7           rst $10
26339 C1           pop bc

26340 CD 2B 2D     call $2d2b
26343 CD F3 2D     call $2de3

66EAh
26346 3A 05 5B     ld a,($5b05)
26349 E6 03        and $03
26351 C2 1E 64     jp nz,$641e

66F2h
26354 AF           xor a
26355 3A 05 5B     ld a,($5b05)
26358 FE 04        cp $04
26360 20 06        jr nz,+$06
26362 AF           xor a
26363 32 A9 7E     ld ($7ea9),a
26366 18 19        jr +$19

6700h
26368 FE 08        cp $08
26370 20 06        jr nz,+$06
26372 AF           xor a
26373 32 C2 7E     ld ($7ec2),a
26376 18 0F        jr +$0f

670Ah
26378 FE 0C        cp $0c
26380 20 06        jr nz,+$06
26382 AF           xor a
26383 32 D5 7E     ld ($7ed5),a
26386 18 05        jr +$05

6714h

26388 D6 25        sub $25
26390 D2 29 61     jp nc,$6129

5718h
26393 ED 4B 76 5C  ld bc,($5c76)
26397 CD 2B 2D     call $2d2b
26400 EF           rst $28

6721h

defb $a1 $0f $34 $37 $16 $04 $34
defb $80
defb $41 $00 $00 $80 $32 $02 $a1
defb $03 $31 $38


6733h

26419 CD A2 2D     call $2da2
26422 ED 43 76 5C  ld ($5c76),bc
26426 79           ld a,c
26427 E6 1F        and $1f
26429 D6 02        sub $02
26431 38 05        jr c,+$05

6741h
26433 3C           inc a

6742h
26434 FE 20        cp $20
26436 20 01        jr nz,+$01
26438 AF           xor a

6747h
26439 F5           push af
26440 47           ld b,a
26441 0E 0A        ld c,$0a
26443 CD 38 25     call $2538
26446 CD F1 2B     call $2bf1
26449 1A           ld a,(de)
26450 F5           push af
26451 CD BF 16     call $16bf
26454 F1           pop af
26455 FE 20        cp $20
26457 28 03        jr z,+$03
26459 F1           pop af
26460 18 E3        jr -$1d
26462 F1           pop af

675Fh
26463 3C           inc a
26464 F5           push af

26465 47           ld b,a
26466 0E 0A        ld c,$0a
26468 CD 38 25     call $2538
26471 CD F1 2B     call $2bf1
26474 1A           ld a,(de)
26475 F5           push af
26476 CD BF 16     call $16bf
26479 F1           pop af
26480 FE 20        cp $20
26482 28 03        jr z,+$03
26484 F1           pop af
26485 18 CA        jr -$36
```

```
6777h
26487 F1          pop af
26488 3D          dec a
26489 32 82 67    ld ($6782),a
26492 18 07       jr +$07
```

```
677Eh
defb $11 $04 $16 $0a $19 $9e $9f
```

```
6785h
26501 3E 02       ld a,$02
26503 CD 01 16    call $1601
26506 11 7E 67    ld de,$677e
26509 01 07 00    ld bc,$0007
26512 CD 3C 20    call $203c
```

```
6793h
26515 CD 6A 66    call $666a
```

```
6796h
26518 C3 29 61    jp $6129
```

Program 'Cross (machine code)'

Appendix 1 Replacement ROM routines

The Spectrum ROM routines are written in such a way that any wrong parameters are spotted and the correct error report given. For example, if you try to input PRINT AT 24, 33; "Message" then the PRINT routine will detect that line 24 column 33 is out of screen.

When writing machine code programs it can be assumed that the correct parameters will always be used and so the ROM routines can be rewritten without the error detection etc., which makes them faster and completely under programmer control.

The following six programs show how CLS., ATTR. SET, PRINT, PLOT, UNPLOT, SCR$ and POINT can be rewritten. The PRINT routine handles characters 32 to 127 inclusive (although it could be adapted to PRINT any character) and actually POKEs the character on to the screen thus making it unnecessary to OPEN CHANNEL 2 and allows printing on lines 22 and 23. The unused variable addresses 23728/9 are used to hold the current PRINT position.

The SCR$ routine detects characters 32 to 127 on lines 0 to 21 as the BASIC version but also allows lines 22 and 23 to be checked. The PLOT and UNPLOT routines have the same parameters as the BASIC, with 0, 0 as the bottom left-hand corner of line 21. If you change the value in address 23774 to 191 then the whole screen can be PLOTted and 0,0 will be the bottom left-hand corner of line 23. (Omitting instructions LD A, 175 at address 23774/5 will make 0,0 the top left-hand corner of line 1). The above also applies to the POINT routine. The address to be modified is 23777. You will see that the PLOT, UNPLOT and POINT routines use identical FIND subroutines to find the pixel to be checked; therefore if you were using all three routines they could share this common subroutine and save more memory. You could increase speed still more by adding DI (disable interrupt) at the start of these routines, or indeed at the beginning of your program, and EI at the end (or when a KEYSCAN is required). With these programs as a guide you could write a CIRCLE routine (one that runs faster than the Spectrum's).

```
org 23760
CLS ( Slow )

23760 21 00 40     ld hl,16384
L1
23763 36 00        ld (hl),0
23765 23           inc hl
23766 7C           ld a,h
23767 FE 58        cp 88
23769 20 F8        jr nz,L1
23771 C9           ret

CLS ( Fast )

23772 21 00 40     ld hl,16384
23775 11 01 40     ld de,16385
23778 01 FF 17     ld bc,6143
23781 36 00        ld (hl),0
23783 ED B0        ldir
23785 C9           ret
```

Program A1.1

```
org 23760
ATTRIBUTE FILL

EXAMPLE
INK 2 PAPER 5
BRIGHT 1 FLASH 1

2+40+64+128=234
```

Program A1.2

```
org 23760
PRINT STRING ROUTINE
POKES CHR. ONTO SCREEN
DOES NOT USE RST 16d

ADDRESS 23728 HOLDS COLUMN
ADDRESS 23729 HOLDS LINE

23760 11 E4 5C     ld de,DATA
L4
23763 1A           ld a,(de)
23764 CB 7F        bit 7,a
23766 20 06        jr nz,L3
23768 CD 02 5D     call PRINT
23771 13           inc de
23772 18 F5        jr L4
L3
23774 CB BF        res 7,a
23776 CD 02 5D     call PRINT
23779 C9           ret


DATA
defs McGRAW-HILL BOOK Co.
defs  (UK) Ltd

128+CHR 46="."

defb 174

PRINT ROUTINE

GET LINE/COLUMN IN HL

PRINT
23810 D5           push de
23811 2A B0 5C     ld hl,(23728)
23814 E5           push hl
23815 F5           push af

CHECK OUT OF SCREEN

23816 AF           xor a


23817 7C           ld a,h
23818 D6 18        sub 24
23820 38 02        jr c,OK
23822 CF           rst 8
defb 4

23760 3E EA        ld a,234
23762 21 00 58     ld hl,22528
23765 11 01 58     ld de,22529
23768 01 FF 02     ld bc,767
23771 77           ld (hl),a
23772 ED B0        ldir
23774 C9           ret

FIND SCREEN POITION

OK
23824 11 00 40     ld de,16384
23827 19           add hl,de
23828 7C           ld a,h
23829 E6 07        and 7
23831 0F           rrca
23832 0F           rrca
23833 0F           rrca
23834 B5           or l
23835 6F           ld l,a
23836 3E F8        ld a,248
23838 A4           and h
23839 67           ld h,a


FIND START OF CHR.
IN CHR. GENERATOR

23840 F1           pop af
23841 E5           push hl
23842 11 00 3C     ld de,15360
23845 6F           ld l,a
23846 26 00        ld h,0
23848 29           add hl,hl
23849 29           add hl,hl
23850 29           add hl,hl
23851 19           add hl,de
23852 D1           pop de

POKE CHR. ONTO SCREEN

23853 06 08        ld b,8
L1
23855 7E           ld a,(hl)
23856 12           ld (de),a


23857 23           inc hl
23858 14           inc d
23859 10 FA        djnz L1

UPDATE SCREEN POSITION

23861 E1           pop hl
23862 2C           inc l
23863 CB 6D        bit 5,l
23865 28 03        jr z,L2
```

```
23867 CB AD       res 5,l
23869 24          inc h
L2
23870 22 B0 5C    ld (23728),hl
23873 D1          pop de
23874 C9          ret
```

Program A1.3

```
org 23760

PROGRAM TO REPLACE SCREEN$
REQUIRES H=LINE, L=COLUMN
RETURNS WITH A REGISTER
HOLDING CHR CODE
OR 0 IF CHR NOT FOUND

23760 26 0A       ld h,10
23762 2E 07       ld l,7
23764 CD D8 5C    call SCR$
23767 C9          ret

SCREEN$ ROUTINE

SCR$

FIND SCREEN ADDRESS OF CHR

23768 11 00 40    ld de,16384


23771 19          add hl,de
23772 7C          ld a,h
23773 E6 07       and 7
23775 0F          rrca
23776 0F          rrca
23777 0F          rrca
23778 B5          or l
23779 6F          ld l,a
23780 3E F8       ld a,248
23782 A4          and h
23783 67          ld h,a

CHECK CHR WITH CHR GEN.

23784 11 00 3D    ld de,15616
L3
23787 06 08       ld b,8
23789 0E 00       ld c,0
```

Program A1.4

```
org 23760
PROGRAM TO REPLACE ROM PLOT
REQUIRES H=y, L=x

23760 26 00       ld h,0
23762 2E 5F       ld l,95
23764 CD D8 5C    call PLOT
23767 C9          ret
PLOT

CHECK FOR DE=16384
23791 CB 72       bit 6,d
23793 20 11       jr nz,NFOUND


23795 E5          push hl
L2
23796 1A          ld a,(de)
23797 BE          cp (hl)
23798 20 01       jr nz,L1
23800 0C          inc c
L1
23801 13          inc de
23802 24          inc h
23803 10 F7       djnz L2
23805 E1          pop hl
23806 CB 59       bit 3,c
23808 20 04       jr nz,FOUND
23810 18 E7       jr L3
NFOUND
23812 AF          xor a
23813 C9          ret

CONVERT TO CHR CODE

FOUND


23814 B7          or a
23815 21 00 3C    ld hl,15360
23818 EB          ex de,hl
23819 ED 52       sbc hl,de
23821 06 03       ld b,3
L4
23823 CB 1C       rr h
23825 CB 1D       rr l
23827 10 FA       djnz L4
23829 7D          ld a,l
23830 3D          dec a
23831 C9          ret


23768 CD DE 5C    call FIND
23771 B6          or (hl)
23772 77          ld (hl),a
23773 C9          ret

FIND SCREEN BIT
RET WITH HL=BYTE, A=BIT

FIND
```

```
23774 3E AF       ld a,175
23776 94          sub h

23777 67          ld h,a
23778 11 00 40    ld de,16384
23781 7D          ld a,l
23782 E6 07       and 7
23784 F5          push af
23785 7D          ld a,l
23786 E6 F8       and 248
23788 1F          rra
23789 1F          rra
23790 1F          rra
23791 5F          ld e,a
23792 7C          ld a,h
23793 E6 38       and 56
23795 17          rla
23796 17          rla
23797 B3          or e
23798 5F          ld e,a
23799 7C          ld a,h
23800 E6 07       and 7
23802 B2          or d
```

Program A1.5

```
org 23760
PROGRAM TO REPLACE
ROM PLOT OVER 1
REQUIRES H=y, L=x

23760 26 00       ld h,0
23762 2E 5F       ld l,95
23764 CD D8 5C    call PLOTOVER
23767 C9          ret
PLOTOVER
23768 CD DE 5C    call FIND
23771 AE          xor (hl)
23772 77          ld (hl),a
23773 C9          ret

FIND SCREEN BIT
RET WITH HL=BYTE, A=BIT

FIND
23774 3E AF       ld a,175


23776 94          sub h
23777 67          ld h,a
23778 11 00 40    ld de,16384
23781 7D          ld a,l
23782 E6 07       and 7
23784 F5          push af
23785 7D          ld a,l
23786 E6 F8       and 248
23788 1F          rra
23789 1F          rra
23790 1F          rra
```

Program A1.6

```
23803 57          ld d,a

23804 7C          ld a,h
23805 E6 C0       and 192
23807 1F          rra
23808 1F          rra
23809 1F          rra
23810 B2          or d
23811 57          ld d,a
23812 F1          pop af
23813 2E 80       ld l,128
L1
23815 A7          and a
23816 FE 00       cp 0
23818 28 05       jr z,L2
23820 CB 1D       rr l
23822 3D          dec a
23823 18 F6       jr L1
L2
23825 7D          ld a,l
23826 EB          ex de,hl
23827 C9          ret
```

```
23791 5F          ld e,a
23792 7C          ld a,h
23793 E6 38       and 56
23795 17          rla
23796 17          rla
23797 B3          or e
23798 5F          ld e,a
23799 7C          ld a,h
23800 E6 07       and 7
23802 B2          or d

23803 57          ld d,a
23804 7C          ld a,h
23805 E6 C0       and 192
23807 1F          rra
23808 1F          rra
23809 1F          rra
23810 B2          or d
23811 57          ld d,a
23812 F1          pop af
23813 2E 80       ld l,128
L1
23815 A7          and a
23816 FE 00       cp 0
23818 28 05       jr z,L2
23820 CB 1D       rr l
23822 3D          dec a
23823 18 F6       jr L1
L2
23825 7D          ld a,l
23826 EB          ex de,hl
23827 C9          ret
```

Appendix 1—continued

```
org 23760
PROGRAM TO REPLACE
ROM POINT
REQUIRES H=y, L=x

23760 26 00       ld h,0
23762 2E 5F       ld l,95
23764 CD DB 5C    call POINT
23767 C9          ret
POINT
23768 CD E0 5C    call FIND
23771 A6          and (hl)
23772 C8          ret z
23773 3E 01       ld a,1
23775 C9          ret

FIND SCREEN BIT
RET WITH HL=BYTE, A=BIT

FIND

23776 3E AF       ld a,175
23778 94          sub h
23779 67          ld h,a
23780 11 00 40    ld de,16384
23783 7D          ld a,l
23784 E6 07       and 7
23786 F5          push af
23787 7D          ld a,l
23788 E6 F8       and 248
23790 1F          rra
23791 1F          rra
23792 1F          rra
23793 5F          ld e,a
23794 7C          ld a,h
23795 E6 38       and 56
23797 17          rla
23798 17          rla
23799 B3          or e
23800 5F          ld e,a
23801 7C          ld a,h
23802 E6 07       and 7

23804 B2          or d
23805 57          ld d,a
23806 7C          ld a,h
23807 E6 C0       and 192
23809 1F          rra
23810 1F          rra
23811 1F          rra
23812 B2          or d
23813 57          ld d,a
23814 F1          pop af
23815 2E 80       ld l,128
L1
23817 A7          and a
23818 FE 00       cp 0
23820 28 05       jr z,L2
23822 CB 1D       rr l
23824 3D          dec a
23825 18 F6       jr L1
L2
23827 7D          ld a,l
23828 EB          ex de,hl

23829 C9          ret
```

Program A1.7

Appendix 2

Spectrum (Z80) machine code listings

NOTES: (HL)—the number held in the address to which register pair HL points
NN is entered as second number first, for example, **4000** is entered as 00 40 (in hex.)
Register A—the general-purpose accumulator

Decimal	*Bytes*	*Hex*	*Mnemonic*	*Description*
0	1	00	nop	No operation
1	3	01	ld bc,NN	Load BC with NN
2	1	02	ld (bc),a	Store A to (BC)
3	1	03	inc bc	Increment BC by 1
4	1	04	inc b	Increment B by 1
5	1	05	dec b	Decrement B by 1
6	2	06	ld b,N	Load B with N
7	1	07	rlca	Rotate left circular A
8	1	08	ex af, af	Set prime AF active
9	1	09	add hl,bc	BC+HL→HL
10	3	0A	ld a,(bc)	Load A with number in location (BC)
11	1	0B	dec bc	Decrement BC by 1
12	1	0C	inc c	Increment C by 1
13	1	0D	dec c	Decrement C by 1
14	2	0E	ld c,N	Load C with N
15	1	0F	rrca	Rotate A right circular
16	2	10	djnz x	Decrement B and JR if B ≠ 0, + or − x
17	3	11	ld de,NN	Load DE with NN
18	1	12	ld (de),a	Store A to (DE)
19	1	13	inc de	Increment DE by 1
20	1	14	inc d	Increment D by 1
21	1	15	dec d	Decrement D by 1
22	2	16	ld d,N	Load D with N
23	1	17	rla	Rotate A left thru carry
24	2	18	jr x	Unconditional jump relative, + or − x
25	1	19	add hl,de	DE+HL→HL
26	3	1A	ld a,(de)	Load A with location (DE)
27	1	1B	dec de	Decrement DE by 1
28	1	1C	inc e	Increment E by 1
29	1	1D	dec e	Decrement E by 1
30	2	1E	ld e,N	Load E with N
31	1	1F	rra	Rotate A right thru carry
32	2	20	jr nz, x	Jump relative if non-zero, + or − x
33	3	21	ld hl,NN	Load HL with NN
34	3	22	ld (NN),hl	Store HL to location NN
35	1	23	inc hl	Increment HL by 1
36	1	24	inc h	Increment H by 1
37	1	25	dec h	Decrement H by 1
38	2	26	ld h,N	Load H with N
39	1	27	daa	Decimal adjust A
40	2	28	jr z, x	Jump relative if zero, + or − x
41	1	29	add hl,hl	HL+HL→HL
42	3	2A	ld hl,(NN)	Load HL with location (NN)
43	1	2B	dec hl	Decrement HL by 1
44	1	2C	inc l	Increment L by 1
45	1	2D	dec l	Decrement L by 1
46	2	2E	ld l,N	Load L with N
47	1	2F	cpl	Complement A (1's comp.)
48	2	30	jr nc, x	Jump relative if no carry, + or − x
49	3	31	ld sp,NN	Load stack pointer with NN
50	3	32	ld (NN),a	Store A to location NN
51	1	33	inc sp	Increment SP by 1
52	1	34	inc (hl)	Increment (HL) by 1
53	1	35	dec (hl)	Decrement (HL) by 1
54	2	36	ld (hl),N	Store N to (HL)
55	1	37	scf	Set carry flag
56	2	38	jr c, x	Jump relative if carry, + or − x
57	1	39	add hl,sp	SP+HL→HL
58	3	3A	ld a,(NN)	Load A with location (NN)
59	1	3B	dec sp	Decrement SP by 1
60	1	3C	inc a	Increment A by 1
61	1	3D	dec a	Decrement A by 1

Decimal	*Bytes*	*Hex*	*Mnemonic*	*Description*
62	2	3E	ld a,N	Load A with N
63	1	3F	ccf	Complement carry flag
64	1	40	ld b,b	Move B to B
65	1	41	ld b,c	Move C to B
66	1	42	ld b,d	Move D to B
67	1	43	ld b,e	Move E to B
68	1	44	ld b,h	Move H to B
69	1	45	ld b,l	Move L to B
70	1	46	ld b,(hl)	Move (HL) to B
71	1	47	ld b,a	Move A to B
72	1	48	ld c,b	Move B to C
73	1	49	ld c,c	Move C to C
74	1	4A	ld c,d	Move D to C
75	1	4B	ld c,e	Move E to C
76	1	4C	ld c,h	Move H to C
77	1	4D	ld c,l	Move L to C
78	1	4E	ld c,(hl)	Move (HL) to C
79	1	4F	ld c,a	Move A to C
80	1	50	ld d,b	Move B to D
81	1	51	ld d,c	Move C to D
82	1	52	ld d,d	Move D to D
83	1	53	ld d,e	Move E to D
84	1	54	ld d,h	Move H to D
85	1	55	ld d,l	Move L to D
86	1	56	ld d,(hl)	Move (HL) to D
87	1	57	ld d,a	Move A to D
88	1	58	ld e,b	Move B to E
89	1	59	ld e,c	Move C to E
90	1	5A	ld e,d	Move D to E
91	1	5B	ld e,e	Move E to E
92	1	5C	ld e,h	Move H to E
93	1	5D	ld e,l	Move L to E
94	1	5E	ld e,(hl)	Move (HL) to E
95	1	5F	ld e,a	Move A to E
96	1	60	ld h,b	Move B to H
97	1	61	ld h,c	Move C to H
98	1	62	ld h,d	Move D to H
99	1	63	ld h,e	Move E to H
100	1	64	ld h,h	Move H to H
101	1	65	ld h,l	Move L to H
102	1	66	ld h,(hl)	Move (HL) to H
103	1	67	ld h,a	Move A to H
104	1	68	ld l,b	Move B to L
105	1	69	ld l,c	Move C to L
106	1	6A	ld l,d	Move D to L
107	1	6B	ld l,e	Move E to L
108	1	6C	ld l,h	Move H to L
109	1	6D	ld l,l	Move L to L
110	1	6E	ld l,(hl)	Move (HL) to L
111	1	6F	ld l,a	Move A to L
112	1	70	ld (hl),b	Move B to (HL)
113	1	71	ld (hl),c	Move C to (HL)
114	1	72	ld (hl),d	Move D to (HL)
115	1	73	ld (hl),e	Move E to (HL)
116	1	74	ld (hl),h	Move H to (HL)
117	1	75	ld (hl),l	Move L to (HL)
118	1	76	halt	HALT
119	1	77	ld (hl),a	Move A to (HL)
120	1	78	ld a,b	Move B to A
121	1	79	ld a,c	Move C to A
122	1	7A	ld a,d	Move D to A
123	1	7B	ld a,e	Move E to A
124	1	7C	ld a,h	Move H to A
125	1	7D	ld a,l	Move L to A
126	1	7E	ld a,(hl)	Move (HL) to A
127	1	7F	ld a,a	Move A to A
128	1	80	add a,b	B+A→A
129	1	81	add a,c	C+A→A
130	1	82	add a,d	D+A→A
131	1	83	add a,e	E+A→A

Appendix 2—continued

Decimal	*Bytes*	*Hex*	*Mnemonic*	*Description*
132	1	84	add a,h	H+A→A
133	1	85	add a,l	L+A→A
134	1	86	add a,(hl)	(HL)+A→A
135	1	87	add a,a	A+A→A
136	1	88	adc a,b	B+A+carry→A
137	1	89	adc a,c	C+A+carry→A
138	1	8A	adc a,d	D+A+carry→A
139	1	8B	adc, a,e	E+A+carry→A
140	1	8C	adc, a,h	H+A+carry→A
141	1	8D	adc, a,l	L+A+carry→A
142	1	8E	adc a,(hl)	(HL)+A+carry→A
143	1	8F	adc a,a	A+A+carry→A
144	1	90	sub b	A−B→A
145	1	91	sub c	A−C→A
146	1	92	sub d	A−D→A
147	1	93	sub e	A−E→A
148	1	94	sub h	A−H→A
149	1	95	sub l	A−L→A
150	1	96	sub (hl)	A−(HL)→A
151	1	97	sub a	A−A→A
152	1	98	sbc a,b	A−B−carry→A
153	1	99	sbc a,c	A−C−carry→A
154	1	9A	sbc a,d	A−D−carry→A
155	1	9B	sbc a,e	A−E−carry→A
156	1	9C	sbc a,h	A−H−carry→A
157	1	9D	sbc a,l	A−L−carry→A
158	1	9E	sbc a,(hl)	A−(HL)−carry→A
159	1	9F	sbc a,a	A−A−carry→A
160	1	A0	and b	A and B→A
161	1	A1	and c	A and C→A
162	1	A2	and d	A and D→A
163	1	A3	and e	A and E→A
164	1	A4	and h	A and H→A
165	1	A5	and l	A and L→A
166	1	A6	and (hl)	A and (HL)→A
167	1	A7	and a	A and A→A
168	1	A8	xor b	A exclusive or B→A
169	1	A9	xor c	A exclusive or C→A
170	1	AA	xor d	A exclusive or D→A
171	1	AB	xor e	A exclusive or E→A
172	1	AC	xor h	A exclusive or H→A
173	1	AD	xor l	A exclusive or L→A
174	1	AE	xor (hl)	A exclusive or (HL)→A
175	1	AF	xor a	A exclusive or A→A
176	1	B0	or b	A or B→A
177	1	B1	or c	A or C→A
178	1	B2	or d	A or D→A
179	1	B3	or e	A or E→A
180	1	B4	or h	A or H→A
181	1	B5	or l	A or L→A
182	1	B6	or (hl)	A or (HL)→A
183	1	B7	or a	A or A→A
184	1	B8	cp b	Compare A:B
185	1	B9	cp c	Compare A:C
186	1	BA	cp d	Compare A:D
187	1	BB	cp e	Compare A:E
188	1	BC	cp h	Compare A:H
189	1	BD	cp l	Compare A:L
190	1	BE	cp (hl)	Compare A:(HL)
191	1	BF	cp a	Compare A:A
192	1	C0	ret nz	Return if non-zero
193	1	C1	pop bc	Pop BC from stack
194	3	C2	jp nz,NN	Jump to NN if non zero
195	3	C3	jp NN	Unconditional jump to NN
196	3	C4	call nz,NN	Call NN if non-zero
197	1	C5	push bc	Push BC onto stack
198	2	C6	add a,N	A+N→A
199	1	C7	rst 0	Call 0000 start routine
200	1	C8	ret z	Return if zero
201	1	C9	ret	Return

Appendix 2—continued

Decimal	*Bytes*	*Hex*	*Mnemonic*	*Description*
202	3	CA	jp z,NN	Jump to NN if zero
203		CB		See special set of CB routines
204	3	CC	call z,NN	Call NN if zero
205	3	CD	call NN	Call NN
206	2	CE	adc a,N	A+N+carry→A
207	1	CF	rst 8	Call 0008 error routine
208	1	D0	ret nc	Return if carry = 0
209	1	D1	pop de	Pop DE from stack
210	3	D2	jp nc,NN	Jump to NN if carry = 0
211	2	D3	out (N),a	Output A to port N
212	3	D4	call nc,NN	Call NN if carry = 0
213	1	D5	push de	Push DE onto stack
214	2	D6	sub N	A−N→A
215	1	D7	rst 16	Call 0010 print routine
216	1	D8	ret c	Return if carry = 1
217	1	D9	exx	Set prime B–L active (exchange registers)
218	3	DA	jp c,NN	Jump to NN if carry = 1
219	2	DB	in a,(N)	Input to A from port N
220	3	DC	call c,NN	Call NN if carry = 1
221		DD	prefixes instructions using ix	See special set of DD routines
222	2	DE	sbc a,N	A−N−carry→A
223	1	DF	rst 24	Call 0018 character routine (1)
224	1	E0	ret po	Return if overflow/parity flag = 0
225	1	E1	pop hl	Pop HL from stack
226	3	E2	jp po,NN	Jump to NN if overflow/parity flag = 0
227	1	E3	ex (sp),hl	Exchange (SP) and HL
228	3	E4	call po,NN	Call NN if overflow/parity flag = 0
229	1	E5	push hl	Push HL onto stack
230	2	E6	and N	A and N→A
231	1	E7	rst 32	Call 0020 character routine (2)
232	1	E8	ret pe	Return if overflow/parity flag = 1
233	1	E9	jp (hl)	Jump to location (HL)
234	3	EA	jp pe,NN	Jump to NN if overflow/parity flag = 1
235	1	EB	ex de,hl	Exchange DE and HL
236	3	EC	call pe,NN	Call NN if overflow/parity flag = 1
237		ED		See special set of ED routines
238	2	EE	xor N	A exclusive or N→A
239	1	EF	rst 40	Call 0028 calculator routine
240	1	F0	ret p	Return if sign flag = 0
241	1	F1	pop af	Pop AF from stack
242	3	F2	jp p,NN	Jump to NN if sign flag = 0
243	1	F3	di	Disable interrupts
244	3	F4	call p,NN	Call NN if sign flag = 0
245	1	F5	push af	Push AF onto stack
246	2	F6	or N	A or N→A
247	1	F7	rst 48	Call 0030 work space routine
248	1	F8	ret m	Return if sign flag = 1
249	1	F9	ld sp,hl	Move HL to SP
250	3	FA	jp m,NN	Jump to NN if sign flag = 1
251	1	FB	ei	Enable interrupts
252	3	FC	call m,NN	Call NN if sign flag = 1
253		FD	prefixes instructions using iy	See special set of FD routines
254	2	FE	cp N	Compare A:N
255	1	FF	rst 56	Call 0038

DD 09	ADD	IX,BC
DD 19	ADD	IX,DE
DD 21 +dddd	LD	IX,+dddd
DD 22 addr	LD	(addr),IX
DD 23	INC	IX
DD 29	ADD	IX,IX
DD 2A addr	LD	IX,(addr)
DD 2B	DEC	IX
DD 34 d	INC	(IX+d)
DD 35 d	DEC	(IX+d)
DD 36 d +dd	LD	(IX+d),+dd
DD 39	ADD	IX,SP
DD 46 d	LD	B,(IX+d)
DD 4E d	LD	C,(IX+d)
DD 56 d	LD	D,(IX+d)
DD 5E d	LD	E,(IX+d)
DD 66 d	LD	H,(IX+d)
DD 6E d	LD	L,(IX+d)
DD 70 d	LD	(IX+d),B
DD 71 d	LD	(IX+d),C
DD 72 d	LD	(IX+d),D
DD 73 d	LD	(IX+d),E
DD 74 d	LD	(IX+d),H
DD 75 d	LD	(IX+d),L
DD 77 d	LD	(IX+d),A
DD 7E d	LD	A,(IX+d)
	ADD	A,(IX+d)
DD 8E d	ADC	A,(IX+d)
DD 96 d	SUB	(IX+d)
DD 9E d	SBC	A,(IX+d)
DD A6 d	AND	(IX+d)
DD AE d	XOR	(IX+d)
DD B6 d	OR	(IX+d)
DD BE d	CP	(IX+d)

DD CB d 06	RLC	(IX+d)
DD CB d 0E	RRC	(IX+d)
DD CB d 16	RL	(IX+d)
DD CB d 1E	RR	(IX+d)
DD CB d 26	SLA	(IX+d)
DD CB d 2E	SRA	(IX+d)
DD CB d 3E	SRL	(IX+d)
DD CB d 46	BIT	0,(IX+d)
DD CB d 4E	BIT	1,(IX+d)
DD CB d 56	BIT	2,(IX+d)
DD CB d 5E	BIT	3,(IX+d)
DD CB d 66	BIT	4,(IX+d)
DD CB d 6E	BIT	5,(IX+d)
DD CB d 76	BIT	6,(IX+d)
DD CB d 7E	BIT	7,(IX+d)
DD CB d 86	RES	0,(IX+d)
DD CB d 8E	RES	1,(IX+d)
DD CB d 96	RES	2,(IX+d)
DD CB d 9E	RS	3,(IX+d)
DD CB d A6	RES	4,(IX+d)
DD CB d AE	RES	5,(IX+d)
DD CB d B6	RES	6,(IX+d)
DD CB d BE	RES	7,(IX+d)
DD CB d C6	SET	0,(IX+d)
DD CB d CE	SET	1,(IX+d)
DD CB d D6	SET	2,(IX+d)
DD CB d DE	SET	3,(IX+d)
DD CB d E6	SET	4,(IX+d)
DD CB d EE	SET	5,(IX+d)
DD CB d F6	SET	6,(IX+d)
DD CB d FE	SET	7,(IX+d)
DD E1	POP	IX
DD E3	EX	(SP),IX
DD E5	PUSH	IX
DD E9	JP	(IX)
DD F9	LD	SP,IX

ED Instructions

ED 40 IN B,(C)	ED 50 IN D,(C)	ED 60 IN H,(C)		ED A0 LDI	ED B0 LDIR
ED 41 OUT (C),B	ED 51 OUT (C),D	ED 61 OUT (C),H		ED A1 CPI	ED B1 CPIR
ED 42 SBC HL,BC	ED 52 SBC HL,DE	ED 62 SBC HL,HL	ED 72 SBC HL,SP	ED A2 INI	ED B2 INIR
ED 43 (addr),BC	ED 53 (addr),DE	ED 63 (addr),HL	ED 73 (addr),SP	ED A3 OUTI	ED B3 OTIR
ED 44 NEG					
ED 45 RETN					
ED 46 IM 0	ED 56 IM 1	ED 66 IM 2			
ED 47 LD I,A	ED 57 LD A,I	ED 67 RRD			
ED 48 IN C,(C)	ED 58 IN E,(C)	ED 68 IN L,(C)	ED 78 IN A,(C)	ED A8 LDD	ED B8 LDDR
ED 49 OUT (C),C	ED 59 OUT (C),E	ED 69 OUT (C),L	ED 79 OUT (C),A	ED A9 CPD	ED B9 CPDR
ED 4A ADC HL,BC	ED 5A ADC HL,DE	ED 6A ADC HL,HL	ED 7A ADC HL,SP	ED AA IND	ED BA INDR
ED 4B LD BC,(addr)	ED 5B LD DE,(addr)	ED 6B LD HL,(addr)	ED 7B LD SP,(addr)	ED AB OUTD	ED BB OTRD
ED 4D RETI					
ED 4F LD R,A	ED 5F LD A,R	ED 6F RLD			

Appendix 3

Decimal-hexadecimal conversion table

Decimal 0–255 Hexadecimal 00–FF, Low byte

Dec.	Hex.	Dec.	Hex.	Dec.	Hex.	2's C.	Dec.	Hex.	2's C.
0	00	64	40	128	80	−128	192	C0	−64
1	01	65	41	129	81	−127	193	C1	−63
2	02	66	42	130	82	−126	194	C2	−62
3	03	67	43	131	83	−125	195	C3	−61
4	04	68	44	132	84	−124	196	C4	−60
5	05	69	45	133	85	−123	197	C5	−59
6	06	70	46	134	86	−122	198	C6	−58
7	07	71	47	135	87	−121	199	C7	−57
8	08	72	48	136	88	−120	200	C8	−56
9	09	73	49	137	89	−119	201	C9	−55
10	0A	74	4A	138	8A	−118	202	CA	−54
11	0B	75	4B	139	8B	−117	203	CB	−53
12	0C	76	4C	140	8C	−116	204	CC	−52
13	0D	77	4D	141	8D	−115	205	CD	−51
14	0E	78	4E	142	8E	−114	206	CE	−50
15	0F	79	4F	143	8F	−113	207	CF	−49
16	10	80	50	144	90	−112	208	D0	−48
17	11	81	51	145	91	−111	209	D1	−47
18	12	82	52	146	92	−110	210	D2	−46
19	13	83	53	147	93	−109	211	D3	−45
20	14	84	54	148	94	−108	212	D4	−44
21	15	85	55	149	95	−107	213	D5	−43
22	16	86	56	150	96	−106	214	D6	−42
23	17	87	57	151	97	−105	215	D7	−41
24	18	88	58	152	98	−104	216	D8	−40
25	19	89	59	153	99	−103	217	D9	−39
26	1A	90	5A	154	9A	−102	218	DA	−38
27	1B	91	5B	155	9B	−101	219	DB	−37
28	1C	92	5C	156	9C	−100	220	DC	−36
29	1D	93	5D	157	9D	−99	221	DD	−35
30	1E	94	5E	158	9E	−98	222	DE	−34
31	1F	95	5F	159	9F	−97	223	DF	−33
32	20	96	60	160	A0	−96	224	E0	−32
33	21	97	61	161	A1	−95	225	E1	−31
34	22	98	62	162	A2	−94	226	E2	−30
35	23	99	63	163	A3	−93	227	E3	−29
36	24	100	64	164	A4	−92	228	E4	−28
37	25	101	65	165	A5	−91	229	E5	−27
38	26	102	66	166	A6	−90	230	E6	−26
39	27	103	67	167	A7	−89	231	E7	−25
40	28	104	68	168	A8	−88	232	E8	−24
41	29	105	69	169	A9	−87	233	E9	−23
42	2A	106	6A	170	AA	−86	234	EA	−22
43	2B	107	6B	171	AB	−85	235	EB	−21
44	2C	108	6C	172	AC	−84	236	EC	−20
45	2D	109	6D	173	AD	−83	237	ED	−19
46	2E	110	6E	174	AE	−82	238	EE	−18
47	2F	111	6F	175	AF	−81	239	EF	−17
48	30	112	70	176	B0	−80	240	F0	−16
49	31	113	71	177	B1	−79	241	F1	−15
50	32	114	72	178	B2	−78	242	F2	−14
51	33	115	73	179	B3	−77	243	F3	−13
52	34	116	74	180	B4	−76	244	F4	−12
53	35	117	75	181	B5	−75	245	F5	−11
54	36	118	76	182	B6	−74	246	F6	−10
55	37	119	77	183	B7	−73	247	F7	−9
56	38	120	78	184	B8	−72	248	F8	−8
57	39	121	79	185	B9	−71	249	F9	−7
58	3A	122	7A	186	BA	−70	250	FA	−6
59	3B	123	7B	187	BB	−69	251	FB	−5
60	3C	124	7C	188	BC	−68	252	FC	−4
61	3D	125	7D	189	BD	−67	253	FD	−3
62	3E	126	7E	190	BE	−66	254	FE	−2
63	3F	127	7F	191	BF	−65	255	FF	−1

Decimal 0–65 280 Hexadecimal 00–FF, high byte

Decimal	Hex.	Decimal	Hex.	Decimal	Hex.	Decimal	Hex.
0	00	16 384	40	32 768	80	49 152	C0
256	01	16 640	41	33 024	81	49 408	C1
512	02	16 896	42	33 280	82	49 664	C2
768	03	17 152	43	33 536	83	49 920	C3
1 024	04	17 408	44	33 792	84	50 176	C4
1 280	05	17 664	45	34 048	85	50 432	C5
1 536	06	17 920	46	34 304	86	50 688	C6
1 792	07	18 176	47	34 560	87	50 944	C7
2 048	08	18 432	48	34 816	88	51 200	C8
2 304	09	18 688	49	35 072	89	51 456	C9
2 560	0A	18 944	4A	35 328	8A	51 712	CA
2 816	0B	19 200	4B	35 584	8B	51 968	CB
3 072	0C	19 456	4C	35 840	8C	52 224	CC
3 328	0D	19 712	4D	36 096	8D	52 480	CD
3 584	0E	19 968	4E	36 352	8E	52 736	CE
3 840	0F	20 224	4F	36 608	8F	52 992	CF
4 096	10	20 480	50	36 864	90	53 248	D0
4 352	11	20 736	51	37 120	91	53 504	D1
4 608	12	20 992	52	37 376	92	53 760	D2
4 864	13	21 248	53	37 632	93	54 016	D3
5 120	14	21 504	54	37 888	94	54 272	D4
5 376	15	21 760	55	38 144	95	54 528	D5
5 632	16	22 016	56	38 400	96	54 784	D6
5 888	17	22 272	57	38 656	97	55 040	D7
6 144	18	22 528	58	38 912	98	55 296	D8
6 400	19	22 784	59	39 168	99	55 552	D9
6 656	1A	23 040	5A	39 424	9A	55 808	DA
6 912	1B	23 296	5B	39 680	9B	56 064	DB
7 168	1C	23 552	5C	39 936	9C	56 320	DC
7 424	1D	23 808	5D	40 192	9D	56 576	DD
7 680	1E	24 064	5E	40 448	9E	56 832	DE
7 936	1F	24 320	5F	40 704	9F	57 088	DF
8 192	20	24 576	60	40 960	A0	57 344	E0
8 448	21	24 832	61	41 216	A1	57 600	E1
8 704	22	25 088	62	41 472	A2	57 856	E2
8 960	23	25 344	63	41 728	A3	58 112	E3
9 216	24	25 600	64	41 984	A4	58 368	E4
9 472	25	25 856	65	42 240	A5	58 624	E5
9 728	26	26 112	66	42 496	A6	58 880	E6
9 984	27	26 368	67	42 752	A7	59 136	E7
10 240	28	26 624	68	43 008	A8	59 392	E8
10 496	29	26 880	69	43 264	A9	59 648	E9
10 752	2A	27 136	6A	43 520	AA	59 904	EA
11 008	2B	27 392	6B	43 776	AB	60 160	EB
11 264	2C	27 648	6C	44 032	AC	60 416	EC
11 520	2D	27 904	6D	44 288	AD	60 672	ED
11 776	2E	28 160	6E	44 544	AE	60 928	EE
12 032	2F	28 416	6F	44 800	AF	61 184	EF
12 288	30	28 672	70	45 056	B0	61 440	F0
12 544	31	28 928	71	45 312	B1	61 696	F1
12 800	32	29 184	72	45 568	B2	61 952	F2
13 056	33	29 440	73	45 824	B3	62 208	F3
13 312	34	29 696	74	46 080	B4	62 464	F4
13 568	35	29 952	75	46 336	B5	62 720	F5
13 824	36	30 208	76	46 592	B6	62 976	F6
14 080	37	30 464	77	46 848	B7	63 232	F7
14 336	38	30 720	78	47 104	B8	63 488	F8
14 592	39	30 976	79	47 360	B9	63 744	F9
14 848	3A	31 232	7A	47 616	BA	64 000	FA
15 104	3B	31 488	7B	47 872	BB	64 256	FB
15 360	3C	31 744	7C	48 128	BC	64 512	FC
15 616	3D	32 000	7D	48 384	BD	64 768	FD
15 872	3E	32 256	7E	48 640	BE	65 024	FE
16 128	3F	32 512	7F	48 896	BF	65 280	FF

Appendix 4

Useful calculator literals

Literal d	Function	Action
1	EXCHANGE	Top two values swapped
3	SUBTRACT	Top value subtracted from the one underneath
4	MULTIPLY	Multiply top two values
5	DIVIDE	Top value divided into the one underneath
15	ADD	Add top two values
31	SIN	Sine of top value
32	COS	Cosine of top value
33	TAN	Tangent of top value
39	INT	Integer of top value
40	SQR	Square root of top value
49	DUPLICATE	Duplicate top value and place on top of stack
52	STK	Stack data held in compressed form (see Chapter 7)
56	END	Finish calculator routine and return to machine code program
61	RESTACK	Replace top value with its floating point form
160	0	Stack 0
161	1	Stack 1
162	½	Stack ½
163	$\pi/2$	Stack $\pi/2$
164	10	Stack 10

Appendix 5

Memory map of display file

Line		Line		Line	
0	4000 4100 4200 4300 4400 4500 4600 4700	8	4700 4800 4900 4A00 4B00 4C00 4D00 4E00	16	5000 5100 5200 5300 5400 5500 5600 5700
1	4020 4120 4220 4320 4420 4520 4620 4720	9	4720 4820 4920 4A20 4B20 4C20 4D20 4E20	17	5020 5120 5220 5320 5420 5520 5620 5720
2	4040 4140 4240 4340 4440 4540 4640 4740	10	4740 4840 4940 4A40 4B40 4C40 4D40 4E40	18	5040 5140 5240 5340 5440 5540 5640 5740
3	4060 4160 4260 4360 4460 4560 4660 4760	11	4760 4860 4960 4A60 4B60 4C60 4D60 4E60	19	5060 5160 5260 5360 5460 5560 5660 5760
4	4080 4180 4280 4380 4480 4580 4680 4780	12	4780 4880 4980 4A80 4B80 4C80 4D80 4E80	20	5080 5180 5280 5380 5480 5580 5680 5780
5	40A0 41A0 42A0 43A0 44A0 45A0 46A0 47A0	13	47A0 48A0 49A0 4AA0 4BA0 4CA0 4DA0 4EA0	21	50A0 51A0 52A0 53A0 64A0 55A0 56A0 57A0
6	40C0 41C0 42C0 43C0 44C0 45C0 46C0 47C0	14	47C0 48C0 49C0 4AC0 4BC0 4CC0 4DC0 4EC0	22	50C0 51C0 52C0 53C0 54C0 55C0 56C0 57C0
7	40E0 41E0 42E0 43E0 44E0 45E0 46E0 47E0	15	47E0 48E0 49E0 4AE0 4BE0 4CE0 4DE0 4EE0	23	50E0 51E0 52E0 53E0 54E0 55E0 56E0 57E0

Column																															
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
00	01	02	03	04	05	06	07	08	09	0A	0B	0C	0D	0E	0F	10	11	12	13	14	15	16	17	18	19	1A	1B	1C	1D	1E	1F

Example : Fifth byte of character in line 13, column 27 = 4BA0 + 1B = 4B BB h

Appendix 6

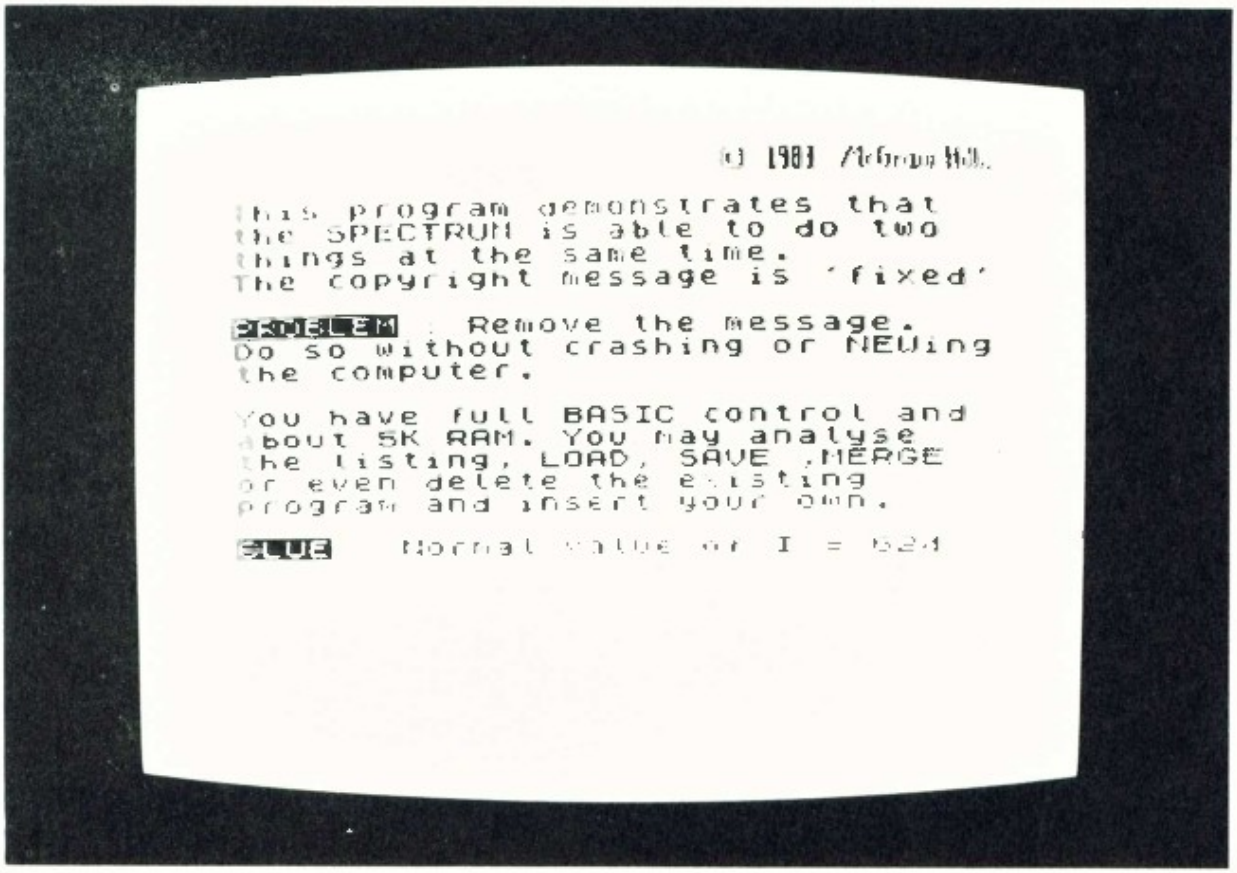
Farewell program

For those of you who like taking programs apart to see how they work, the tape contains a machine code program called PROBLEM. The object of the program is to demonstrate the fact that the Spectrum can run a machine code routine while giving full BASIC control to the programmer.

When loaded, the computer will display a copyright message in the top right-hand corner of the screen. This copyright message will remain on the screen at all times. Your problem is to find out how it is achieved and to remove the message without crashing or NEWing the Spectrum.

The program is such that it would be impossible to produce a useful listing and it has several features that make it difficult to trace the machine code. To remove the message you will need a suitable machine code routine.

If you successfully remove the message and disassemble the routine you will see that it opens up a whole new area of programming possibilities. Good luck.



```
  10 RANDOMIZE USR (PEEK (PEEK 23
627+256*PEEK 23628+1)+(256*(PEEK
(PEEK 23627+256*PEEK 23628+2))))
  20 CLEAR 29100
  30 PRINT AT 2,0;"This program d
emonstrates that  the SPECTRUM is
 able to do two  things at the sa
me time."'"The copyright message
is 'fixed'"
  35 PRINT
  40 PRINT "PROBLEM : Remove the
message."'"Do so without crashing
 or NEWingthe computer."
  50 PRINT
  60 PRINT "You have full BASIC c
ontrol and about 5K RAM. You may
analyse   the listing, LOAD, SAVE
 ,MERGE  or even delete the exist
ing     program and insert your o
wn."
  70 PRINT '"CLUE : Normal value
of I = 62d"
  80 STOP
  90 LOAD ""CODE : GO TO 10
```

Program 'Problem'

Software to accompany this book . . .

A cassette tape, for 16K and 48K Spectrums, is available to go with this book. It includes many useful programs, as well as demonstrations of the techniques described in the book. And there is a full machine-code version of CROSS, an arcade game of professional quality!

Contents of the cassette tape are:—

PLOTDEMO	— plots messages anywhere on the screen, using BASIC to set height and width.
REACTION	— a reaction timer to demonstrate fast machine-code counting.
RNDEMO	— produces random height 'skyscrapers' using machine-code.
KEYDEMO	— machine-code fast keyscan.
MOVEDEMO	— demonstrates independent high-resolution foreground and background movement.
PIXELDEMO	— demonstrates movement at pixel level.
NUMBERS	— utility to print Sinclair floating-point form of any number.
SOUND	— five different machine-code sounds, including white noise.
CROSS-BASIC	— 'Cross' game in BASIC and machine-code.
CROSS-M/C	— Full machine-code version of 'Cross'.
PROBLEM	— If you've understood the book you should be able to erase the rather persistent McGraw-Hill logo that is always on the screen!

The tape is distinctively packed to match this book, and comes complete with a card enabling you to use the free McGraw-Hill software support service.

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