If you have a Sinclair ZX81 and want to use it to its full potential then, as the experts have all agreed, this is the book for you. It contains detailed guidelines and documented programs in the areas of gaming, information retrieval and education, as well as a unique listing of the 8K ROM for machine code applications.

'Far and away the best . . . once again Linsac has produced the book for the serious end of the market'. – *Your Computer, November 1981.*

'The ZX81 Companion is a most professional product . . . with many good illustrative programs, tips and warnings'. – *Education Equipment, October 1981.*

'Bob Maunder's attempt to show meaningful uses of the machine is brilliantly successful . . . thoughtfully written, detailed and illustrated with meaningful programs . . . To conclude – the book is definitely an outstandingly useful second step for the ZX81 user'. – *Educational ZX80/81 Users' Group Newsletter, September 1981.*

Bob Maunder has been involved in the ZX series of microcomputers since he acquired the first ZX80 kit in March 1980, and he is co-author of Linsac's *'The ZX80 Companion'*. He holds a MSc in Computer Science from Birmingham University and is Head of Computing at Hartlepool College, where he pioneered the use of the ZX80 in education.

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PREFACE

The Sinclair ZX81 microcomputer has been widely acclaimed as a tremendous breakthrough in personal computing, even surpassing its predecessor the ZX80. Certainly no other computer has been bought in such quantities by such a wide range of people in such a short space of time since its launch in February 1981. The ZX81 advertising campaign has sought to attract the general public to the concept of using a computer in the home.

"The ZX81 Companion" has been written to assist ZX81 owners in using their computer in the specific areas of information retrieval, education, and games. The Sinclair ZX81 Manual, while being an excellent introduction to ZX81 BASIC, does not discuss any real uses for the machine. However in the **Companion**, readers will find documented programs that can be used immediately to utilise the ZX81 to its full potential, as well as detailed guidelines on the design and development of their own programs. The book is therefore aimed at those familiar with the concepts of ZX81 BASIC but keen to get the ZX81 moving onto higher things. The fourth chapter is aimed at more advanced users who are interested in the workings of the ZX81 Monitor and methods of displaying and using Monitor routines.

It is the opinion of the author that for any serious applications the ZX81 definitely requires the addition of a 16K RAM pack. However many programs in the book can be run on 1K machines, the main exception being Chapter Two which develops a sophisticated information retrieval package for which 16K is naturally vital.

The author has been involved in the ZX series of microcomputers since he acquired the first ZX80 kit in March 1980, and he is co-author of Linsac's 'The ZX80 Companion'. He holds an MSc in Computer Science from Birmingham University and is Head of Computing at Hartlepool College, where he pioneered the use of the ZX80 in education.

Thanks are due to Sinclair Research for permission to reprint the ZX81 keyboard layout (but not the Monitor listing!), to Joe Foster for contributing the Appendix on program development and to Ian Logan for the section on Monitor routines and entry points.

CONTENTS

INTRODUCTION AND NOTATION

Readers who own 16K ZX81's will be able to get the most out of this book, but those with 1K ZX81's or updated ZX80's will also benefit. Memory requirements for programs are clearly marked, and in many of the routines in Chapter One in particular, 1K and 16K alternatives are given. It is the author's opinion that owners of 8K ROM ZX80's are certainly at a disadvantage with regard to the main benefit of the ZX81 – animated displays. Such users will be well advised to consider the purchase of a conversion kit, currently available in the UK from Compshop Ltd., to provide the SLOW compute and display facility. However ZX80 owners without this conversion will still be able to use most of the programs herein, in some cases with the addition of suitable PAUSE statements to simulate SLOW mode.

Material in the four chapters is developed from a simple starting point, and in the first three chapters exercises are used to give the reader practice in the techniques discussed. Solutions are found at the end of the book.

A technique known as logical assignment is used in many of the programs to save on program space: a necessity for 1K machines. This technique combines several conditions and values in a single LET statement, and may not be familiar to some readers: study of the Sinclair Manual is recommended to clarify the use of the technique.

The notation used in the program listings is designed to be as unambiguous as possible. Since spaces in printed text can be important in some circumstances, many of the listings specify a space by the letter b (for blank). Confusion between the letter l and the number 1, or the letter O and the number zero can occur so the following conventions are used:

l = letter
1 = number one
O = letter
Ø = number zero

Graphics and inverse characters can also be difficult to represent. If text is to be represented in inverse form then this is indicated by the word "inverse" in brackets at the end of the PRINT statement. Graphics characters are generally drawn in and sometimes also identified by their key, e.g. 500 PRINT "■" (inverse space)

CHAPTER ONE
GRAPHICS AND REALTIME TECHNIQUES

1.1 INTRODUCTION

We consider in this chapter the use of ZX81 statements to produce diagrams, pictures and moving displays. **Graphics** is the art of drawing items on the ZX81 screen by means of addressing different parts of the display as you might fill in squares on a piece of graph paper. **Realtime** methods involve getting the ZX81 to respond to you *immediately* : although all ZX81 programs work in a conversational mode with the user entering information (in response to INPUT statements) and the computer replying with a display, programs can be written which will react immediately the user presses a key, whether or not the computer was doing something else at the time.

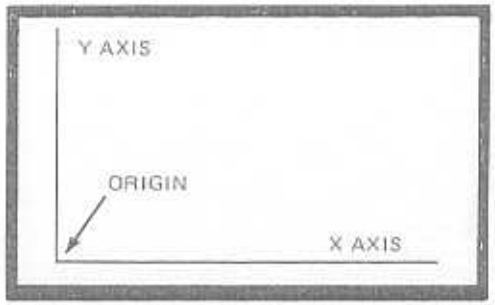
These two techniques can be immensely useful. On the serious side, information can often be more clearly presented and understood if it is in the form of diagrams, such as graphs or histograms; simple maps or room layouts can also be shown. On the lighter side, games have much more realism and challenge if they involve pictures, and if the pictures move and the player has to respond quickly to this movement, so much the better.

It will be helpful if the reader has looked over Chapters 17, 18 and 19 of the'ZX81 BASIC Programming' manual first. The statements covered in the theory and practical exercises below are PLOT, UNPLOT and PRINT AT (graphics) and INKEY$ and PAUSE (realtime). Do not be deterred by the initial emphasis on theory: in order to produce good graphics you need to have a good grasp of what is often titled 'coordinate geometry'. At the end of this chapter you will be programming your own arcade-type games so stick with it!

1.2 AXES AND COORDINATES

In using the graphics features of the ZX81 we think of the TV screen as a piece of graph paper split into squares. We can black-in a square using PLOT and rub out a blacked-in square using UNPLOT. However to pick out a blacked-in square we must have some way of identifying squares to the ZX81, and this is done by considering the screen as having two

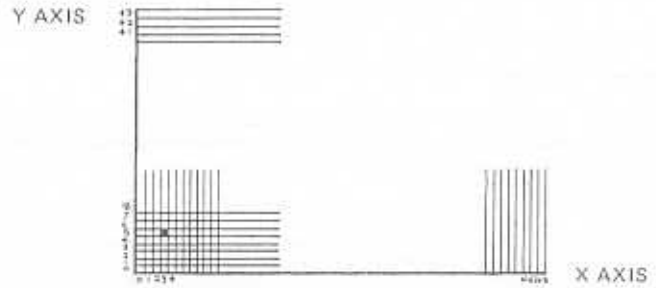
lines of reference or axes, at right angles to each other at the left and bottom of the screen.



The vertical axis at the left of the screen is known as the **y axis**, and the horizontal axis at the bottom is called the **x axis**. The point at which they intersect is called the **origin**.

Coordinates

The number of 'squares' on the ZX81 screen is fixed at 64 x 44, i.e. there are 64 divisions along the x axis and 44 divisions along the y axis. To complicate the issue the divisions are numbered from 0 to 63 and from 0 to 43, as shown below.



To identify a particular square on the graph we specify how far along the x axis it is, and then how far along the y axis. For example the blacked-in square in the diagram above is at position 3 on the x axis and position 5 on the y axis and we say its position on the graph is therefore (3,5). This pair of numbers in brackets is known as the coordinates of

the square. Note that the Sinclair Manual calls these squares "pixels". The PLOT statement uses the coordinates to identify a square's position and black it in (however brackets are omitted). Try this:

```
PLOT 3, 5
```

A black square appears towards the bottom left hand corner of the screen, or at position (3,5).

Any square in the 64 x 44 graph can be identified using coordinate pairs, from the origin at (Ø,Ø) to the top right at (63,43). RUN the following program to get the four corners of the screen display

```
10 PLOT Ø, Ø
20 PLOT Ø, 43
30 PLOT 63, Ø
40 PLOT 63, 43
```

The next section shows how squares may be drawn in groups to form lines.

1.3 STRAIGHT LINES

Equations of X and Y Axes

A straight line may be drawn on the screen by drawing in several squares together. The squares which form a line all have something in common and we can form an equation for a line using this fact. As an example, consider squares along the x axis:

(Ø, Ø) , (1,Ø) , (2, Ø) and so on up to (63, Ø)

All of these squares have something in common — they have their y position equalling zero. Therefore we say that the x axis has the equation

y = Ø

Similarly all squares along the y axis have their x coordinate equalling zero so the equation of the y axis is

x = Ø

Therefore in order to draw in the y axis on the screen, all we need to do is PLOT every square where x = Ø. Thus

```
10 FOR Y = Ø TO 43
20 PLOT Ø,Y
30 NEXT Y
```

Add the following lines and we produce a set of x and y axes on the screen.

```
40 FOR X = Ø TO 63
50 PLOT X,Ø
60 NEXT X
```

In fact any vertical line will have an equation

x = a number

while any horizontal line will have an equation.

y = a number

Drawing a Rectangle

You can get some interesting visual effects using just these simple concepts. The following program draws the edges of the screen 'graph':

```
10 FOR X = Ø TO 63
20 PLOT X,Ø
30 PLOT X,43
40 NEXT X
50 FOR Y = Ø TO 43
60 PLOT Ø, Y
70 PLOT 63,Y
80 NEXT Y
```

Notice how the vertical lines and horizontal lines are plotted in pairs through use of a pair of PLOT statements in each of the two loops. For 1K ZX81's, substitute 37 for 43 in lines 30 and 50 for a complete rectangle.

Another example shows how the entire screen may be blacked in from

the left

```
10 FOR X = 0 TO 63 . . . . . (Use 61 for 1K ZX81's)
20 FOR Y = 0 TO 43
30 PLOT X,Y
40 NEXT Y
50 NEXT X
```

Try reversing the order of the loops and see the effect.

Exercise 1 (a): Produce an entirely black screen display by drawing vertical lines from right to left, going down the screen.

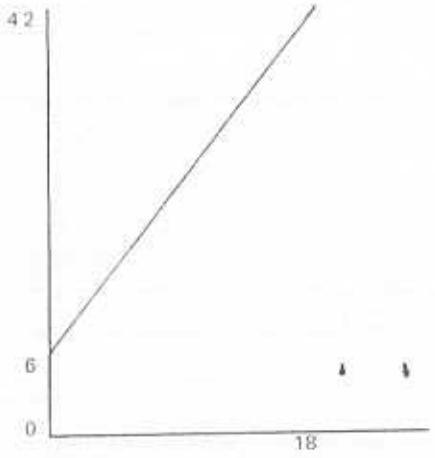
1 (b): Draw a black square with its bottom left corner at position (10,5), sized 20 x 20 squares.

(Solutions on page 115)

Equations of General Lines

Most lines that we will need to draw on the ZX81 will not be vertical or horizontal, but diagonal. We now discuss how we can work out the common features or **equations** of such lines, and thus how they can be plotted on the screen.

The diagram below shows a line drawn between points (0,6) and (18,42).



If this line were drawn on graph paper we would see that it also passes through a sequence of positions starting

(1,8) (2,10) (3,12) (4,14) (5,16) ...

The common factor about all the positions through which the line passes is that the y coordinate is twice the x coordinate plus six. We can therefore say that the line has the following equation

$y = 2x + 6$

and we can therefore draw it on the ZX81 screen thus

```
10 FOR X = 0 TO 63
20 PLOT X, 2*X + 6
30 NEXT X
```

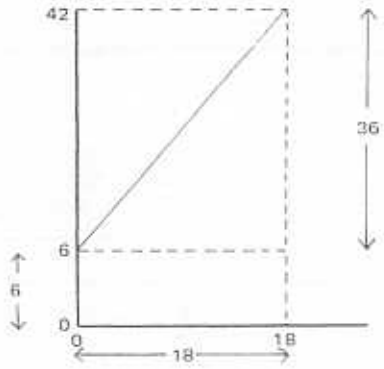
However this teminates with error code B after getting as far as x = 18, since the y value calculated when x = 19 is 44, which is off the screen.

Any diagonal line that we care to choose can be reduced to a simple equation of the form

$y = mx + c$

where m and c represent numbers.

The values of m and c can be seen more clearly from the following graph showing y = 2x + 6 again.



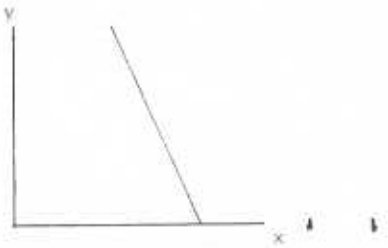
The gradient or steepness of the line is measured by height divided by length. As shown above the line goes *up* 36 squares as it goes *along* 18 squares, so the gradient is 36 ÷ 18 or 2. This represents m in the general equation of a straight line, y = mx + c. Similarly c is given by where the line cuts the y axis. To understand this, remember that the y axis is where x = Ø. Therefore when the line y = mx + c and the line x = Ø intersect then

y = m.Ø + c

= y = c

This value is often called the y intercept.

Consider a different line. This one slopes downwards and cuts the x-axis.



Again this line fits the general equation y = mx + c, but this time the gradient m will be negative. The x intercept is easily found by remembering that the x-axis is where y = Ø.

so y = mx + c
becomes Ø = mx + c
therefore $x = \frac{-c}{m}$

The following program can be used to demonstrate the effects of different values for m and c.

```
 5 REM ENTER VALUES AND PRINT EQUATION
10 CLS
20 PRINT "M=";
30 INPUT M
40 PRINT M;"bC=";        (b = space)
```



```
50 INPUT C
60 CLS
70 PRINT AT Ø,12;"Y=";M;"X+";C
75 REM DRAW AXES
80 FOR X=Ø TO 63          (For 1K ZX81's omit the REM lines)
90 PLOT X,Ø
100 NEXT X
110 FOR Y=Ø TO 43
120 PLOT Ø, Y
130 NEXT Y
135 REM DRAW LINE
140 FOR X=Ø TO 63
150 PLOT X,M*X+C
160 NEXT X
```

RUN the program with varying positive and negative values for m and c and finally c = Ø or m = Ø. If the y value becomes negative some peculiar effects occur because the PLOT statement always takes the positive values of coordinates. To overcome this add the line

```
145 IF M*X+C<Ø THEN STOP
```

If you find it difficult to understand why the ZX81 does not do **continuous** diagonal lines as it would if they were horizontal or vertical, remember that it is only blacking-in squares on a grid. You may have come across computers which appear to draw continuous lines on an output screen, but this is only because the number of squares or **resolution** of the display is higher.

1.4 MOVING OBJECTS

Moving Spots

To relieve what for some might be a tedious excursion into school maths, let us look at how we can get things to move on the ZX81 screen.

The way to produce animation by computer is the same as in cartoons: display a picture then display it in a slightly different position, and so on. When we drew lines on the screen we saw them being extended, and all we need to do to get moving spots is to rub out the trail. Modifying one of the previous routines gives us

```
10 FOR X=0 TO 63
20 PLOT X,0
30 UNPLOT X,0
40 NEXT X
```

and we see a spot moving quickly along the bottom of the screen. To slow it down and make it a bit clearer we could add a PAUSE

```
25 PAUSE 10
26 POKE 16437,255
```
(Vital for updated ZX80's)

Two points here – remember to include the POKE after every PAUSE if you use FAST mode, and also make sure you PAUSE while the spot is on the screen, not after you have just rubbed it out.

Exercise 1(c): Write a program to get a spot to move round the edges of the screen anti-clockwise starting at the origin (the program above starts you off).

Moving Objects

For greater realism a complete object can be built up and moved across the screen. As we will see later this is much better using the PRINT AT instruction but it can be achieved by PLOT, as below

```
10 FOR X=0 TO 61
20 PLOT X,0
30 PLOT X+1,0
40 PLOT X+2,0
50 PLOT X+1,1
60 PAUSE 10          )   or try  60 FOR A=1 TO 20
70 POKE 16437,255    )            70 NEXT A
80 UNPLOT X,0
90 UNPLOT X+1,1
100 NEXT X
```

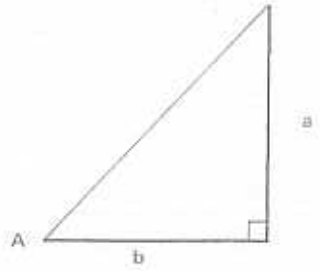
We see that not all of the object need be rubbed out each time, since the remaining part forms part of the next drawing of the object. The annoying blinking is much less accentuated using PRINT AT as we shall see, or even using the dummy loop.

1.5 TRIGONOMETRY

Tangents

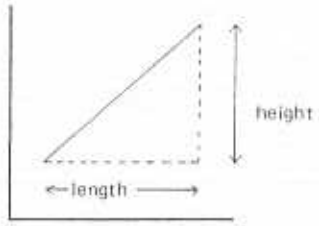
If you have started to read this section in spite of seeing the title then you are doing well. It is true that sines, cosines and particularly tangents can be useful in our theory of graphics. We will consider just tangents, but you can read up any secondary school maths text book to swot sines and cosines if you find it interesting.

A tangent is the ratio of two sides of a right-angled triangle:



The tangent of the angle at A is $\frac{a}{b}$

But think of this on a graph



and we see that the tangent is the same as the gradient of a straight line.

Therefore we can start talking about lines being drawn at certain angles on the screen. For example the following program invites you to enter an angle (0-90°) and it then draws a line from the origin at this angle to the x axis.

```
10 PRINT AT 0,0;"ANGLE=";
20 INPUT A
30 PRINT A
40 IF A<0 OR A>90 THEN GO TO 20
```

```
 50 LET M=TAN(A*2*PI/360)
 60 FOR X=0TO 63
 70 IF M*X>43 THEN GO TO 100
 80 PLOT X,INT(M*X)
 90 NEXT X
100 PAUSE 100
110 POKE 16437,255
120 PRINT AT 0,6;"bbbb"          (b = one space)
130 GO TO 10
```

Lines 10–50 invite the user to enter an angle and then the value of m in the general equation for straight lines through the origin ($y = mx$) is calculated. As an added complication, the ZX81 will only handle tangents of angles expressed in **radians** which is a unit of circular measure but since one degree is $\frac{2\pi}{360}$ radians (or $\frac{\pi}{180}$)

we can do an easy conversion.

Lines 60 – 90 draw the line, making sure to stop drawing when the top of the screen is hit

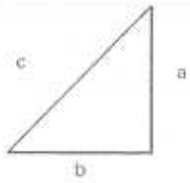
Lines 100 – 130 cause the program to repeat so that several lines can be drawn on the same graph.

Exercise 1 (d): Write a program to draw a "spider's web" of lines, similar to the ones above using the angles 0° to 90° at 5° intervals.

The program above and the exercise will crash when the angle is equal to ninety degrees because the tangent of 90° is infinitely large – draw the triangle if you cannot see why! A good way of stopping it anyway!

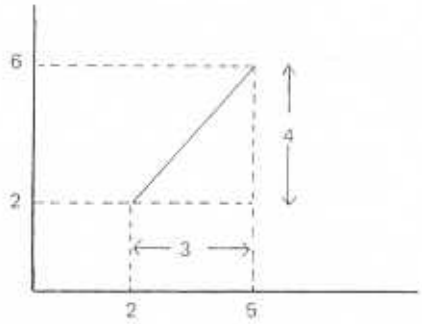
Pythagoras

The above-named gentleman may again not be too popular amongst some readers but his theorem can help us draw some nice pictures if nothing else. Basically he informs us that in a right angled triangle such as the one below the square of the hypotenuse is equal to the sum of the squares of the other two sides.



i.e. $c^2 = a^2 + b^2$

This can be used in straight line geometry to work out the length of a line e.g.



Take length of line as L

then $L^2 = 3^2 + 4^2$

$= 25$

so $L = 5$

Try changing this instruction in the solution of exercise 1(d) to see an example of how Pythagoras can justify his existence:

```
50 IF X*X + Y*Y> 1849 THEN GO TO 80
```

and a very nice set of equal length lines are produced in an arc.

Beware when using Pythagoras' theorem, particularly in loops, because the SQR function and even powers of numbers are very slow to evaluate. For example the following statement has the same effect as the instruction above but it is much slower:

```
50 IF SQR(X**2 + Y**2) > 43 THEN GO TO 80
```

Try it and see.

1.6 MORE STRAIGHT LINES

Lines Through a Point

Having done a quarter of a spiders web above, why not try a full web-shape. To do this we need to know some more theory about equations of lines on a graph, and in particular how to calculate the equation of a line between two points.

For example, say we want to draw a line between (2,3) and (15,20). Both of them are on the line (general equation $y = mx + c$) so both satisfy its equation.

So for point (2,3) we have $3 = 2m + c$
and for point (15,20) we have $20 = 15m + c$

and then we have another mathematical unpleasantry, a pair of simultaneous equations! We eventually find that in a general case, the equation through two points (p,q) and (r,s) is obtained by

$$\frac{y - q}{s - q} = \frac{x - p}{r - p}$$

Enough of the theory, let's draw some more pictures. We want to get a web or star shape, with the centre at the centre of the screen, (32,22). Therefore we want to draw lines from different points on the y axis through (32,22). This makes things easier since the y axis has the equation $x = 0$.

So taking $(p,q) = (32,22)$
and $(r,s) = (0,y)$

we get $\frac{y - 22}{s - 22} = \frac{x - 32}{-32}$ for S from 0 to 43

which after a lot of bashing comes to

$$y = 22 - \frac{(x - 32)(s - 22)}{32} \quad \text{for S from 0 to 43}$$

giving the following program

```
10 FOR S=0 TO 43 STEP 5 . . . (Use 39 rather than 43
20 FOR X=0 TO 63                          with 1K ZX81's)
30 LET Y=INT(22-(X-32)*(S-22)/32)
40 IF Y>43 OR Y<0 THEN GO TO 70
50 PLOT X,Y
60 NEXT X
70 NEXT S
```

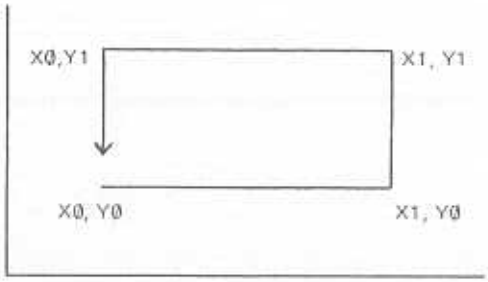
Lines with a Given Slope

Exercise 1(e): The display from the program above does not give a complete web effect because lines are only drawn from the y axis. Extend it by working out the equation of lines through a point *with a given gradient* and thus produce a complete web.

Spirals

An interesting display can be produced by drawing lines around the outside of the screen which gradually move into the centre in a 'rectangular spiral'. It is also quite an interesting exercise in logic.

Consider a general case where we are somewhere in the middle of the display:



We can label the corners of the current rectangle as shown above. Therefore we initially set the values of X0, X1, Y0, Y1 to be at the edges of the screen and then gradually change them in the course of the program

to produce the spiral. However we have to be very careful as to *where* in the program we modify these values.

This works very nicely:

```
10 LET X0=0    ...   15 )
20 LET X1=63   ...   48 )  for 1K ZX81's
30 LET Y0=0    ...   20 )
40 LET Y1=43   ...   43 )
50 FOR X=X0 TO X1
60 PLOT X,Y0
70 NEXT X
80 FOR Y=Y0 TO Y1
90 PLOT X1,Y
100 NEXT Y
110 FOR X=X1 TO X0 STEP -1
120 PLOT X,Y1
130 NEXT X
140 LET X1=X1-1
150 LET Y0=Y0+1
160 LET Y1=Y1-1
170 FOR Y=Y1 TO Y0 STEP -1
180 PLOT X0,Y
190 NEXT Y
200 LET X0=X0+1
210 GO TO 50
```

We need to stop the process somewhere so add

```
165 IF Y0>=Y1 THEN GO TO 500
```

and if you want to check that we stop at the right place add

```
500 PRINT "0"
```

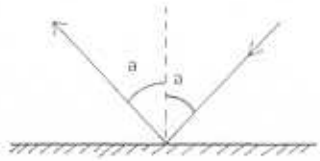
If you like this display and feel it could be extended to give a continuously moving video background in a room, you are absolutely right : wait for Section 1.7!

Bouncing

Many of the early TV games involved a ball bouncing around the screen.

We are now going to look at how to get a moving object to bounce off a flat object.

We assume that if our ball hits a wall at a certain angle it will bounce off at the same angle, i.e.:—



You are probably getting the sinking feeling that this is going to involve more theory: true, but not too much. It all has to do with the gradient of the line followed by the ball. We find that the gradient has its sign reversed after reflection from the wall. If you are into such things, this is because

$$\tan(90-a) = -\tan(90+a)$$

or incident gradient = −reflected gradient

Therefore if a ball travelling with a gradient of m hits a wall at a point (a,b) then it will continue with gradient negated and its equation will be

$$y = m(x-a) + b$$

or $y = mx + (b-ma)$

For drawing on the ZX81 we also have to be clear that if the ball hits a wall it will change direction on the screen, and therefore needs to be plotted carefully.

The following program draws a line starting at the origin on the screen at an angle specified by the user and then bounces it off the edges of the screen. Its path is left on the screen to illustrate the theory above. Use angles between 20° and 80° for useful results.

```
10 PRINT "ANGLE=";
20 INPUT A
30 CLS
40 LET M=TAN(A*PI/180)
```

```
 50 LET X=0
 60 LET I=1
 70 LET C=0
 80 LET X=X+I
 90 LET Y=M*X+C
100 IF X<=0 OR Y<=0 THEN STOP
110 IF X>=43 OR Y>=43 THEN GO TO 140
120 PLOT X,Y
130 GO TO 80
140 LET M=-M
150 LET I=I-2*(X=43)
160 LET C=Y-M*X
170 GO TO 80
```

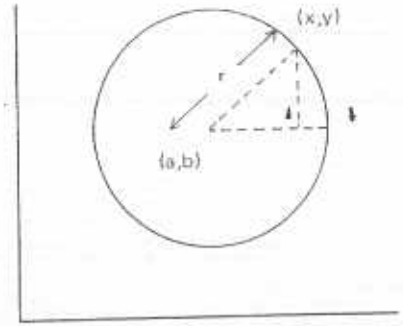
If you want to show just a single moving spot rather than continuous lines, add suitable UNPLOT and PAUSE statements.

1.7 CIRCLES AND OTHER INTERESTING SHAPES

We will use all this theory eventually in developing some good graphics games, so let us consider a final chunk of coordinate geometry.

Circles

We can specify the equation of a circle by noting that every point on the circle is the same distance away from the centre:



Taking the centre (a,b) and the radius as r then we can say for a general point (x,y) on the circle, using the ubiquitous pythagoras that

$$(x-a)^2 + (y-b)^2 = r^2$$

and we can take $x-a$ as $r \cos\theta$
and $y-b$ as $r \sin\theta$ where θ is any angle

since $(r\cos\theta)^2 + (r\sin\theta)^2 = r^2(\cos^2\theta + \sin^2\theta)$
$= r^2$ as it happens

Therefore we get $x = a + r\cos\theta$
and $y = a + r\sin\theta$

So let's see what the ZX81 makes of plotting a circle:

```
 10 PRINT "RADIUS=";
 20 INPUT R
 30 PRINT R;"bCENTRE:bX=";
 40 INPUT A
 50 PRINTA;"bY=";
 60 INPUT B
 70 PRINT B
 80 FOR Q=0 TO 360
 90 LET P=Q*PI/180
100 PLOT A+R*COS P,B+R*SIN P
110 NEXT Q
```

RUN the program and enter the radius followed by the x— and y— co-ordinates of the centre. Make sure that the circle does not go over the edge of the screen in any direction. Before your eyes a circle will appear, albeit slowly. The slowness results from the evaluation of cosines and sines at line 100 — the ZX81 takes a long time to work these out.

Exercise 1(f): Work out the equation of a circle centred at the origin and radius 40 and therefore write a program to draw a circle quadrant (quarter arc) on the screen with radius 40.

Finally we choose a selection of interesting shapes and show how they may be plotted.

Parabola

Here is a nice parabola

```
10  FOR X=0 TO 63
20  LET Y=INT((2.52-0.04*X)*X)
30  PLOT X,Y
40  NEXT X
```

Ellipse

An ellipse is almost a general case of a circle or a parabola. Try this general ellipse plotter:

```
1   PRINT "A=";
2   INPUT A
3   PRINT A;"bB=";
4   INPUT B
5   PRINT B
10  FOR Q=0 TO 360
20  LET P=Q*PI/180
30  PLOT A*(1+COS P),B*(1+SIN P)
40  NEXT Q
```

Try it with various values for A and B such as:

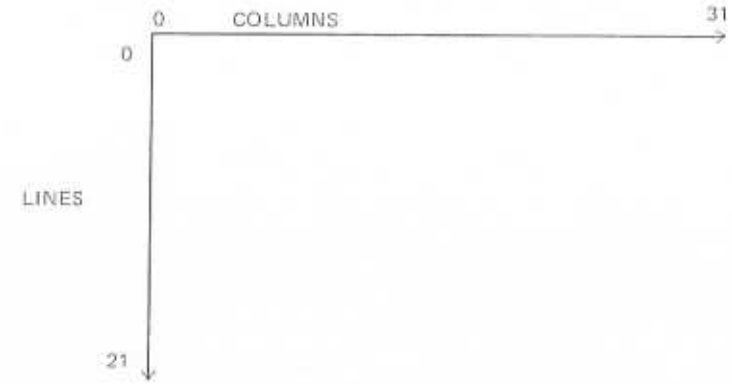
```
A = 30,   B = 20
A = 20,   B = 20
A =  5,   B = 21
```

1.8 DRAWING WITH OTHER CHARACTERS

The PRINT AT Instruction

All our graphics work so far has been of the 'join the dots' variety, since all the PLOT statement can do is to black-in squares. Fortunately this is not the limit of the ZX81's capability. The PRINT AT statement can also be used for picture drawing and it has one disadvantage but one considerable advantage over PLOT. The disadvantages is that it cannot address parts of the screen in so much detail as PLOT – the figure

below shows its limitations



It can only draw in 22 x 32 positions and it works by means of specifying a line number and a column number, rather than standard x and y coordinates. Its great advantage is that any ZX81 character can be placed at a position.

The following simple routine illustrates the point

```
10 INPUT L
20 IF L<0 THEN STOP
30 INPUT C
40 INPUT S$
50 PRINT AT L,C;S$
60 GO TO 10
```

RUN the program and then keep entering groups of three items specifying line number, column number and character (or character sequence) and the ZX81 puts the character at this screen position.

ZX81 Video Show

Any of the programs previously considered can be modified to use PRINT AT rather than PLOT, and as promised here is a program to give a pleasant background video display to any room:

```
10 LET L0=0
```

```
20 LET L1=21   ... 15 for 1K ZX81's
30 LET C0=0
40 LET C1=31   ... 15 for 1K ZX81's
45 LET Z$=CHR$(INT(RND*11+128*(RND<0.5)))
50 FOR L=L0 TO L1
60 PRINT AT L,C0;Z$
70 NEXT L
80 FOR C=C0 TO C1
90 PRINT AT L1,C;Z$
100 NEXT C
110 FOR L=L1 TO L0 STEP-1
120 PRINT AT L,C1;Z$
130 NEXT L
140 LET L1=L1-1
150 LET C0=C0+1
160 LET C1=C1-1
170 FOR C=C1 TO C0 STEP -1
180 PRINT AT L0,C;Z$
190 NEXT C
200 LET L0=L0+1
205 IF L0>=L1 THEN GO TO 500
210 GO TO 45
500 CLS
510 RUN
```

It could even prove as addictive as 'Emmerdale Farm'!

or if you do not appreciate squares, how about circles?

```
10 FOR R=10 TO 2 STEP -1
15 LET Z$=CHR$(INT(RND*11+128*(RND<0.5)))
20 FOR Q=0 TO 360 STEP 10
30 LET P=Q*PI/180
40 PRINT AT 10+R*COS P,15+R*SIN P;Z$
50 NEXT Q
60 NEXT R
70 CLS
80 GO TO 10
```

Try making your own variations — perhaps using a basic ellipse shape which grows fatter, thinner, longer or shorter with varying characters being used to draw it. You need not stick to graphics characters, many normal characters or inverse video characters can be very nice.

1.9 REALTIME

Instructions

At the beginning of the chapter we saw that realtime programs are ones in which the computer responds to user action **immediately**, no matter what other action it is currently taking. The ZX81 instruction that provides this facility is INKEY$. There is however another instruction which assists in a similar feature, moving displays, and that is PAUSE.

Almost all the programs in this section are designed for ZX81's running in compute and display mode (i.e. SLOW). However FAST mode is also available and in fact on 8K ROM ZX80's it is compulsory. In FAST mode, the only way to generate moving displays in BASIC is to cause the ZX81 to display the results of its processing by the PAUSE instruction, or rather PAUSE and POKE together since problems occur if you forget the accompanying POKE. We will put very little emphasis on PAUSE in this section, since INKEY$ is the centre of the ZX81's realtime facilities.

INKEY$

INKEY$ is at the same time the most peculiar and the most powerful instruction on the ZX81, and we hope that after reading this section and trying out the programs you will be rather better informed than if you only had access to Chapter 19 of the Sinclair Manual!

First of all let us get our terminology right. INKEY$ is not really an **instruction** like LET or IF but a **function**, since it is used as part of a ZX81 statement, and in fact has to be accessed via the FUNCTION key. Whenever the ZX81 executes a statement which includes INKEY$ it looks at the keyboard, and if a key is being pressed **at that instant**, the character of the key is put into INKEY$, i.e. if you were pressing 3 then

```
INKEY$ = "3"
```

If a key is not being pressed when the line containing INKEY$ is executed, then INKEY$ is set to the null string.

The following two line routine shows how it works

```
10 PRINT INKEY$;
20 GO TO 10
```

RUN the program and then briefly touch any key on the keyboard. Let's assume you touched P – you will see a number of P's displayed on the screen. You may wonder why there are several rather than just one, since you touched the key only once. To understand this you need to have an appreciation of how fast the ZX81 is computing (even in SLOW mode!): while you have your finger on a key, albeit briefly, the ZX81 cycles round the GOTO 10 loop several times, the number of times being shown by the number of characters printed. Try pressing another key, and as soon as you do you will see some more characters displayed on the screen. See if you can touch a key so briefly that only one character is displayed! While you are not touching a key, nothing is displayed on the screen, since INKEY$ is the nullstring, and PRINT ""; produces nothing. However if line 10 had read

```
10 PRINT INKEY$
```

i.e. no semi-colon at the end, the program would have given quite a different effect since PRINT "" causes a new line to be displayed, and the ZX81 quickly runs out of screen space.

Try using the two line program above with entry of keys such as *, + or =, ie. shift keys. You will see that depression of SHIFT has no effect, but SHIFTed keys are displayed normally, even keywords. There are however some exceptions eg: EDIT, FUNCTION, GRAPHICS and RUBOUT. These all produce "?" on the screen, as does the NEWLINE key. We see from this that we can never enter graphic symbols via INKEY$ – rather a shame as we shall see later. Also SPACE is always interpreted as BREAK and this stops the program.

To summarise where we have reached so far, we have seen that INKEY$ is a way of entering single characters into a program without the need for INPUT statements or even NEWLINE.

Moving Blobs in Realtime

Your reaction to the above treatment of INKEY$ may well be "OK, so what?" since it is not immediately obvious how INKEY$ can be used. Hopefully this little program may change your mind.

```
10 LET L = 10
20 LET C = 15
30 LET Z$ = "■" (inverse space)
40 IF INKEY$ = "5" THEN LET C=C-1
50 IF INKEY$ = "6" THEN LET L=L+1
```



```
60 IF INKEY$ = "7" THEN LET L=L-1
70 IF INKEY$ = "8" THEN LET C=C+1
200 PRINT AT L, C; Z$
210 GO TO 40
```

The program enables you to move a blob around the screen by pressing keys 5,6,7 or 8 and the blob moves according to the direction of the arrows on the keys. This is achieved by testing which key the user is pressing and changing accordingly the line and column numbers at which the blob is printed. RUN the program and see what interesting patterns can be produced. Only keys 5,6,7 or 8 will have any effect since these are the only values of INKEY$ for which the program takes any action. If the blob goes off a screen edge, the program generally crashes, so to overcome this add the following lines

```
80 LET L = L - L* (L=22) + 22* (L=-1)   ... 16 not 22 for 1K
90 LET C = C - C* (C=32) + 32* (C=-1)   ... 26 not 32 for 1K
```

and we get what is known as "wraparound" – if the line goes off one edge it reappears at the other edge.

It would also be pleasant if we had a choice of the type of character shown on the screen, rather than just a blob. With ZX81 technology all things are possible! Add this

```
100 LET K = CODE INKEY$
110 IF (K<>0 AND K<33) OR (K>36 AND K<64)
THEN LET Z$ = CHR$ K
```

If you now press any single character key other than 5,6,7 or 8 this character becomes the one being used for drawing on the screen. To stop any of these programs, simply press the SPACE key.

Note that in line 110 above we are careful to avoid taking a value of INKEY$ when no key is being pressed: we exclude it when it is equal to the null string (character code 0). Note also that line 110 has

```
LET Z$ = CHR$ K
```

rather than LET Z$ = INKEY$ as you might have expected. This is because it is possible that the value of INKEY$ might have changed between lines 100 and 110 (in particular it might be null) and this could cause inconsistencies in the program and therefore the resulting display.

1.10 EXAMPLE PROGRAMS

Introduction

In this section we will see how many of the concepts, and especially the maths, outlined above can be used in sophisticated realtime programs. Each program is given with detailed documentation so that the reader can understand how the program has been designed and developed. Appendix One shows the method of program design used and it is strongly recommended that a definite methodology should be used in programming. Although it is very tempting to start typing in BASIC instructions as soon as possible when developing a program, this causes more delay later, and it is in fact much quicker to design a program properly before touching the keyboard. Also, if a program is developed according to our method, documentation such as that given below builds up naturally so that you do not have to write it all up afterwards.

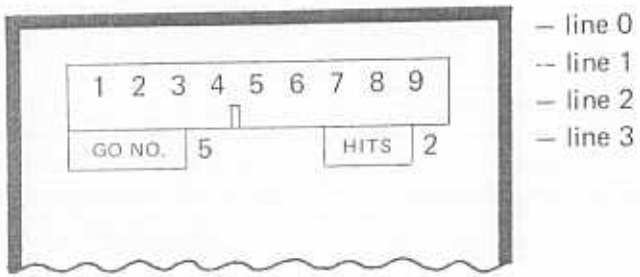
Anyway, on with the programs.

SHOOTING GALLERY (1K Memory)

Description

The program simulates a shooting gallery that you might find at a fair. An object moves from left to right across the screen under a row of numbers 1 to 9. The player attempts to hit the object by pressing one of the numeric keys 1 to 9 as the object passes under the number. There are ten goes and the program displays the current number of hits and the go number.

Sample Screen Format



Method

i. Set up screen and initialise hits H to zero
ii. Carry out the following with go number G = 1,2, ---, 10
  a. Set object position C to zero
  b. Clear shot line
  c. Clear message line & print go number
  d. Display object at position C
  e. If a key 1 — 9 pressed
    1. display shot
    2. if object hit:
      A. Display message
      B. Increment & display H
      C. Jump to (6)
    3. Wait for key to be released
    4. Increment C
    5. If C less then 31 jump to (d)
    6. Wait for 5 seconds
iii. Display end message & stop

List of Variables

H = no. of hits scored
G = go number (between 1 and 10)
N = number of key pressed (valid only for keys 1 — 9)
C = position of object on line

Program Listing

```
10  LET H=0
20  PRINT
30  PRINT "bbb1bb2bb3bb4bb5bb6bb7bb8bb9bbb"
    (inverse spaces & digits)
40  PRINT AT 4,0;"GO b NO." (inverse)
50  PRINT AT 4,26;"HITS" (inverse)
60  FOR G=1 TO 10
65  LET C=0
70  PRINT AT 3,0;"                              "
    (inverse — 30 spaces)
100 PRINT AT 4,6;G;TAB 12;"bbbbbbb"
110 PRINT AT 3,C;" " (inverse space and graphics 5)
130 LET N=CODE INKEY$-28
140 IF N<1 OR N>9 THEN GO TO 220
```

```
150  PRINT AT 3,N*3;"*" (inverse asterisk)
160  IF N*3<>C+1 THEN GO TO 210
170  PRINT AT 4,12;"GOT b HIM"  (inverse)
180  LET H=H+1
190  PRINT AT 4,30 ;H
200  GO TO 240
210  IF INKEY$<>" " THEN GO TO 210
220  LET C=C+1
230  IF C<>31 THEN GO TO 110
240  PAUSE 250
250  NEXT G
260  PRINT AT 4,12;"THE b END" (inverse)
```

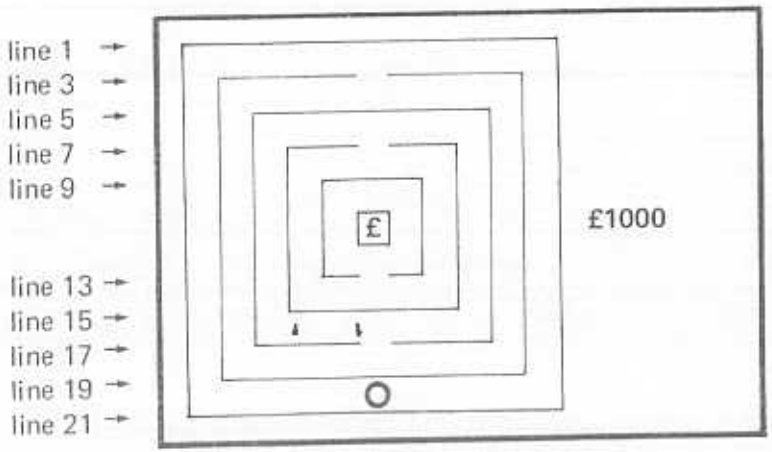
MONEY MAZE (16K Memory)

Description

A treasure chest full of £5 notes is located in the centre of a maze. You are on the outside of the maze and have to reach the treasure by using keys 5,6,7 or 8 to control your movement (direction arrows). However the chest has caught fire and the longer you take the less money there will be.

The program sets up and displays a 21 x 21 maze. The treasure chest is shown by £ and the player by O. A running counter of the amount of money left is shown to the right of the screen. The maze is displayed on the screen so that element i,j is at line i column j.

Sample Screen Format



Method

Array A of size 21 x 21 is used to hold the maze, with walls held as 128, space as 0 and the cash is 140 (inverse £).

i. Set up array as shown
ii. Print array in character form
iii. Set sum of money M to 1000
iv. Display M
v. Set player's position at bottom of maze, line L and column C.
vi. Display player's position
vii. Pause to allow player time to see screen
viii. Display player's position
ix. Burn a fiver from M, and if M is zero, display message and stop
x. Display M
xi. Read number N from keyboard
xii. If N between 5 and 8
  a. Use N to update L and C to LI and CI
  b. If position (CI, LI) is the chest print message and stop
  c. If position (CI, LI) is space (not a wall)
    1. rubout position (C,L)
    2. change C to CI
    3. change L to LI
    4. jump to (viii)
xiii. jump to (ix)

List of Variables

A – array of size 21 x 21 holding maze
I,J – loop counters used in setting up array
M – amount of money left
L – line no. of player's position
C – column no. of player's position
N – code number of key pressed (valid for 5 to 8)
LI – new line no. of player's position
CI – new column no. of player's position

Program Listing

```
10  DIM A (21,21)
20  FOR I=0 TO 8 STEP 2
30  FOR J=I+1 TO 21–I
```

```
 40  LET A(I+1,J)=128
 50  LET A(21-I,J)=128
 60  LET A(J,I+1)=128
 70  LET A(J,21-I)=128
 80  NEXT J
 90  NEXT I
100  LET A(3,11)=0
110  LET A(7,11)=0
120  LET A(13,11)=0
130  LET A(17,11)=0
140  LET A(11,11)=140
200  PRINT
210  FOR I=1 TO 21
220  PRINT "b";
230  FOR J=1 TO 21
240  PRINT CHR$ A(I,J);
250  NEXT J
260  PRINT
270  NEXT I
300  LET M=1000
310  PRINT AT 11,22;"£";M
320  LET L=20
330  LET C=11
332  PRINT AT L,C;"O"
336  PAUSE 500
340  PRINT AT L,C; "O"
350  LET M=M-5
355  IF M<0 THEN GO TO 600
356  IF M<100 THEN PRINT AT 10,
     22;"HURRY"
360  PRINT AT 11,23;M;"bbb"
370  LET N=CODE INKEY$-28
380  IF N<5 OR N>8 THEN GO TO 350
390  LET LI=L-(N=7)+(N=6)
400  LET CI=C+(N=8)-(N=5)
410  IF A(LI,CI)=140 THEN GO TO 500
420  IF A(LI,CI)<>0 THEN GO TO 350
425  PRINT AT L,C;"b"
430  LET L=LI
440  LET C=CI
450  GO TO 340
500  PRINT AT 10,22;"YOU GOT"
```



```
510  STOP
600  PRINT AT 10,22;"TOO SLOW"
```

DUCK SHOOT (16K Memory)

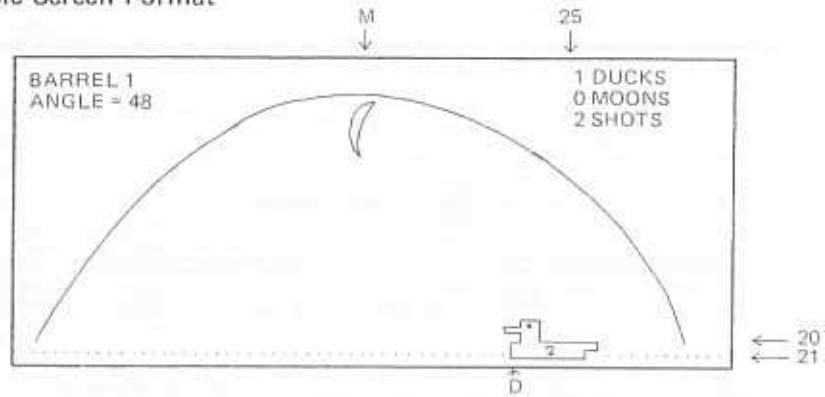
The author wishes to thank the designer of a similar game for the Research Machines 380 Z Microcomputer for the idea behind "Duck Shoot", the author's first experience of graphical games on a micro.

Description

A picture of a duck on a pond is displayed on the screen with the moon in the sky. The object is to shoot the duck making sure that you do not hit the moon in the process. Shooting is done by means of a double-barrelled cannon at the bottom left of the screen which fires up into the sky and the cannon ball travels in a parabola to eventually hit the pond and hopefully the duck. The player chooses the angle of elevation of the cannon. There are five goes.

For each go the duck and the moon are displayed at different (random) positions. The duck is drawn at a position starting between columns 12 and 27 at the bottom of the screen, and the moon starting between columns 12 and 18 at the top of the screen. Scores are shown at the top right of the screen while the barrel number and angle are displayed at the top left. The number of the go is shown on the duck itself. The duck has a range of comments which it makes depending upon the accuracy or otherwise of the player's shot. The moon drops out of the sky if the cannon ball hits it.

Sample Screen Format



Method

(i) Initialise scores HD(ducks), HM(moons) and S(shots) to zero
(ii) Carry out the following for go number G = 1 . . . 5
  (a) clear screen
  (b) choose duck position D between 12 & 27 along line
  (c) choose moon position M between 12 & 18 along line
  (d) draw screen display and headings
  (e) carry out the following for barrel number B = 1 and 2
    (1) Display barrel number
    (2) Enter angle of elevation A
    (3) If angle not between 45° and 85° go to (2) above
    (4) Display angle
    (5) Plot path of cannonball. For each plot position (x,y)

      A. If (x,y) is on the moon
        (i) Increment HM (moon hits)
        (ii) Drop moon out of sky
        (iii) Increment and display S (shots)
        (iv) Go to (f) below

      B. If (x,y) is on the duck
        (i) If (x,y) is a central hit
          (a) Display "DEAD"
          (b) Increment HD (duck hits)
          (c) Increment and display S (shots)
          (d) Go to (f) below
        (ii) Display "OUCH"
        (iii) Go to (7) below
    (6) Display "MISS"
    (7) Increment and display S (shots)
    (8) Wait
  (f) Wait
(iii) Clear screen
(iv) Display final score of ducks hit.

List of Variables

HD = no. of ducks killed
HM = no. of times moon hit
S = no. of shots fired

G = go number (1–5)
D = starting x-axis position of duck
M = x-axis position of moon
B = barrel number (1 or 2)
A = angle of elevation of cannon (valid for 45°–85° only)
I = loop counter for display of cannon ball's path
X = x position of cannon ball
Y = y position of cannon ball
M2 = 2 times M
D2 = 2 times D
Z = loop counter for display of falling moon

Equation

The path of the cannon ball is plotted using the following equations:

$$X = \text{INT}(0.0\,14*1*(90-A))$$

and

$$Y = \text{INT}(I*(100-I)*0.0172) \quad \text{for } I = 0 \ldots 100$$

The X equation is chosen so that the cannon ball lands in the pond at the far right of the screen when angle A is 45°. The Y equation is chosen so that the cannon ball reaches its maximum height when I = 50, i.e. in the middle of its flight path.

Program Listing

```
 2  LET HD = 0
 4  LET HM = 0
 6  LET S = 0
10  FOR G=1 TO 5
20  CLS
30  LET D=INT(RND*16)+12
40  LET M= INT(RND*7)+12
45  LET M2=M*2
46  LET D2=D*2
50  PRINT "BARREL"
60  PRINT "ANGLE=?"
70  PRINT AT 0,25;HD;"DUCKS"
80  PRINT AT 1,25;HM;"MOONS"
90  PRINT AT 2,25;S;"SHOTS"
100 PRINT AT 1,M;"▄"
110 PRINT AT 2,M;"▀"
```

```
120 PRINT AT 3,M;"▄"
130 PRINT AT 21,0;" ....."      (32 dots)
140 PRINT AT 20,D;"–⁝ bb/"
150 PRINT AT 21,D;"▯▮▮";CHR$(G+156);"▄"
160 FOR B=1 TO 2
170 PRINT AT 0,6;B
180 PRINT AT 1,6;"?b"
190 INPUT A
200 IF A>85 OR A<45 THEN GO TO 190
205 PRINT AT 1,6;A
210 FOR I=0 TO 100
220 LET X=INT(0.014*I*(90–A))
230 LET Y=INT(I*(100–I)*0.0172)
240 PLOT X,Y
250 IF X<M2 OR X>M2+1 OR Y>41 OR Y<36 THEN GO
    TO 400
270 LET HM=HM+1
280 FOR Z=1 TO 18
290 PRINT AT Z,M;"b"
300 PRINT AT Z+1,M;"▄"
310 PRINT AT Z+2,M;"▌"
320 PRINT AT Z+3,M;"▄"
330 NEXT Z
340 LET S=S+1
350 PRINT AT 2,25;S
360 GO TO 530
400 IF X<D2 OR X>D2+9 OR Y>3 THEN GO TO 495
410 IF X=D2 OR X=D2+1 OR X=D2+8 OR X=D2+9 THEN GO
    TO 450
420 PRINT AT 20,D–4;"DEAD"
430 LET HD=HD+1
432 LET S=S+1
434 PRINT AT 2,25;S
440 GO TO 530
450 PRINT AT 20,D–4;"OUCH"
491 GO TO 500
495 NEXT I
497 PRINT AT 20,D–4;"MISS"
500 LET S=S+1
505 PRINT AT 2,25;S
510 PAUSE 150
520 NEXT B
```



```
530 PAUSE 150
540 NEXT G
550 CLS
560 PRINT AT 10,10;"THE END"(inverse)
570 PRINT AT 12,3;"YOU KILLEDb";HD;"bDUCKS"
```

Several more games are included in Chapter Three.

CHAPTER TWO – INFORMATION PROCESSING

2.1 INTRODUCTION

This chapter is aimed at readers who want to use a ZX81 with 16K RAM to store and retrieve quantities of information, i.e. who want the microcomputer to act as an electronic filing system. The objective may be to design programs to assist in leisure activities or in small businesses. If you do not have a 16K RAM pack you will not be able to use much of the material in this chapter, but perhaps as you read through you will be encouraged to invest in one!

Data and Data Processing

RG Anderson in his book 'Data Processing and Management Information Systems' defines **data processing** as "the systematic recording, arranging, filing, processing and dissemination of facts". The term is often used synonymously with business computing as against scientific or technical computing. As a general rule business data processing involves the simple manipulation of large quantities of information while technical computing involves the complex manipulation of small quantities of information.

For example, a typical data processing activity might involve stock control: here a large number of records are maintained but the most complex processing involved would be simple addition or subtraction for goods received or despatched respectively. Contrast this with a typical technical computing activity, the evaluation of sets of equations: here a small set of coefficients is used as data but complex matrix arithmetic has to be used to produce the solutions.

It is the author's opinion that data processing is a much more realistic function for a home computer than technical computing. Many people would like a computer to handle all their filing, from addresses and telephone numbers to recipes, but how many require trigonometric and logarithmic processing capabilities? The only possible application of such facilities is in games (certainly a useful way to use a home computer), but in general, sophisticated maths is not required. It is unfortunate that home computer manufacturers, Sinclair Research included, have addressed themselves more towards providing these technical computing facilities rather than data processing facilities such as large main memory capacities and good backing storage. In other words, Mr. Sinclair, why not forget about ARCSIN, ARCCOS and LN and give us a megabyte of online storage instead!

Hobbyhorses aside, a 16K ZX81 can be used for some very useful small tasks on the data processing side and we hope to give you the tools to develop your own such programs in this chapter.

2.2 CHARACTER HANDLING

Character Processing

While technical computing is mainly concerned with crunching numbers together, data processing deals largely with characters, either alphabetic characters or numbers not used for arithmetic purposes (e.g. code numbers). It is therefore essential that the reader has a good grasp of ZX81 character handling before embarking upon an information processing project. We suggest that you read over Chapters 7 and 21 of the Sinclair Manual and then follow the sections below.

Dimensions of Strings

A string can be used without first DIMensioning it, but giving a string a dimension can be useful if we always want it to be of fixed length. As an example, try this:

```
10 DIM A$(3)
20 PRINT "ENTER A WORD"
30 INPUT A$
40 PRINT A$
50 GO TO 20
```

The program will print the first three characters of any word you enter because A$ can only contain three characters.

To stop the above program is difficult, but possible: rubout the quotes around the cursor when invited to enter a word and then enter CHR$ (99**99). This causes the ZX81 to attempt to evaluate 99^{99} – a

number too large for it to hold – so it crashes with error code 6.

Returning to dimensions of strings, it can be very useful to define a one character string which will always be used to INPUT responses to questions in a program, e.g.

```
10 DIM Z$(1)
...
100 PRINT "DO YOU WANT TO CONTINUE?"
110 INPUT Z$
120 IF Z$="N" THEN STOP
```

You may wonder why we bother with a dimension – why not do this:

```
100 PRINT "DO YOU WANT TO CONTINUE"
110 INPUT Z$
120 IF Z$(1)="N" THEN STOP
```

The answer is that if the user makes a null entry, i.e. just presses NEW-LINE, the first version is OK but the second version crashes with code 3 at line 120 because Z$(1) does not exist! It is vital in data processing programs which other people will use that the INPUTs be made as idiot-proof as possible. (See BOMB-PROOFING in Section 2.5).

Substrings

As we will see later in this chapter, verification of information input to a program is very important. Otherwise bad data gets onto files and it tends to make the whole system look ropy. A common verification is to check whether a string is alphabetic, i.e. contains letters A ... Z only.

```
10 PRINT "ENTER ALPHABETIC WORD"
20 INPUT A$
30 IF A$=""THEN GO TO 20
40 PRINT A$;
50 FOR I=1 TO LEN A$
60 IF A$(I)<"A" OR A$(I)>"Z" THEN GO TO 100
70 NEXT I
80 PRINT "IS ALPHABETIC"
90 STOP
100 PRINT "HAS ERROR CHARACTER AT POSITION";I
110 PRINT "PLEASE RE-ENTER"
120 GO TO 20
```


Several techniques are employed in this program. Firstly at line 30 – always test for a null input and if one is found go back to the INPUT statement: try this out and see the effect from the user's end. Secondly at line 60 – relational operators work with characters as well as numbers. Lastly at line 100 – error messages should be as precise as possible to inform the user what he is doing wrong.

N.B. Be careful when using this routine because it treats 'space' as non-alphabetic, so "JOHN SMITH" would be rejected as non-alphabetic.

Exercise 2(a): modify the above program to allow spaces and hyphens as well as letters A to Z.

We often need to determine whether a string contains a given word or sequence of characters.

Exercise 2(b): write a program to enter a sentence and then test whether it contains the word "THE" and give an appropriate message.

2.3 DESIGN OF DATA PROCESSING PROGRAMS

Systems Analysis

In the world of business computing the analysis, design and implementation of computerised systems is a profession in itself. Obviously we are not going to call in a professional systems analyst to design programs for our 16K ZX81, but many of the methods used by the professionals can be be scaled down and applied for our purposes.

Is It Feasible?

One of the first stages in systems analysis is the feasibility study – a survey of whether the area under study can usefully be computerised. Many data processing tasks are best done manually rather than by computer, and this applies especially to home DP. For example you may have some excellent ideas for a Recipe Access and Testing System for your spouse but how feasible is it that he/she will use RATS on a day-to-day basis? Do you have enough extra sockets or even room in the

kitchen for a ZX81, TV and cassette recorder? Will you be able to convince him/her that it is ten times better than his/her present manual system? Can the ZX81 cope with RATS storage requirements? Clearly these questions need honest answers before embarking upon a project which could consume many hours of precious time. A few of the areas you should consider are listed below:

BENEFITS — what substantial advantages would a computerised system have over the present system?

ZX81 CAPACITY — can the ZX81 store the program routines and data necessary for the system?

TECHNICAL ABILITY — are you sufficiently knowledgeable about the system and the relevant ZX81 facilities to implement your aims?

TIMESCALE — can the system be implemented in the time available?

USE — will the system be regularly and conscientiously used by the person(s) for whom it is designed?

Only after getting a positive answer to the above questions should you proceed with the design.

How Is It Done Now?

Before designing a new system a systems analyst takes a detailed look at how the present system operates using techniques such as interviewing staff, examination of documents, questionnaires and observation. If you are designing a system to be used by yourself you will have a clear idea of how you currently handle things and how things could be improved. However if you are producing a program to be used by someone else, you must get all this information from them. Since we are considering mainly filing systems on the ZX81 you need details of

Number of file records — present and future requirements
Size of records
How records are identified
How often records are added, changed or deleted.
Typical contents of records
How records are processed
Checking procedures

When we discuss the design of DP programs you will see why such facts are needed.

How Should It Be Done?

When getting together your ideas regarding features to be included in the computerised DP system, you need to be clear of the limitations of the current system and how these could be overcome. Eventually of course the facilities to be provided need to be listed in detail and a program routine designed to provide each facility. Appendix One describes a programming methodology that works: it is very important when writing a large program that a considerable amount of detailed program design is put in before touching the ZX81 keyboard.

You will need to pay particular attention to record formats and screen formats, i.e. what will be held in a file and what will appear on the screen. File formats are discussed in detail in Section 2.4. Good screen formats are vital for a workable program, particularly if the program will be used by a non-computer specialist, for example your husband or wife. Typically, in a section of the program to allow you to add new records to the file, the information presented on the screen should clearly and concisely describe what data needs to be entered and in what order. Features such as inverse video and judicious use of PRINT AT statements can make the program very user-friendly rather than user-nasty. It is best to actually map out on a piece of graph paper what will appear on the screen at major points in the program, and this can then be used to give you line and column numbers when you come to program your PRINT statements.

The Moment of Truth

Having designed the program, written it and debugged it according to the rules in Appendix One, the time comes to actually use it — "go live" in computing terminology. If someone else is using the program make sure that they are well-informed as to what to do to reap the amazing benefits offered by the program or else your efforts will have been wasted. In fact, if your family or others will be using your masterpiece of the programmer's art, a major exercise on your part will be selling the

system to them and training them: people will not use a computer (particularly if they object to nasty electronic objects and trailing wires) unless they are convinced it will help them in their own tasks or activities.

A final word of caution – a "parallel implementation" is often the best way of introducing your new system. In other words do not burn all your address books and telephone directories on the day that you introduce your Computerised Address and Telephone System. There is the remote possibility that someone might try something that you had not thought of and a hitherto unnoticed bug in CATS will jump out and grab the ZX81 by the throat; or even the not unheard of vagaries of 16K RAM packs could make the system die just after you have typed in a hundred and fifty names and addresses.

2.4 DATA STRUCTURES

Definitions

In this section we consider how information may best be organised for use as an 'electronic filing system'.

First we define the terms used. A **field** is an item of data on a particular topic. A **record** is a collection of fields with some feature in common, and a **file** is a collection of related records, often organised in order.

To illustrate this terminology we introduce a sample application, a club membership list. This example will be used as the basis for all the concepts introduced in later sections of the chapter also. Assume that the list is currently kept by means of cards in a box, one card per member. The **file** is then the collection of cards in the box, while a **record** is an individual card and a **field** is some item on the card, e.g. name.

A card might look like this:

BETELGEUSE BREAKERS CLUB

Membership Form

Name ..... Ford Prefect .....

Address ..... 23 Chatham Gardens .....

..... London .....

Post Code ..... SW1X 1LB .....

Telephone ..... 01-235-9649 .....

Special Interest ..... Demolition .....

Membership Number ..... 42 .....

Handle ..... Earthman .....

N.B. For the uninitiated, HANDLE is the code name used to identify a breaker or CB user

Files

The formats of records and fields are very important since the file forms the heart of the data processing system. Each heading on the card above will be a field on a member's record in the Betelgeuse Breakers Club (BBC) system which we are now starting to design. Whereas on a card we can have a few dotted lines upon which can be entered information, in a computerised system we must be much more precise as to the length of fields. The maximum number of characters allowed for each field must be chosen carefully. Every character will take up a byte of ZX81 memory so brevity is to be encouraged, although clarity must not suffer as a result.

Assume we choose the following:

NAME – length 15 characters
ADDRESS – length 50 characters
POSTCODE – length 8 characters
TELEPHONE NUMBER – maximum of 10 digits
SPECIAL INTEREST – length 20 characters
MEMBERSHIP NUMBER – 3 digits
HANDLE – length 15 characters

Two fields above are numeric. As the reader is no doubt aware, numbers can either be stored in the ZX81 as characters or digits, e.g.

```
    LET A$="123"        (characters)
or  LET A=123           (digits)
```

As far as memory requirements are concerned, a character string is stored in N+2 bytes where N is the number of characters, while a number is always stored in five bytes. Therefore if a number is more than three digits long it is more economic to use numeric format than character format. Another consideration is the usage to which the number is put: if the number will be used in any calculations it may be best to store it in numeric format since arithmetic cannot be carried out on characters, although of course VAL can be used to convert a number from character format to numeric format.

It may be helpful to the programmer if we split some of the fields down into subfields. For example, if we want to access membership records by surname then we could make NAME split into FORENAME and SURNAME, or perhaps INITIALS and SURNAME. Similarly, a separate field for TOWN could be useful: it all depends, as we discuss below, on how the file will be accessed.

Tables

The SPECIAL INTEREST field merits more detailed attention. It is quite likely that the interests of the Betelgeuse Breakers can be classified into main areas. To save space on the file we could then choose some code or code number to identify each of these special interests. For example:

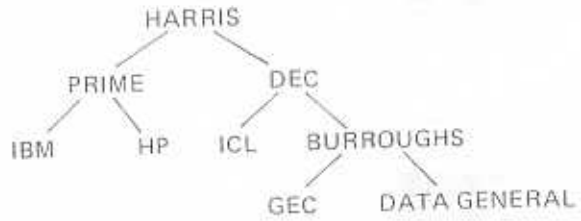
Code No.	Special Interest
1	Demolition
2	Pangalactic Gargle Blasters
3	Sirius Cybernetics Corporation
4	Improbability Drive
5	Interplanetary DX
6	Vogon Poetry

and so on.

If the actual interest had to be displayed somewhere in the program, a table could be kept relating the code number to the special interest. In fact, for simplicity the code number could act as the subscript to a string array holding the special interests.

Other Data Structures

For completeness it should be mentioned that several other ways of organising data apart from simple files and tables are possible. Linked lists and tree structures can be very useful in certain applications. The diagram below shows a binary tree structure:



Such structures are implemented by means of each record having a left and right pointer to other records. Such organisation can be very useful in manipulating the data contained therein, since to move records around the tree (e.g. in sorting) involves only the resetting of pointers.

Files, Tables and the ZX81

Most microcomputers have facilities to store files of data on a secondary memory device such as cassettes or floppy discs. Unfortunately the Sinclair ZX81 does not. However, when a ZX81 program is SAVED on cassette the data used by the program (in variables and arrays) is stored as well, and it is this feature that enables us to consider file processing on a ZX81.

Returning to our example, BBC could use an array for each field on a record

```
e.g. array N$   for NAMES
     array A$   for ADDRESSES
     array P$   for POSTCODES
     array T    for TELEPHONE NUMBERS
     array S    for SPECIAL INTEREST code numbers
```

array M for MEMBERSHIP numbers
array H$ for HANDLE

Then a complete record would consist of a combination of members of these arrays, e.g. the first member would have his name stored in N$(1) address in A$(1), postcode in P$(1), telephone number in T(1) and so or Assuming the system is designed for one hundred members, the arrays would be declared as follows:

```
DIM N$(100,15)
DIM A$(100,50)
DIM P$(100,8)
DIM T(100)
DIM S(100)
DIM M(100)
DIM H$(100,15)
```

We can immediately calculate how much storage time this will occupy

array	N$	takes up about	100 x 15	=	1500 bytes
array	A$	" " "	100 x 50	=	5000 bytes
"	P$	" " "	100 x 8	=	800 bytes
"	T	" " "	100 x 5	=	500 bytes
"	S	" " "	100 x 5	=	500 bytes
"	M	" " "	100 x 5	=	500 bytes
"	H$	" " "	100 x 15	=	1500 bytes
			Total		10300 bytes

Another approach to file storage on the ZX81 is to have a single array, s R$, holding the records so that R$(1) = first record, and so on. In this case each field starts at a given position and the numbers must be stored in character form. We may describe the records in R$ using a RECORD FORMAT document such as the one following :—

BBC System — RECORD FORMAT — Member File

No. of Records = 100 — Length of Record = 102 bytes

Name of Array = R$

FIELD No.	FIELD NAME	START BYTE	END BYTE	LENGTH	VALUES
1	Name	1	15	15	
2	Address	16	65	50	
2·1	Street	16	45	30	
2·2	Town	46	65	20	
3	Postcode	66	73	8	
4	Tel. No.	74	83	10	Numeric
5	Interest Code	84	84	1	1-9
6	Membership No.	85	87	3	Numeric
7	Handle	88	102	15	

For 100 records we declare R$ as DIM R$(100, 102) which will take up 10200 bytes approximately.

Notice that we have split ADDRESS into STREET and TOWN, that is the TOWN will always start at the 46th character position.

This is in fact the record format that we will use in this chapter to develop BBC programs. However it may help to mention an alternative in record design — that of **variable length fields.** In the record format above, much space will be wasted by data not filling their allowed field sizes. For example our sample record would be stored as :

```
1               16                                46
+               +                                 +
FORDbPREFECTbbb23bCHATHAMbGARDENSbbbbbbbbbbbbLONDON

                66        74          84 85 88              102
                +         +           + +  +                +
bbbbbbbbbbbbbbSW1Xb8LB012359649b 1  42b EARTHMANbbbbbbb
```

(b=space)

Which contains a lot of unused space. With variable length working we store a special terminator symbol after each field, and it is this that indicates to the program the end of one field and the start of another. We could use inverse characters as terminators, e.g.:

FORDbPREFECT [S]23bCHATHAMbGARDENS[T]LONDON[P]SW1Xb8LB
[T]01235964d[I]1 [M]42[E]EARTHMAN

which only takes up 71 bytes rather than 102 above. If this is an average saving of space, then with 100 records we will save about 3100 bytes. The trade-off is that extra processing is required by the program to find and pick out specific fields. If you are short on file storage space this is certainly the technique to use, if your computer has the facilities to do this. Unfortunately the ZX81 does not since we are limited by the way i which the ZX81 handles string arrays. If we want to store 100 records in a string array R$, we must dimension R$ thus
thus

```
DIM R$(100,N)
```

where N is the length of each record. Thus we must choose a fixed recor length, although we may have variable length fields within a record.

Variable Length Records

The only way of implementing true variable length records is to store the entire file as one long string with separator symbols between each of the records. We could for example use inverse asterisks, e.g.

R$

RECORD 1	*	RECORD 2	*	RECORD 3	*	RECORD 4	*		etc.

In this way each record only takes up the number of bytes that it needs. However what you win on the swings you lose on the roundabouts and efficient storage formats require extra processing to access and use them. One fairly easy way of accessing records stored in this format is to set up a pointer array P, in which P(i) shows the starting position of record i in R$. So to extract record 15 from the array and put it into X$ we have

```
LET X$ = R$(P(15) TO P(16)-1)
```


Using this method we can dispense with the separator symbols and store one record immediately after another.

As an example we can write a program which invites the user to enter ten names; store the names in a single string N$ and set up pointers in array P to indicate the starting position of each name. Then we invite the user to enter a record number (between 1 & 10) and extract and print out the appropriate record.

The program is listed below:

```
 10 DIM N$(300)
 15 DIM P(11)
 20 LET C=1
 30 PRINT "PLEASE ENTER 10 NAMES"
 40 FOR I=1 TO 10
 50 PRINT TAB 5;I;")b";
 60 INPUT X$
 70 IF X$="" THEN GO TO 60
 80 LET P(I)=C
 90 LET L=LEN X$
 95 LET N$(C TO C+L-1)=X$
100 LET C=C+L
110 PRINT X$
120 NEXT I
125 LET P(I)=C
130 PAUSE 200
135 POKE 16437,255
140 CLS
150 PRINT AT 10,0;"ENTER RECORD NUMBER OR 0 TO STOP"
160 INPUT N
165 IF N=0 THEN STOP
170 IF N<0 OR N>10 THEN GO TO 160
180 CLS
190 PRINT AT 10,7;"RECORD NUMBER";N
200 PRINT AT 12,14;"IS"
210 PRINT AT 14,(31+P(N)-P(N+1))/2;N$(P(N) TO P(N+1)-1)
220 GO TO 130
```

Method:

(i) Set current position pointer C to 1
(ii) Carry out the following for entry number I=1...10

(a) Enter name X$
(b) Store C at position I in pointer array P
(c) Calculate length L of X$
(d) Insert name X$ into array N$ between positions C and C+L−1
(e) Update C to next free position in array N$
(f) Print name X$

(iii) Store final value of C in P(11)
(iv) Wait for 4 seconds
(v) Clear screen
(vi) Enter record number N
(vii) If N=Ø stop
(viii) If N not between Ø and 1Ø then go back to (vi)
(ix) Clear screen
(x) Display record number N by accessing between positions P(I and P(N+1)−1 in array N$
(xi) Go back to (iv)

List of Variable Names

array N$	=	holds the 1Ø names as a single string
array P	=	holds pointers to starting positions of names in N$
C	=	shows next free position in array N$
I	=	loop counter indicating sequence number of name being entered
X$	=	name as entered
L	=	length of X$
N	=	record number to be printed

Comments

The technique of adding records to a single string is very useful and can be applied to records having multiple fields, each of which can themselv be of variable length.

N.B. The weird looking algebra at line 21Ø in the column position is to make sure that the name is printed centrally on the screen, whatever the length. As we will see in the next section, clarity or even prettiness of output gives greater user-friendliness (Programs with Pleasant Personalities).

2.5 FILE PROCESSING

Introduction

Having considered the different ways in which information can be stored in memory we can look at typical ways of processing it. We will first of all look at our example of the Betelgeuse Breakers Club (BBC) membership list in more detail, delving into what processing facilities would be required; we then think of what features need to be incorporated in file processing systems generally; and finally we split file processing down into typical modules such as file creation, validation, sorting and update, and use the BBC example to illustrate each of these concepts.

Sample Requirement

In Section 2.4 a typical Betelgeuse Breakers Club membership card was shown, and the file format for a computerised system was also explained (see page 46).

In the design of large computer program suites it is common for a user department to write a report specifying what facilities are required – an OPERATIONAL REQUIREMENT. Although we are considering information processing on a much smaller scale, it is still necessary to list what features our program aims to provide, since for every major facility a section will need to be included in the program.

The Secretary of the Betelgeuse Breakers Club will probably be looking for facilities in a computer system similar to the requirements of any Club Secretary. Let us assume these are:

(i) finding a record by name, membership number or handle
(ii) getting a list of all members' names and handles
(iii) getting a list of all members interested in a certain topic.
(iv) finding out which membership subscriptions are due: if, as is likely, membership numbers are handed out chronologically, this effectively means listing members with numbers in a certain range.

In addition there are certain run-of-the-mill facilities that must be available including adding and removing records and so on. These facilities will be formalised and developed as program modules in the final subsection of 2.5.

Program Features

Before seeing how a typical file processing program is written it is a salutary exercise to consider certain elements of programming style and technique. We aim to design systems which will be **bomb-proof** (or idiot-proof), **user-friendly** and **garbage-free.** Such terms may mean as little to the reader at this stage as redneck radio to an Easter Bunny, but all will be made clear.

BOMB-PROOFING is the careful design of programs and particularly INPUT sections so that the program cannot be made to terminate abnormally, (i.e. crash or bomb out). This is particularly important if the program user is not the program author. To achieve good bomb-proofing the program designer has to develop a very low opinion of the abilities of the intended user (even if it is himself), and hence the synonymous term idiot-proofing. In other words, if a mistake can be made, assume the user will make it.

As a simple example, consider a part of a program in which a number between Ø and 999 must be entered, e.g. as a membership number. Bomb-proofing theory suggests that we should tell the user the valid range and also check his entry:

```
100 PRINT "ENTER MEMBERSHIP NO. (Ø–999)"
110 INPUT M
120 IF M<Ø OR M>999 THEN GO TO 110
```

We find that causing the program to wait until the user enters a correct number is usually sufficient, but some designers prefer to add an extra message, e.g.

```
110 INPUT M
120 IF M>=Ø AND M<=999 THEN GO TO 150
130 PRINT "OUT OF RANGE:REENTER"
140 GO TO 110
150 . . .
```

However with this system, if the user persists in entering rubbish the number of error messages printed will eventually fill the screen and thus crash the system.

Nevertheless the major fault in the discussion so far is that if the user makes a non-numeric entry, e.g. WHAT, then the system crashes. The

only way to get round this is never to have straight *numeric* INPUT statements but always to use strings and then convert them to numbers if they are valid, e.g.

```
. . .
100 PRINT "ENTER MEMBERSHIP NO.(Ø–999)"
110 INPUT M$
120 FOR I=1 TO LEN M$
130 IF M$(I)<"Ø" OR M$(I)>"9" THEN GO TO 110
140 NEXT I
150 LET M=VAL M$
160 IF M>999 THEN GO TO 110
```

If several numbers are required to be input in a program it is a good idea to write a general subroutine to carry out the string-to-numeric conversion.

As far as string inputs are concerned, the main idiotic action to beware of is the null input, i.e. where the user just hits the NEWLINE key. In the last example above LEN M$ at line 120 evaluates to zero so the FOR . . NEXT loop is stopped and line 150 cannot be executed because VAL of the null string is incorrect (error code C). Therefore every string input must be followed by a test for the null string. Here:

```
115 IF M$=""THEN GO TO 110
```

However the reader should note that if the string has previously been DIMensioned then this test will not work. This is because the ZX81 sets a string to all spaces when it is DIMensioned. You can show this by the following simple program

```
10  DIM M$(3)
20  INPUT M$
30  PRINT ".";M$;"."
```

Do a RUN 20 and enter just NEWLINE : M$ is null. However including the DIM statement by RUN and following the exactly similar procedure causes three spaces to be printed for M$.

USER-FRIENDLINESS was the second objective in program design. We have already referred to this and in fact idiot-proofing is part of being user-friendly or perhaps user-condescending. It consists of making

the program as easy to use and human-like as possible. Prompts should be in plain English wherever possible and screen formats should look nice with clear headings, central placing and highlighted where appropriat

As suggested in Section 2.3 the program designer may map out each screen display on a piece of graph paper and check whether the display meets these objectives.

GARBAGE-FREE was the third quality required, and this refers to the old computer adage "GIGO" or "garbage in, garbage out". In other words if you accept incorrect data into a computer system then you will get incorrect results. Here we are not considering errors which cause a program to crash but rather errors which produce wrong results. This is particularly relevant when information is being fed in to be used as file records: once information is on file it may be difficult and messy to remove it.

Books on systems analysis theory list a vast range of checks which can be carried out on input data to avoid garbage being accepted onto file. Such validation methods include format checks, range checks, period checks, compatibility checks and many more. The alphabetic validation listed on page 37 is a typical example of making sure that numeric or special characters are not accepted into straight alphabetic fields such as that for a person's name.

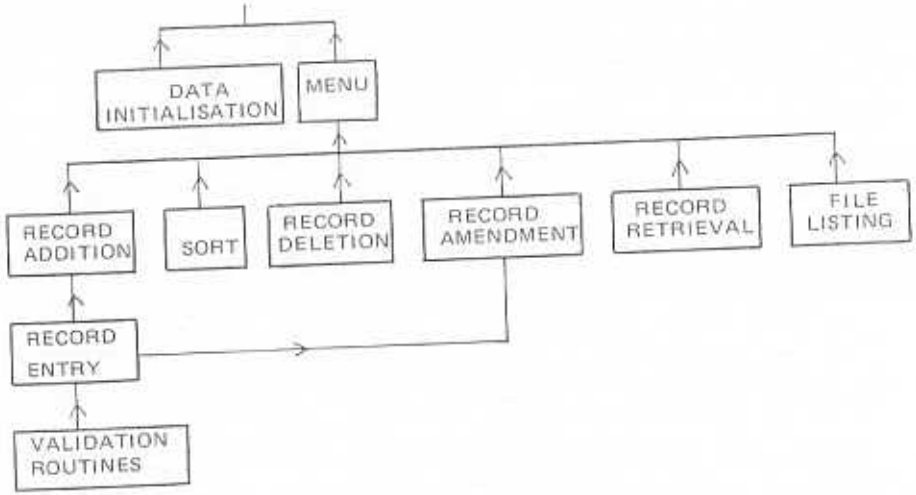
Validation techniques often include an element of redundancy and the use of a **check digit** is a good example. A check digit is an extra digit at the end of a code number which is formed by some specified calculation on the code number. The check digit would initially be calculated when the code-number was first allocated and then when the code is entered into a program, the program includes a routine to recalculate the check digit : if a discrepancy appears then the entry is incorrect.

Unfortunately the reader may find that in all these three aims, some limitations have to be made purely because of lack of ZX81 memory space.

Program Modules

All of the program modules required by the Betelgeuse Breakers Club will be included in a single ZX81 program. The program will be **menu-driven**, that is, a menu of options available will be displayed at the beginning, and after the option chosen is completed the program returns to the menu.

The modular structure of the program is shown below



DATA INITIALISATION

In the first section of the program we declare the arrays required and other initial data values.

The arrays used are:

N$ = Member's name, length 15 characters
S$ = Member's street, length 30 characters
T$ = Member's town, length 20 characters
P$ = Member's postcode, length 8 characters
B$ = Member's telephone number, length 10 characters
C$ = Member's interest code, length 1 character
M$ = Member's number, length 3 characters
H$ = Member's handle, length 15 characters
R$ = the membership file, 80 records of 102 characters

Z$ = general user's response, length 1 character
I$ = table of interests, 9 records of 15 characters each
X$ = record number entry, length 3 characters
W$ = working space for sorting, length 102 characters

We also define N, the number of records currently on file. Note we are restricting this to a maximum of EIGHTY because of memory limitation

This section is only used in the first program run to give initial values to data – All subsequent program runs are started by GO TO 50 so that previously defined data are retained.

```
10  DIM N$(15)
12  DIM S$(30)
14  DIM T$(20)
16  DIM P$(8)
18  DIM B$(10)
20  DIM C$(1)
22  DIM M$(3)
24  DIM H$(15)
26  DIM R$(80,102)
28  DIM Z$(1)
30  DIM I$(9,15)
32  DIM X$(3)
34  DIM W$(102)
40  LET N=0
41  LET I$(1)="Interest 1"
42  LET I$(2)="Interest 2"
43  LET I$(3)="Interest 3"
44  LET I$(4)="Interest 4"
45  LET I$(5)="Interest 5"
46  LET I$(6)="Interest 6"
47  LET I$(7)="Interest 7"
48  LET I$(8)="Interest 8"
49  LET I$(9)="Interest 9"
```

. . . actual data chosen as require

MENU:

The menu section displays the choice of options available and directs program control to the appropriate module (b=space, below).


```
50  CLS
60  PRINT TAB 4;"BETELGEUSEbBREAKERSbCLUB"
70  PRINT
80  PRINT "1.bADDbAbRECORD"
90  PRINT "2.bSORTbRECORDS"
100 PRINT "3.bDELETEbAbRECORD"
110 PRINT "4.bCHANGEbAbRECORD"
120 PRINT "5.bDISPLAYbAbRECORD"
130 PRINT "6.bLISTbTHEbFILE"
140 PRINT AT 19,0;"ENTERbNO.bREQUIREDbORb0bTObSTOP"
150 INPUT Z$
155 IF Z$="0" THEN STOP
160 LET MO=CODE Z$-28
170 IF MO<1 OR MO>6 THEN GO TO 150
180 GO TO 500*MO
```

MO is the menu option number chosen.

RECORD ENTRY:

Both option number 1 and option number 4 will require the entry of a record. In the former case, a new record will be added, whereas in the latter case an already existing record will be changed. However the entries will both require formatting and checking of inputs, so we write a general-purpose record entry module which can be used by both options.

The module will be entered with RN set to the number of the record to be entered. It then follows this method:

(i) Clear screen.
(ii) Display sequence number RN of record to be entered
(iii) Enter a member record:
  (a) Enter name into N$
  (b) Enter street into S$
  (c) Enter town into T$
  (d) Enter postcode into P$
  (e) Enter telephone number into B$, checking it is numeric
  (f) Enter interest code into C$, checking it is 1–9
  (g) Enter membership number into M$, checking it is 0–999
  (h) Enter handle into H$
(iv) Display record as entered.
(v) User confirms or cancels record

(a) If confirmed (1) move N$, S$, T$, P$, B$, C$, M$ and H$ to R$ (RN)
(2) add 1 to RN
(3) Output confirmation message
(4) Go to (vi) below

(b) If cancelled (1) Clear screen
(2) Output cancellation message.

(vi) Invite entry of NEWLINE or M
(a) If NEWLINE, go to (i) above
(b) If M return to menu.

Notice that we do not put the user's entries straight onto the file R$: we demand positive confirmation of his entries before this happens (step (v) above).

The BASIC for this section appears below:

```
5000    CLS
5010    PRINT TAB 4;"ENTRYbOFbRECORDbNUMBERb";RN
5020    PRINT AT 2,0;"NAME:"; (inverse)
5030    INPUT N$
5050    PRINT N$
5060    PRINT AT 4,0;"ADDRESS" (inverse)
5070    PRINT AT 5,4;"STREET:"; (inverse)
5080    INPUT S$
5100    PRINT S$
5110    PRINT TAB 4;"TOWN:"; (inverse)
5120    INPUT T$
5140    PRINT T$
5150    PRINT "POSTCODE:"; (inverse)
5160    INPUT P$
5180    PRINT P$
5190    PRINT AT 9,0;"TELbNO:"; (inverse)
5200    INPUT B$
5220    GO SUB 9000
5230    IF NOT OK THEN GO TO 5200
5240    PRINT B$
5250    PRINT AT 11,0;"INTERESTbCODE:"; (inverse)
5260    INPUT C$
5280    GO SUB 9100
5290    IF NOT OK THEN GO TO 5260
5300    PRINT C$
```

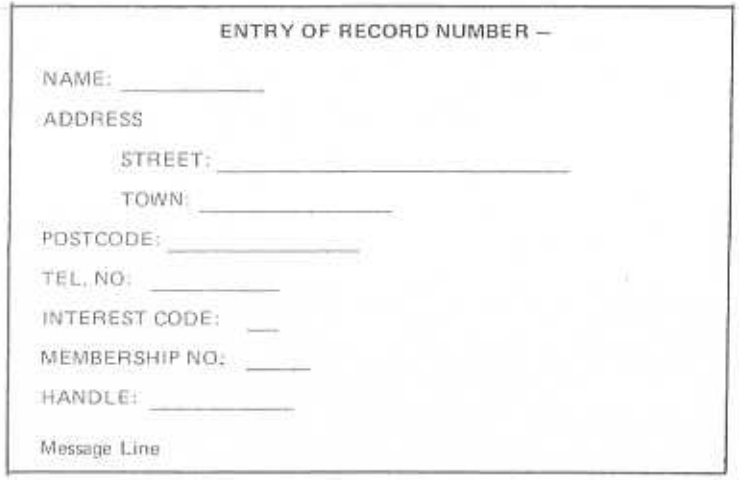


```
5310    PRINT AT 13,0;"MEMBERSHIPbNO:";(inverse)
5320    INPUT M$
5340    GO SUB 9200
5350    IF NOT OK THEN GO TO 5320
5360    PRINT M$
5370    PRINT AT 15,0;"HANDLE:"; (inverse)
5380    INPUT H$
5400    PRINT H$
5410    PRINT AT 19,0;"ISbTHISbCORRECT?"
5420    INPUT Z$
5430    IF Z$="N" THEN GO TO 5570
5440    IF Z$="Y" THEN GO TO 5460
5450    GO TO 5420
5460    LET R$(RN,1 TO 15)=N$
5470    LET R$(RN,16 TO 45)=S$
5480    LET R$(RN,46 TO 65)=T$
5490    LET R$(RN,66 TO 73)=P$
5500    LET R$(RN,74 TO 83)=B$
5510    LET R$(RN,84)=C$
5520    LET R$(RN,85 TO 87)=M$
5530    LET R$(RN,88 TO 102)=H$
5540    PRINT AT 19,0;"RECORDbADDEDbTObFILE"
5550    LET RN=RN+1
5560    RETURN
5570    CLS
5580    PRINT AT 19,0;"ENTRYbCANCELLED"
5590    RETURN
```

As you can see it is all good solid boring stuff — the meat of data processing. However, having it as a subroutine at least means we do not need to enter it twice.

The routine returns with RN incremented by one if a record has been entered onto the file, or the same if no record has been entered.

The screen format used is:



VALIDATION ROUTINES

The record entry section invokes three subroutines to check the entry o telephone number, interest code and membership number. Each of the routines return a value OK, set to zero if the entry was invalid or one if it was valid.

Telephone number validation:

```
9000    LET OK=0
9010    FOR I=1 TO 10
9020    IF B$(I)="b" OR (B$(I)>="0" AND B$(I)<="9") THE
          GO TO 9040
9030    RETURN
9040    NEXT I
9050    LET OK=1
9060    RETURN
```

Interest code validation:

```
9100    LET OK=0
9110    IF C$="b" THEN LET C$="0"
9120    IF C$<"0" OR C$>"9" THEN RETURN
9130    LET OK=1
9140    RETURN
```


Membership number validation:

```
9200    LET OK=0
9210    FOR I=1 TO 3
9230    IF M$(I)<"0" OR M$(I)>"9" THEN RETURN
9240    NEXT I
9250    LET M=VAL M$
9260    IF M=0 THEN RETURN
9270    LET OK=1
9280    RETURN
```

We can also have record number validation:

```
9300    LET OK=0
9310    IF X$(1)="b" THEN RETURN
9320    FOR I=1 TO 3
9330    IF X$(I)="b" OR (X$(I)<="9" AND X$(I)>="0")
          THEN GO TO 9350
9340    RETURN
9350    NEXT I
9360    LET VN=VAL X$
9370    IF VN>N OR VN=0 THEN RETURN
9380    LET OK=1
9390    RETURN
```

RECORD ADDITION:

This just adds a record at the end of the file and optionally repeats

```
500     LET RN=N+1
510     GO SUB 5000
520     IF RN=N+2 THEN LET N=N+1
530     PRINT AT 20,0;"PRESSbNEWLINEbTObADDbRECORD
          b";RN
540     PRINT AT 21,6;"ORbMbFORbMENU"
550     INPUT Z$
560     IF Z$="b" THEN GO TO 510
570     IF Z$="M" THEN GO TO 50
580     GO TO 550
```

RECORD AMENDMENT

This is very similar to record addition, but allows the user to re-input and therefore change a record already on file:

```
2000    CLS
2010    PRINT AT 20,0;"ENTERbNUMBERbOFbRECORD"
2020    INPUT X$
2030    GO SUB 9300
2040    IF NOT OK THEN GO TO 2020
2050    LET RN=VN
2100    GO SUB 5000
2200    PRINT AT 20,0;"PRESSbNEWLINEbTObCHANGEb
          ANOTHER"
2210    PRINT AT 21,6;"ORbMbFORbMENU"
2220    INPUT Z$
2230    IF Z$="b" THEN GO TO 2000
2240    IF Z$="M" THEN GO TO 50
2250    GO TO 2220
```

SORT:

It is likely that the membership file will be in membership number orde since as previously mentioned, numbers will probably be allocated in chronological sequence. However a sorting routine is included to allow for any anomalies.

There are many different methods of sorting information into sequence and such methods are easily found in computing textbooks. The following routine uses a simple exchange sort:

> For pointer q from 1 to p :
> If no. of record q > no. of record q + 1 then swop record q and q + 1

The routine uses characters 85 to 87 of record R$, the membership number: if sequencing is required on name or another attribute this specification may easily be changed.

```
1000    CLS
1002    PRINT AT 20,0;"SORTING ..."
1006    FOR P=N-1 TO 1 STEP-1
```



```
1010    FOR Q= 1 TO P
1020    IF R$(Q,85 TO 87)<=R$(Q+1,85 TO 87) THEN GO
          TO 1060
1030    LET W$=R$(Q)
1040    LET R$(Q)=R$(Q+1)
1050    LET R$(Q+1)=W$
1060    NEXT Q
1070    NEXT P
1080    PRINT AT 20,0;"SORTbCOMPLETED"
1090    PAUSE 250
1100    POKE 16437,255
1110    GO TO 50
```

RECORD DELETION:

If someone leaves the Betelgeuse Breakers Club then their record must be deleted from file. To do this the user selects this option and specifies the sequence number of the record to be removed.

```
1500    CLS
1505    PRINT AT 20,0;"ENTERbNO.bOFbRECORDbFORb
          DELETION"
1510    INPUT X$
1520    GO SUB 9300
1522    IF NOT OK THEN GO TO 1510
1524    LET D=VN
1530    PRINT AT 21,0;"DELETING ..."
1540    FOR I=D TO N-1
1550    LET R$(I)=R$(I+1)
1560    NEXT I
1570    LET N=N-1
1580    CLS
1590    PRINT AT 19,0;"RECORDb";D;"bHASbBEENb
          DELETED"
1600    PRINT AT 20,0;"PRESSbNEWLINEbFORbMOREb
          DELETIONS"
1610    PRINT AT 21,6;"OR M FOR MENU"
1620    INPUT Z$
1630    IF Z$="b" THEN GO TO 1500
1640    IF Z$="M" THEN GO TO 50
1650    GO TO 1620
```

RECORD RETRIEVAL

One of the requirements of the Breakers Club Secretary was to retrieve a record by name, membership number or handle. This is how it is done

```
2500  CLS
2510  PRINT AT 10,0;"SPECIFYbONEbOFbTHEb
      FOLLOWING:"
2520  PRINT AT 12,0;"NAME:"
2530  PRINT "MEMBERSHIPbNO:"
2540  PRINT "HANDLE:"
2550  PRINT AT 20,0;"ENTERbVALUEbORbNEWLINEb
      FORbEACH"
2560  INPUT N$
2570  PRINT AT 12,5;N$
2580  INPUT M$
2590  PRINT AT 13,14;M$
2600  INPUT H$
2610  PRINT AT 14,7;H$
2620  IF N$(1)="b"THEN LET N$(1)="*"
2630  IF M$(1)="b" THEN LET M$(1)="*"
2640  IF H$(1)="b" THEN LET H$(1)="*"
2650  PRINT AT 20,0;"SEARCHINGbbbbbbbbbbbbbbbbbbb
2660  FOR I=1 TO N
2670  IF R$(I, 1 TO 15)=N$ OR R$(I,85 TO 87)=M$ OR
      R$(I,88 TO 102)=H$ THEN GO TO 2715
2680  NEXT I
2690  CLS
2700  PRINT AT 10,5;"NObRECORDbFOUND"
2710  GO TO 2810
2715  CLS
2720  PRINT TAB 10;"RECORDbNO.b";I
2730  PRINT AT 2,0;R$(I,1 TO 15)
2740  PRINT R$(I,16 TO 45)
2750  PRINT R$(I,46 TO 65)
2760  PRINT R$(I,66 TO 73)
2770  PRINT R$(I,74 TO 83)
2780  PRINT R$(I,84)
2790  PRINT R$(I,85 TO 87)
2800  PRINT R$(I,88 TO 102)
2810  PRINT AT 20,0;"PRESSbNEWLINEbFORbANOTHER
      RECORD"
2820  PRINT AT 21,6;"ORbMbFORbMENU"
2830  INPUT Z$
2840  IF Z$="b" THEN GO TO 2500
2850  IF Z$="M" THEN GO TO 50
2860  GO TO 2830
```


Notice that it is helpful to the user to display a message to show that the ZX81 is busy doing something, e.g. SEARCHING at line 2650.

FILE LISTING:

This section shows how to implement a full or selective file listing. In the listing, only members' names and handles are displayed.

Options are:

(i) full listing
(ii) listing of members with a given interest
(iii) listing of members with membership numbers above a certain figure

```
3000  CLS
3010  PRINT TAB 10;"LISTbRECORDS"
3020  PRINT AT 20,0;"DObYOUbWANTbAbFULLbLISTb
      (Y/N)?"
3030  INPUT Z$
3040  IF Z$="Y" THEN GO TO 3065
3050  IF Z$="N" THEN GO TO 3120
3060  GO TO 3030
3065  CLS
3070  FOR I=1 TO N
3080  SCROLL
3090  PRINT AT 15,0;R$(I,1 TO 15);";";R$(I,88 TO 102)
3100  NEXT I
3110  GO TO 3350
3120  PRINT AT 20,0;"SELECTbBYbINTERESTbORb
      NUMBER?b"
3130  INPUT Z$
3140  IF Z$="I" THEN GO TO 3170
3150  IF Z$="N" THEN GO TO 3260
3160  GO TO 3130
3170  PRINT AT 2,10;"INTERESTS"
3180  FOR I=1 TO 9
```

```
3190    PRINT I;".b";N$(I)
3200    NEXT I
3210    PRINT AT 20,0;"ENTERbINTERESTbCODEb
        NUMBERb(1-9)"
3220    INPUT C$
3230    GO SUB 9100
3240    IF NOT OK THEN GO TO 3220
3245    LET M$="999"
3250    GO TO 3300
3260    PRINT AT 20,0;" LISTbMEMBERSbWITHbNUMBERSb
        >?bbb"
3270    INPUT M$
3280    GO SUB 9200
3290    IF NOT OK THEN GO TO 3270
3295    LET C$="*"
3300    CLS
3310    FOR I=1 TO N
3320    IF R$(I,84)<>C$ AND R$(I,85 TO 87)
        <=M$ THEN GO TO 3340
3330    SCROLL
3335    PRINT AT 15,0;R$(I,1 TO 15);":";
        R$(I,88 TO 102)
3340    NEXT I
3350    PRINT AT 20,0;"PRESSbNEWLINEbFORbMENU"
3360    PAUSE 5000
3370    POKE 16437,255
3380    GO TO 50
```

Summary

When the above routines have been entered, records can be added and the system used. Once data has been entered, it is vital that the system is always started by GO TO 50, since RUN automatically clears data. Always SAVE the system on cassette whenever any file additions or modifications have been made.

Although your own file processing application may not be identical to the Betelgeuse Breakers Club system, the same principles apply and many of the routines in this chapter may be used directly.

CHAPTER THREE – EDUCATION

3.1 THE ZX81 AS AN EDUCATIONAL TOOL

Introduction

At the time of writing Sinclair Research is operating a special offer to UK schools whereby a complete 16K ZX81 system with printer can be obtained at half-price. The offer came about in response to a Government-funded scheme to install a microcomputer in every secondary school, by providing a 50% subsidy for the purchase of either an Acorn Atom or a Research Machines 380Z.

Even without such a scheme for the Sinclair ZX80 this microcomputer found a place in many educational institutions. Certainly the ZX81 will prove even more popular. School students themselves will start to find that it is within their budgets, or rather their parents'. The ZX81 has many facilities that could make it a useful educational resource, but the key facility in education is of course suitable software. In this chapter we consider various types of educational computing and the design of software to be used in the primary and secondary sectors.

Computer Studies

Many secondary schools use microcomputers largely for examination subjects such as CSE or GCE 'O' level Computer Studies or GCE 'A' level Computer Science. These subjects generally require students to carry out substantial programming with a number of documented programs being submitted as part of the course assessment.

Most schools equipped with microcomputers allow and encourage students to get involved with programming. Even many primary schools in the author's region are encouraging children to develop their own programs with assistance from teaching staff.

In order for a microcomputer to be suitable for the learning of computer programming by a range of school students and also for more complicated project work for external assessment, the machine must be very flexible. The ZX81 scores well in this area and has a number of facilities that make program entry and development much easier than on many

similar micros. In particular the entry of keywords by single key depressions and the automatic syntax checking of lines has been found to aid beginners considerably. The ZX81's line editing capability is also unusually sophisticated for a machine of its size.

For more advanced programming the ZX81 has many powerful number-handling and text-handling facilities permitting a range of applications programs to be developed. Obviously the addition of 16K memory extensions are vital for any degree of sophistication, but with this a great deal of potential is available. Finally, the addition of a printer at around £50 (projected at the time of writing) makes the system suitable for project work where hard copy is vital : in fact the cheapness of the printer is a considerable advantage over other systems.

On the negative side, ZX81 report codes are clumsy in program development. It is a nuisance having to look up the meaning of codes in order to find out why a program is going wrong. The tiny keyboard with its multifunction keys, while being a novelty and definite aid for those not familiar with keyboards, is a considerable disadvantage when entering long and complicated programs.

General Subjects

Increasingly schools are buying computers for use as educational aids in general subjects, rather than in computer studies. This seems to be a more realistic and sensible approach for many secondary students since it is much easier to recognise the value of computer technology if a student is already aware of actual problems which he later discovers a computer can help to solve. Similarly for primary schoolchildren a background in using micros as *tools* similar to cassette recorders or projectors enables them to encounter computers in their later educational or working lives without having inbuilt prejudices against the technology involved.

In this area therefore we are analysing the validity of the ZX81 as a black-box (!) providing educational facilities. Obviously a crucial aspect here is the quality and relevance of the software used, and since the best educational software is written by subject teachers rather than by computer people, this chapter aims to aid the reader in producing good software. However we can make some general comments about ZX81 BASIC and its relevance in this area of use. Presentation of information is very important in many subjects, and the graphics features of the

ZX81 are helpful although of limited resolution; similarly the SLOW compute and display facility is very useful in displaying active processes on the ZX81 screen. The inverse character displays available are also good but it could be argued that the provision of lower case characters would have been more helpful: it is a considerable disadvantage at the primary level or in any language work to have to use upper case characters only.

Being able to interact with computer programs in realtime, using INKEY$ can be an advantage in the educational area, and exercises in coordination can easily be designed using a limited number of keys. In fact the touch-sensitive keyboard can easily be partitioned off by overlays, with the active keys being labelled with special symbols according to the application currently in use.

Categories of Educational Programs

Before embarking upon the study of specific programs let us consider what general categories of programs can be used in the primary and secondary spheres to aid the teaching of non-computing subjects: this chapter does not seek to develop programs for Computer Studies, or for use in educational administration (see Chapter Two for ideas on this).

Demonstration or simulation programs are those with little student involvement, either run by a teacher or without any more inputs. Such programs are of limited value but can be used to demonstrate the facilities of a machine to an introductory group or at a more advanced level to demonstrate some process that is difficult to explain or model otherwise, eg: a dangerous chemical experiment might be shown by the reagents and products being displayed on the screen.

Programmed learning programs depend upon a program taking on to a small extent the role of a teacher: typically a program might contain teaching material on a topic and the student would respond to certain questions posed by the program. His response would determine the next block of material displayed by the program. Since these programs often require the storage of a great deal of textual material to be effective, the value of such programs on the ZX81 is limited.

Test or **quiz** programs are a simpler variant of the previous category. Here a bank of questions is held in a program and the student is given each question in turn (or perhaps randomly from a large section of

questions) and has to reply by entering his answer on the keyboard. The computer then responds by assessing his answer as right or wrong, and if the latter a hint or further help may be given. At the end a score appears. If the quiz is substantial the program may be written so that the student may stop in the middle, SAVE everything on cassette and restart from where he left off at a later time: the ZX81 is one of the few microcomputers which makes this very easy.

Modelling programs simulate a real-life process so that the user can be involved in the process without the accompanying problems or equipment. For example a complete list of chemical compounds with their reactions to certain tests can be held on file and the student can then be presented by the program with an unnamed compound and can perform a series of tests on it until he can finally determine what it is — all without getting his white coat dirty.

Games programs often have sound educational value, and many programs at primary level can be written as games to achieve their goals. Even quite stuffy programs such as maths quizzes can be written with a game-like flavour eg: a game of snakes and ladders in which the player has to get a sum right before he can throw dice.

A selection of different types of programs appears in the remainder of the chapter. Many 'standard' educational programs can be picked up easily from text books, magazines or groups such as MUSE, and it is not the author's intention to re-reproduce such material. Instead programs have been chosen which particularly use the educational facilities of the ZX81.

3.2 EDUCATIONAL PROGRAMS

MATHS STEPPING STONES (16K)

Background

The first program in this section has been chosen to illustrate how an essentially simple and boring maths testing program can be made interesting and dynamic using realtime graphics.

Here is the simple and boring version:

```
10  LET S=0
20  FOR I=1 TO 10
30  LET A=2+INT(RND*8)
40  LET B=2+INT(RND*8)
50  LET C=A*B
60  PRINT AT I,0;I;TAB 2;")b";A;"bXb?b=b";C;"b"
70  INPUT G
80  IF G=B THEN GO TO 110
90  PRINT AT I,15;"NO.bANSWERbISb";B
100 GO TO 120
110 PRINT AT I,15;"CORRECT" (inverse)
115 LET S=S+1
120 PRINT AT I,8;B
130 NEXT I
140 PRINT
150 PRINT "YOUbGOTb";S;"bRIGHTbOUTbOFb10"
```

There are 10 questions of the type 4 x ? = 32 and the data names used are

S = number of questions answered correctly
I = question number
A)
B) the question posed in the form A X B = C
C)
G = user's attempt

There is nothing novel about this type of program and personal computer magazines and books are full of such things. Let us now consider a program which aims to test exactly the same principles but which does

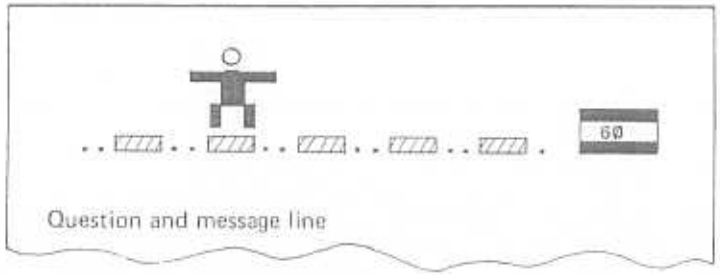
nuch more attractive way.

tion

yer is on one side of a river and a treasure chest is on the other
ne chest contains magic gold coins which as time goes on are
into frogs: the longer the player takes to cross the river the more
d less gold coins. The player crosses the river by means of five
g stones, but to reach each stepping stone he has to answer a
uestion. If the player has not crossed the river after twenty
ns the stones disappear and the player falls into the river. This
ppens if all the coins have turned into frogs.

(i) Initialise score S to zero and coins CO to 100
(ii) Draw river scene on screen
(iii) For I from 1 to 20
  a) choose A at random between 2 and 9
  b) choose B at random between 2 and 9
  c) Evaluate C as A times B
  d) Display I and question as A x ? = C
  e) If a key has been pressed:
    1) If key = value of B then
      (a) Display message
      (b) Add 1 to S
      (c) If S = 6 display message and stop
      (d) Move man
      (e) Go to (3) below
    2) Display message
    3) Pause
    4) Repeat to (iii)
  f) Subtract 1 from CO and display CO.
  g) Go to (e) if no key pressed above.
  h) If CO is zero, go to (iv) below.
  i) Repeat to (iii)
(iv) Display message and stop.

Screen Format



Program Listing (16K)

```
 10 LET S=0
 20 LET CO=100
 30 PRINT AT 3,3;"..▒▒▒..▒▒▒..▒▒▒..▒▒▒..▒▒▒
    .";CO
 40 PRINT AT 2,29;"■■■"
 50 PRINT AT 4,29;"■■■"
 60 LET X=0
 70 GO SUB 500
 80 FOR I=1 TO 20
 90 LET A=2+INT(RND*8)
100 LET B=2+INT(RND*8)
110 LET C=A*B
120 PRINT AT 5,0;I;TAB 2;")b";A;"bxb?b=";C;
125 IF C<10 THEN PRINT "b"
130 PRINT AT 5,15;"bbbbbbbbbbbbbb"
140 LET K$ = INKEY$
150 IF K$=""THEN GO TO 310
155 PRINT AT 5,8;B
160 IF CODE K$-28<>B THEN GO TO 280
170 PRINT AT 5,15;"CORRECT"
180 LET S=S+1
190 IF S<>6 THEN GO TO 220
200 PRINT AT 6,0;"YOUbGOTb";CO;"bGOLDbCOINSb+b";100-CO;
    "bFROGS"
210 STOP
220 LET X=5*S
230 FOR J=0 TO 2
```

```
240 PRINT AT J,X-5;"bbb"
250 NEXT J
260 GO SUB 500
270 GO TO 290
280 PRINT AT 5,15;"NO.bANSWERbISb";B
300 PAUSE 300
310 LET CO=CO-1
315 IF CO=0 THEN GO TO 340
320 PRINT AT 3,29;"b";CO
325 IF CO<10 THEN PRINT "b"
326 IF K$="" THEN GO TO 140
330 NEXT I
340 PRINT AT 3,3;"....."
350 PRINT AT 6,0;"HARDbLUCKb-bYOUbWILLbGETbWET"
360 STOP
500 PRINT AT 0,X+1;"O"
510 PRINT AT 1,X;"▄▄▄"
520 PRINT AT 2,X;"▯▮b▯"
530 RETURN
```

List of Variables

S = number of stepping stone upon which man is standing
CO = number of gold coins left
X = column position of man
I = number of current question
A =)
B =) the question posed in the form A X B = C
C =)
J = loop counter

Comments

The child using the program need only press a single key to enter his answer – the use of INKEY$ removes the need for NEWLINE at the end of entries.

After each attempt the correct sum stays on the screen for six seconds and the coin transmutation also temporarily halts. This period can be cut short by pressing NEWLINE if required, since this terminates the PAUSE. If the man reaches the chest then the game ends with a

message showing how many coins (and frogs!) he obtains.

To make the program easy to use a number of PRINT statements giving instructions on play should be included at the beginning of the listing.

Exercise 3(a): The theme of the program – crossing a river to a Treasure Chest – could be used in many different tasks other than a maths quiz, or at varying levels of difficulty. Modify the program to apply to a subject area of your choice.

SPELLING BIG WORDS (16K)

Description

This program is a spelling test which works by means of a word being displayed with a missing letter and the child has to enter the letter within a time limit. The word is displayed as four times normal size using direct access to the monitor character table. Words are entered by the teacher in a separate part of the program with the letter to be omitted being entered as an inverse character. N.B. Words up to 8 letters.

Method

Teacher :
(i) For I from 1 to 10
Enter word number I
(ii) Stop

Child:
(i) Set score S to 0
(ii) For I from 1 to 10
a) Display word I, large with letter omitted
b) Set counter to 20
c) Display counter
d) If no key pressed
1) Decrement counter
2) Display counter
3) If counter = 0, display message & go to (g)
4) Go to (d) above
e) If key pressed is correct
1) Add 1 to S
2) Display message
3) Go to (g)

f) Display message and show correct letter
g) Pause

(iii) Display score S and stop

Screen Format

Program Listing (16K)

```
10  DIM W$(10,8)
20  PRINT TAB 7;"TEACHERSbSECTION"
30  PRINT "ENTERbWORDSbWITHbLETTERbTObBE"
40  PRINT "OMITTEDbINbINVERSEbFORM"
50  FOR I=1 TO 10
60  PRINT AT I+5,5;"WORD";I;TAB 12;"=";
70  INPUT W$(I)
80  PRINT W$(I)
90  NEXT I
100 STOP
210 LET S=0
220 FOR I=1 TO 10
225 CLS
226 FAST
227 PRINT AT 0,0;I
230 FOR K=1 TO 8
240 LET C=CODE W$(I,K)
250 IF C<128 THEN GO TO 280
260 LET M$=CHR$(C-128)
270 LET C=0
280 FOR L=0 TO 7
290 LET P=PEEK(7680+C*8+L)
300 LET V=128
```



```
310 FOR J =0 TO 7
320 IF P<V THEN GO TO 350
330 PLOT 8*(K-1)+J,39-L
340 LET P=P-V
350 LET V=V/2
360 NEXT J
370 NEXT L
380 NEXT K
390 SLOW
400 LET X=20
410 PRINT AT 0,13;"TIME:20"
420 LET K$=INKEY$
430 IF K$<>""THEN GO TO 490
440 LET X=X-1
450 PRINT AT 0,18;X;"b"
460 IF X<>0 THEN GO TO 420
470 PRINT AT 7,0;"TOObSLOW"
480 GO TO 540
490 IF K$<>M$ THEN GO TO 530
500 LET S=S+1
510 PRINT AT 7,0;"CORRECT."
520 GO TO 540
530 PRINT AT 7,0;"WRONG."
540 PRINT AT 7,10;"IT bWASb";W$(I)
550 PAUSE 300
560 POKE 16437,255
570 NEXT I
580 CLS
590 PRINT AT 7,5;"YOUbSCOREDb";S;"bOUTbOFb10"
```

List of Variables

W$	=	array holding ten eight-character words
I	=	number of word currently considered
S	=	score out of ten
K	=	letter of current word
C	=	code of letter in word
M$	=	missing letter in word
L	=	loop counter
P	=	value of location in character table
V	=	a power of two used to access bits in P

J = loop counter
X = time counter
K$ = key pressed by player

Comments

The large display of the word being tested helps to give the program considerable visual impact and the single key entry of answers is also useful. The quiz proper is started by GOTO 210.

There is a delay while the ZX81 sets up the large word on the screen and this takes place with a blank screen (uses FAST mode) in order that the player only has a given time limit to choose his answer: he does not see the word gradually appearing on the display. The routine is explained on page 102. Display of large characters is applicable to many areas of language teaching.

Exercise 3(b): Write statements to ensure that only valid entries are permitted in the teacher's section.

SPOTS BEFORE THE EYES (1K)

Description

Here is a ZX81 version of a program which first appeared in *'The ZX80 Companion'* under the title of PATTERN RECOGNITION. The idea behind the program is based upon Glenn Doman's book *'Teach Your Baby Maths'*, in which it is suggested that children can be taught to recognise quite large numbers of dots (up to one hundred) with sufficient practice. The program makes use of the PAUSE instruction to display a collection of spots for a very short time before the user enters the number. There are ten goes and a score is given at the end. The program runs on a 1K ZX81.

Method

(i) Set scores S, T and U to zero
(ii) For go number G from 1 to 10
  a) Choose R at random between 20 and 100
  b) Display R spots for 2 seconds

  c) Enter user's attempt N
  d) If N=R (1) display "CORRECT"
    (2) add 1 to S
    (3) go to (h) below
  e) If |N−R| ⩽5,(1) add 1 to T
    (2) go to (g) below
  f) If |N−R| ⩽10, add 1 to U
  g) Display "INCORRECT" and value of R
  h) Wait for five seconds
(iii) Display scores.

Program Listing (1K)

```
10  LET S=0
20  LET T=0
30  LET U=0
40  FOR G=1 TO 10
50  LET R=20+INT(RND*81)
60  FAST
70  FOR I=1 TO R
80  PRINT "■□";
85  IF RND<0.5 THEN PRINT "b";
90  NEXT I
100 PAUSE 100
105 POKE 16437,255
110 CLS
120 SLOW
130 PRINT "HOWbMANY?b";
140 INPUT N
145 PRINT N
150 IF N<>R THEN GO TO 190
160 PRINT "YES" (inverse)
170 LET S=S+1
180 GO TO 250
190 IF ABS(N−R)>5 THEN GO TO 220
200 LET T=T+1
210 GO TO 240
220 IF ABS(N−R)>10 THEN GO TO 240
230 LET U=U+1
240 PRINT "NO,b";R
250 PAUSE 250
255 POKE 16437,255
```

```
260   CLS
270   NEXT G
280   PRINT "SCORE:bb";S;"bCORRECT,b";T;"bWITHINb5,
      bb";U;"bWITHINb10"
```

List of Variables

S	=	score correct
T	=	score within 5
U	=	score within 10
G	=	go number, 1--10
R	=	number of spots
I	=	loop counter
N	=	user's attempt

Comments

Note that the addition of line 85 ensures that the spots appear in a random pattern – without it the user can use the length of the pattern to estimate the number. The score given at the end in three parts (correct, within 5 and within 10) gives the user a clear idea of his performance.

The program would run perfectly well in FAST Mode, but the listing above reverts to SLOW mode for the input section as a matter of the author's preference! The display of the spots **must** be in FAST mode so that the two second display of the spots is effective.

Exercise 3(c): Why is the ABS function included in lines 190 and 220 and what would happen if it was omitted?

GRAB THE GRUNGER (16K)

Description

No discussion of primary level educational programs is complete without looking at grid games, of the HUNT THE HURKLE variety. In such programs a grid is displayed on the screen and an object (an imaginary creature such as a Hurkle, or in this case a GRUNGER) is chosen to be at a random position in the grid. The player then has a number of

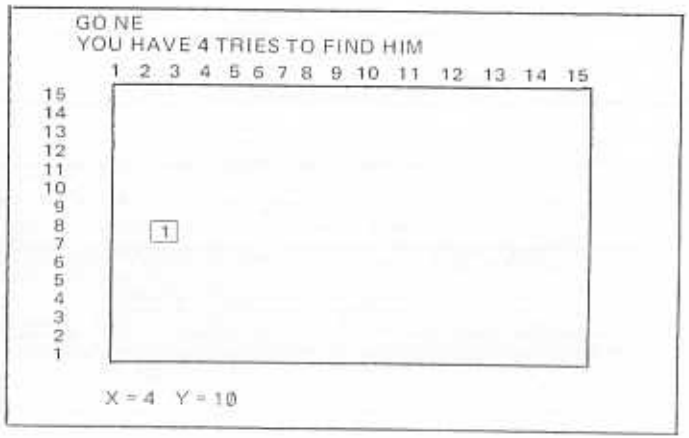
guesses to find the object and in some variations the object may move or even try and find the player. The educational value lies in that the player has to specify grid positions by means of standard X and Y axis co-ordinates, and the program gives the player hints by means of specifying the direction in which to move to find the object.

The following program uses a 15 x 15 grid in which the dreaded Grunger is hiding. The player has five tries to find it and after each attempt the program tells the player in which direction to proceed, e.g. SOUTH-EAST. The game ends and repeats when the player finds the Grunger or when he runs out of guesses.

Method

(i) Display instructions and grid with labelled axis
(ii) Choose random position of Grunger as (A,B)
(iii) For go number I from 1 to 5
  (a) Enter user's version of position, (X,Y)
  (b) If (X,Y) = (A,B)
    (1) Display CORRECT
    (2) Go to (v) below
  (c) Display direction to move
(iv) Show Grunger's position
(v) Wait
(vi) Go to (i)

Screen Format



Program Listing

```
 10 PRINT TAB 5;"AbGRUNGERbISbHIDINGbIN", TAB 8;"Ab
    15bXb15 GRID","YOUbHAVEb5bTRIESbTObFINDbHIM"
 20 FOR I = 15 TO 1 STEP -1
 30 PRINT TAB 6;I;TAB 9;" ▒▒▒▒▒▒▒▒▒▒▒▒▒▒▒▒▒▒▒▒▒▒▒▒▒▒"
 40 NEXT I
 50 PRINT TAB 9;"123456789111111bX"
 60 PRINT TAB 18;"012345"
 70 PRINT AT 10, 1;"Y"
 80 LET A = INT (RND*15) + 1
 90 LET B = INT (RND*15) + 1
100 FOR I = 1 TO 5
110 PRINT AT 2,9;6-I
120 PAUSE 500
130 POKE 16437,255
140 PRINT AT 21,0;"bbbbbbbbbbbbbbbbbbb"
150 PRINT AT 21,0;I;"}bX=";
160 INPUT X
170 IF X<1 OR X>15 THEN GO TO 160
180 PRINT X;",Y=";
190 INPUT Y
200 IF Y<1 OR Y>15 THEN GO TO 190
210 PRINT Y
220 PRINT AT 15-Y+3, X+8;I
230 IF X=A AND Y=B THEN GO TO 500
240 PRINT AT 0,5;"bbbbbbbbbbbbbbbbbbbb",TAB 8;
    "bbbbbbbbbbbbb"
250 PRINT AT 0,13;"GOb"; CHR$ (51*(Y<B) + 56*(Y>B));
    CHR$(42*(X<A) + 60* (X>A))
260 NEXT I
270 PRINT AT 0,7;"SORRYb-bITbWASb",A;",";B
280 PRINT AT 15-B + 3,A + 8; "G"
290 GO TO 510
500 PRINT AT 0,12; "CORRECT"
510 PRINT AT 2,0;"bbbbbbbbbbbbbbbbbbbbbbbbbbbbb"
520 PAUSE 9000
530 POKE 16437,255
540 CLS
550 RUN
```


List of Variables

A = x position of Grunger
B = y position of Grunger
X = user's guess, x position
Y = user's guess, y position
I = loop counter and go number

Comments

Notice how the number of tries left is shown at the top of the screen, as part of the original playing instructions. To modify the program for 1K, omit the display of the grid, i.e. lines 20–70, 220,280 and modify lines 140 and 150 to use screen line 4 instead of line 21.

Exercise 3 (d): What size grid can be designed for a 1K ZX81 to include a grid display?

COPYCAT (1K)

Description

Here is a straight forward memory test. A sequence of letters is displayed, one letter at a time, on the ZX81 screen and the player has to repeat the sequence afterwards. The sequence starts at three letters but goes up to twenty! Letters are displayed eight times normal size for clarity, using a PRINT AT version of the routine used in BIG WORDS on page 74. At the end the player is given a mark showing the maximum number of letters he has copied correctly. The program works on a 1K ZX81.

Method

(i) Generate 20 random letters in A$
(ii) For no. of letters I from 3 to 20
  (a) For letter number J from 1 to I
    1) Display letter J of A$, large
    2) Wait for two seconds
    3) Clear screen
  (b) Enter user's version of sequence, X$

(c) If correct
    1) Display "RIGHT SO FAR . . ."
    2) Wait for five seconds
(d) If incorrect display message, correct sequence and score (I−1)

(iii) Display "CONGRATULATIONS"

Program Listing (1K)

```
10 DIM A$(20)
20 FOR I=1 TO 20
30 LET A$(I)=CHR$(INT(RND*27)+38)
40 NEXT I
50 FOR I=3 TO 20
55 CLS
60 FOR J=1 TO I
70 LET C=CODE(A$(J))
80 FOR H=0 TO 7
90 LET P=PEEK(7680+C*8+H)
100 LET V=128
110 FOR G=0 TO 7
120 IF P<V THEN GO TO 150
130 PRINT AT H,G;"■"
140 LET P=P−V
150 LET V=V/2
160 NEXT G
170 NEXT H
180 PAUSE 100
186 POKE 16437,255
190 CLS
200 NEXT J
210 PRINT "SEQUENCE=";
220 INPUT X$
225 PRINT X$
230 IF X$<>A$(1 TO I) THEN GO TO 300
240 PRINT "RIGHT SO FAR ..." (inverse)
250 PAUSE 250
260 POKE 16437,255
270 NEXT I
280 PRINT "CONGRATULATIONS" (inverse)
290 STOP
300 PRINT "NOb−b";A$(1 TO I);".bYOUbGOTb";I−1
```


List of Variables

A$	=	array holding 20 character sequence
I	=	loop counter and count showing length of current sequence
J	=	counter showing character in current sequence
H	=	counter indicating appropriate number of byte in character table
P	=	value of byte in character table
V	=	a power of 2
G	=	counter showing current bit being tested
X$	=	player's version of sequence
C	=	character code of current character

Comments

By changing the randomising instruction at line 30 the program can easily be modified to handle sequences of numbers, or even graphics symbols.

Exercise 3(e): Change line 30 to produce sequences of digits 0 to 9 rather than letters.

PICKING PAIRS (16K)

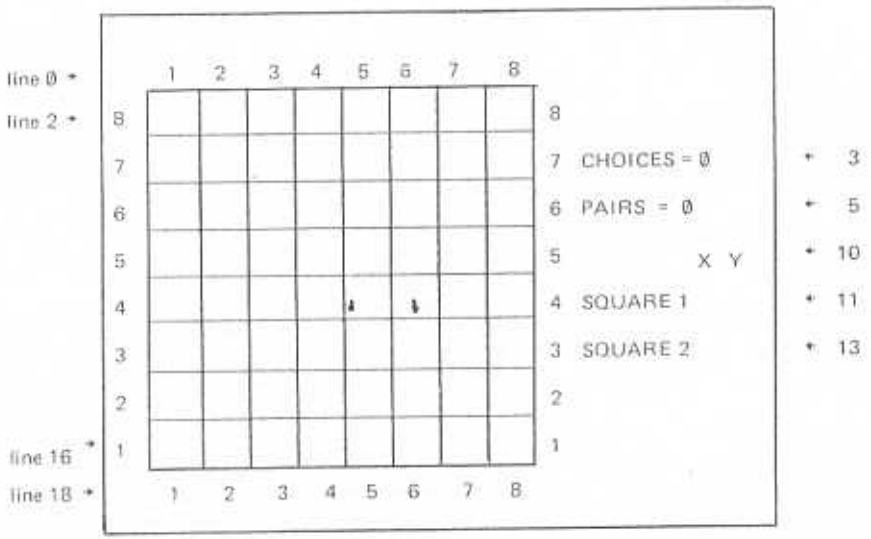
Description

A useful exercise of memory whether by a child or an adult is the card game of Concentration, in which a number of cards are shuffled and laid out singly face down. The player then has to choose a pair of cards, look at them, and if they are a pair of the same type (e.g. Aces, Threes) they are left face up. Otherwise they are turned face down again and another pair chosen. This continues until all the cards are face up. Clearly the player has to try and remember the positions of cards that he has seen.

This program works on the same basis, using a grid sized 8 x 8 filled with eight sets of the letters A to H. The player chooses a pair by specifying a pair of column (X) and row (Y) positions. If an identical pair is found the letters stay on the screen, whereas if the letters chosen are different

they disappear after ten seconds. Running totals of choices and pairs are displayed on the screen. Entry of positions is done by single key depressions, NEWLINE not being needed (i.e. INKEY$ is used) and there is built-in error checking.

Screen Format



Program Listing

```
 5 DIM B(4)
10 DIM A$(8,8)
15 PRINT "SETTINGbUP";
20 FOR I=1 TO 8
30 LET A$(I)="ABCDEFGH"
40 NEXT I
45 FOR I=1 TO 100
47 IF I=10*INT(I/10) THEN PRINT ".";
50 FOR J=1 TO 4
55 LET B(J)=INT(RND*8)+1
60 NEXT J
65 LET X$=A$(B(1),B(2))
70 LET A$(B(1),B(2))=A$(B(3),B(4))
```



```
75 LET A$(B(3),B(4))=X$
80 NEXT I
85 CLS
90 PRINT
95 FOR I=1 TO 8
100 PRINT "b■■■■■■■■■■■■■■■■"
105 PRINT "b■b■b■b■b■b■b■b■"
107 NEXT I
110 PRINT "b■■■■■■■■■■■■■■■■"
115 PRINT AT 18,2;"1b2b3b4b5b6b7b8"
120 PRINT AT 0,2;"1b2b3b4b5b6b7b8"
130 FOR L=2 TO 16 STEP 2
140 PRINT AT L,0;9-L/2;TAB 18; 9-L/2
150 NEXT L
160 LET P=0
170 LET O=0
180 PRINT AT 3,21;"CHOICES = 0"
190 PRINT AT 5,22;"PAIRS=0"
200 PRINT AT 10,29;"XbY"
210 PRINT AT 11,20;"SQUARE 1"
220 PRINT AT 13,20;"SQUARE 2"
230 PRINT AT 13,29;"bbb"
232 PRINT AT 11,29;"bbb"
235 LET L=11
240 LET C=29
250 GO SUB 600
260 LET X1=K
270 LET C=31
280 GO SUB 600
290 LET Y1=K
300 IF CODE (A$(X1,Y1))>128 THEN GO TO 230
310 LET L=13
320 LET C=29
330 GO SUB 600
340 LET X2=K
350 LET C=31
360 GO SUB 600
370 LET Y2=K
380 IF CODE (A$(X2,Y2))>128 THEN GO TO 230
390 PRINT AT 18-2*Y1,2*X1;A$(X1,Y1)
400 PRINT AT 18-2*Y2,2*X2;A$(X2,Y2)
410 LET O=O+1
```

```
420 PRINT AT 3,29;O
430 IF A$(X1,Y1)=A$(X2,Y2) THEN GO TO 480
440 PAUSE 500
450 PRINT AT 18-2*Y1,2*X1;"b"
460 PRINT AT 18-2*Y2,2*X2;"b"
470 GO TO 230
480 LET P=P+1
490 PRINT AT 5,28;P
500 LET A$(X1,Y1)=CHR$(CODE(A$(X1,Y1))+128)
510 LET A$(X2,Y2)=CHR$(CODE(A$(X2,Y2))+128)
520 IF P<>32 THEN GO TO 230
530 PRINT AT 15,22;"WELLbDONE" (inverse)
540 PRINT AT 2,29;"▄▄"
550 PRINT AT 4,29;"▀▀"
560 STOP
600 PRINT AT L,C;"?" (inverse)
610 LET K$ = INKEY$
620 IF K$<="8" AND K$>="1" THEN GO TO 650
630 PRINT AT L,C;"?"
640 GO TO 600
650 LET K=VAL K$
660 PRINT AT L,C;K
670 RETURN
```

List of Variables

B	=	array of four random numbers used to shuffle A$
A$	=	8 x 8 array of characters
I	=	loop counter
J	=	loop counter
L	=	line number counter
C	=	column number counter
P	=	no. of identical pairs chosen
O	=	no. of choices made
X1,Y1	=	coordinates of first member of pair
X2,Y2	=	coordinates of second member of pair
K$	=	value of key pressed
K	=	entry of x or y position

Comments

The program demonstrates several interesting features. The subroutines

at line 600 shows how an input prompt may be highlighted by a 'blinking' question mark and then accepted without NEWLINE, i.e. using INKEY$.

The eight sets of eight letters are initially put into A$ in sequence and then shuffled using one hundred random exchanges.

Exercise 3(f): How can you crash the program while it is waiting for an x or y input? Modify the program to overcome this.

PRIMES (1K)

Background

Having considered a number of primary level programs we now look at higher things. As mentioned above, the best educational programs are written by subject specialists, so the author's intention with the rest of the chapter is to illustrate some techniques for readers to apply to their own areas. The topic chosen is mathematics, and the next two programs are *demonstrations* to illustrate mathematical concepts or techniques. An excellent reference for mathematical computer programs is "A Collection of Programming Problems and Techniques" by Maurer and Williams, published by Prentice-Hall, Inc.

There is a slight problem when doing complex maths on the ZX81, as illustrated by

```
PRINT 20 - 0.000000001
```

which does not give 19.999999999 or even 20 but 52. Yes, there is a bug in the ZX81's floating point arithmetic which leaps out when handling numbers of considerably different magnitudes. Beware!

Description

The following program accepts any number greater than one and calculates and prints the number's factors if any, or indicates that it is a prime number.

Method

(i) Enter number M
(ii) If M less than two, stop
(iii) Set N to M
(iv) Set divisor D to 2
(v) If N is divisible by D
  a) Display D
  b) Divide N by D
  c) Go to (v)
(vi) Add 1 to D
(vii) If D less than M go to (v)
(viii) If N>1 display "PRIME"
(ix) Wait
(x) Go to (i)

Program Listing (1K)

```
 5 CLS
10 PRINT "ENTERbNUMBERb";
20 INPUT M
30 IF M<2 THEN STOP
40 LET N=M
50 PRINT N
60 LET D=2
70 IF N<>D*INT(N/D) THEN GO TO 100
80 PRINT D;"b";
85 LET N=N/D
90 GO TO 70
100 LET D=D+1
110 IF D<M THEN GO TO 70
120 IF N>1 THEN PRINT "PRIME"
130 IF N=1 THEN PRINT "AREbTHEbFACTORS"
140 PAUSE 9999
150 RUN
```

List of Variables

M = number as input
N = number divided by factor(s)
D = divisor

Exercise 3(g): Modify the above program so that when calculating whether m is prime, the highest possible factor used is the square root of m.

ITERATION (1K)

Description

The ZX81 is an excellent tool for demonstrating simple iterative techniques for the solution of equations. The Newton Raphson method is used to solve an equation of the form

$$f(x) = 0$$

by taking an initial approximation x_0 to the solution $x=\alpha$ and successively improving it by generating a sequence:

$$x_0\ x_1\ x_2\ x_3\ \ldots$$

which converges to the solution.

The iterative formula is

$$x_{n+1} = x_n - \frac{f(x_n)}{f^1(x_n)}$$

Where f'(x) is the differential of f(x).
We determine whether we have reached the solution by considering successive approximations : if two approximations xj and x_{j+1} fulfill:

$|x_j - x_{j+1}| < \epsilon$ where ϵ is a small constant then we are close enough. ϵ is chosen by the user according to the accuracy required.

The program accepts an equation of up to the fifth order and given an initial approximation, calculates a solution.

Method

(i) Enter order of equation N
(ii) For counter I from N+1 to 1

(a) Enter coefficient A(I) (for a_{i+1} in $a_{i+1}x^i$)
(iii) Enter approximation XA
(iv) Calculate array B, the differential coefficients.
(v) Calculate and print next approximation XB using coefficients in A and B
(vi) If XA−XB <0.00001 then
(a) Display solution
(b) Stop
(vii) Set XA to XB
(viii) Go to (v)

Program Listing

```
10  DIM A(6)
30  PRINT "ORDER=";
40  INPUT N
50  IF N>5 OR N<1 THEN GO TO 40
60  LET N=INT(N)
65  PRINT N
70  FOR I=N+1 TO 1 STEP −1
75  SCROLL
80  PRINT AT 1,0;"COEFFTbOFbX**";I−1;"=";
90  INPUT A(I)
100 PRINT A(I)
110 NEXT I
120 PRINT "APPROX=";
130 INPUT XA
140 PRINT XA
150 LET C=2
180 LET F=A(1)
190 FOR I=2 TO N+1
200 LET F=F+A(I)*XA**(I−1)
210 NEXT I
220 LET DF=A(2)
230 FOR I=2 TO N
240 LET DF=DF+A(I+1)*I*XA**(I−1)
250 NEXT I
260 LET XB=XA−F/DF
265 SCROLL
270 PRINT AT 1,0;"APPROXb";C;"=";XB
280 LET C=C+1
290 IF ABS(XA−XB)< 0.00001 THEN GO TO 320
300 LET XA=XB
310 GO TO 180
320 PRINT "SOLUTION=";XB
```


List of Variables

A = array holding coefficients of powers of x
e.g. $f(x) = a_6x^5 + a_5x^4 + a_4x^3 + a_3x^2 + a_2x + a_1$
N = order of f(x) i.e. highest power of x
I = loop counter
XA, XB = successive approximations
F = f(x) at XA
DF = f'(x) at XA
C = number of approximations

Comments

The program almost fills a 1K ZX81 and there is very little room left for a screen display. Therefore if using a 16K machine, extend the number of approximations displayed, i.e. change the PRINT AT instructions to use a line around 15 or so.

Exercise 3(h): In what circumstances would line 260 terminate with an error? Modify the program to overcome this.

THE QUIZ (16 K)

Description

At the beginning of the chapter we reviewed types of educational programs. This program is a general purpose quiz in which the teacher can set up a bank of questions and answers on any topic (and in any language!) and the ZX81 then poses the questions to a student in the form of an interactive quiz. There are two notable points about this program: firstly a standard question format is entered by the teacher

e.g. WHAT IS THE FORMULA FOR

or TRANSLATE INTO SWAHILI
or WHAT IS THE CAPITAL OF

and then pairs of question and answer keywords make up the remainder; secondly, a student's answer is marked correct providing it **contains** the answer keyword

e.g. if the answer keyword is OPTIC

then all the following responses are correct

OPTICAL ISOMERISM
OPTIC
OPTICALLY
CHANGES OPTICALLY
OPTICALLISH

Naturally enough, this is a 16K program.

Method

TEACHER:
(i) Enter number of questions Q
(ii) Enter maximum length L1 of question word and L2 of answer word.
(iii) Enter form of question F$
(iv) For counter I from 1 to Q
  (a) Enter question word number I into Q$(I)
  (b) Enter answer word number I into A$(I)
  (c) Store length of A$(I) in A(I)
(v) Stop

STUDENT:
(i) Set score S to 0
(ii) For counter I from 1 to Q
  (a) Display question F$ and question word Q$(I)
  (b) Enter student's response X$
  (c) If X$ contains answer word A$(I)
    1) Display CORRECT
    2) Add 1 to 5
    3) Go to (e) below
  (d) Display WRONG & answer word A$(I)
  (e) Repeat

(iii) Display score S

Program Listing

```
10 PRINT "NO.bOFbQUESTIONS"
20 INPUT Q
30 IF Q<5 OR Q >50 THEN GO TO 20
40 PRINT Q
50 PRINT "MAX.bLENGTHbOFbQbWORD=";
60 INPUT L1
70 IF L1<1 OR L1>30 THEN GO TO 60
80 PRINT L1
90 PRINT TAB 15;"AbWORD=";
100 INPUT L2
110 IF L2<1 OR L2>30 THEN GO TO 100
120 PRINT L2
122 DIM Q$(Q,L1)
124 DIM A$(Q,L2)
126 DIM A(Q)
130 PRINT "QUESTIONbFORMAT="
140 INPUT F$
150 IF F$="" THEN GO TO 140
160 PRINT F$
165 PAUSE 250
170 CLS
180 FOR I=1 TO Q
182 SCROLL
185 SCROLL
190 PRINT AT 18,0;"Q";I;"=";
200 INPUT Q$(I)
210 PRINT Q$(I)
220 PRINT "A";I;"=";
230 INPUT A$(I)
231 FOR J=L2 TO 1 STEP -1
232 IF A$(I,J)<>"b" THEN GO TO 234
233 NEXT J
234 LET A(I)=J
240 PRINT A$(I)
270 NEXT I
280 PRINT "ENDbOFbINPUT"
290 STOP
300 LET S=0
```

```
310 FOR I=1 TO Q
320 CLS
330 PRINT I;")b";F$
340 PRINT Q$(I)
350 INPUT X$
355 PRINT X$
360 IF LEN X$<A(I) THEN GO TO 400
370 FOR J=1 TO LEN X$-A(I)+1
380 IF X$(J TO J+A(I)-1)=A$(I,1 TO A(I)) THEN GO TO 420
390 NEXT J
400 PRINT "NOb-bANSWERbISb";A$(I)
410 GO TO 440
420 PRINT "CORRECT" (inverse)
430 LET S=S+1
440 PAUSE 500
450 NEXT I
460 CLS
470 PRINT "SCORE:b";S;"bOUTbOFb";Q
```

List of Variables

Q	=	number of questions
L1	=	maximum length of question words
L2	=	maximum length of answer words
Q$	=	questions
A$	=	answers
A	=	array holding actual lengths of answer words
F$	=	question format
X$	=	student's answer
S	=	score

Comments

The teacher sets up a bank of questions and answers having started the program by RUN. The student uses the program by GO TO 300, and each of the questions appear in turn. Providing the student's response to a question **contains** the answer keyword, it is marked correct. A score appears at the end.

Exercise 3(i): What is the purpose of line 360 and what would happen if it was omitted?

CHAPTER FOUR – THE MONITOR

4.1 EXAMINING AND USING THE MONITOR

Introduction

This chapter aims to introduce readers to the way in which the 8K ROM Monitor is organised, how it may be examined and how it may be used. Much of the chapter is taken up by a listing of the contents of the ROM in terms of tables of data and assembly language instructions. In order to understand in any detail the workings of the Monitor a knowledge of Z80 low level language is required, but readers without this knowledge will find that parts of the chapter illustrating data tables in the monitor or describing start addresses of Monitor routines will be useful. A good book for learning about the Z80 is Rodnay Zacs' "Programming the Z80". Readers should see Chapters 24 - 27 of the Sinclair Manual for further background information.

Hexadecimal

As described in Chapter 24 of the Sinclair Manual, binary and hexadecimal numbering is generally used when discussing the contents of ZX81 memory locations. Consider a location containing the decimal number 28. In binary this is

0	0	0	1	1	1	0	0
2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0

since $2^4 + 2^3 + 2^2 = 16 + 8 + 4 = 28$

In hexadecimal we have

1C hex = 28 decimal

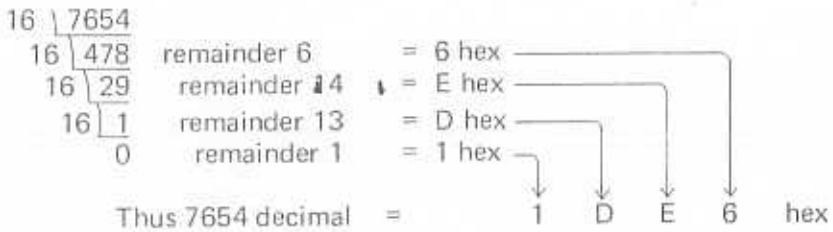
But taking each hex digit as four binary digits

1	C
0 0 0 1	1 1 0 0

thus showing how hexadecimal is a useful "shorthand" for binary.

In this chapter we will be using both decimal and hexadecimal numbers to represent memory addresses and contents. Therefore a useful start is a program to convert decimal numbers to hexadecimal.

The program uses an algorithm based upon a manual method of conversion. Consider for example 7654 decimal. If we successively divide this by 16 and take the remainders we have



Here is the program:

```
  5 DIM H$(4)
 10 PRINT "NUMBER=";
 20 INPUT C
 25 IF C=0 THEN STOP
 30 GO SUB 500
 40 PRINT C;"bbHEX=";
 50 IF C>255 THEN PRINT H$(1);H$(2);
 60 PRINT H$(3);H$(4)
 70 PRINT
 80 GO TO 10
500 LET D1=C
510 FOR I=4 TO 1 STEP -1
520 LET D2=INT(D1/16)
530 LET H$(I)=CHR$(D1-16*D2+28)
540 LET D1=D2
550 NEXT I
560 RETURN
```

The subroutine at line 500 does the conversion to hexadecimal while the first part of the program enters a number and then prints a hexadecimal number of an appropriate size.

Conversion from hexadecimal to decimal is simpler.


```
 10 PRINT "HEXbNUMBER=";
 20 INPUT H$
 30 IF H$=""THEN STOP
 40 LET D=CODE H$(1)-28
 50 FOR I=2 TO LEN H$
 60 LET D=16*D + CODE H$(I)-28
 70 NEXT I
 80 PRINT H$;"b,DECIMAL=";D
 90 PRINT
100 GO TO 10
```

Monitor Routines and Entry Points

The disassembled listing of the 8K monitor given in Section 4.2 gives readers a chance to work out for themselves just how the ZX81 works. To make the task a little bit simpler the following points will be helpful. Addresses given below are in hexadecimal.

(i) The program starts are location 0000 as in any Z80 system.
(ii) RST 0008 is the 'error report handling' entry point. It is entered by using the instruction 'CF – RST 0008' followed by a data byte for the required error., e.g. see
02F4 RST 0008
02F5 '0E'
which gives error 'F'.
(iii) RST 0010 is the character printing routine. The normal way to print a character to the next position on the screen is to load the A register with the appropriate character code (including NEWLINE) and then call this routine by using the instruction 'D7 – RST 0010.'
(iv) RST 0018 and RST 0020 are routines for collecting the next character in a BASIC line.
(v) RST 0028 is the entry point for the 'floating-point calculator', which starts at location 199C. (See note xxxvii).
(vi) RST 0030 is a routine that will make 'BC' spaces in the variable area.
(vii) RST 0038 is the interrupt routine that handles the lines of the T.V. display.
(viii) The routine at 0066 is the NMI routine that leads to a T.V. display being formed following a NM interrupt in 'slow' mode.
(ix) The main 'key table' is at 007E to 00CB. There is a code for

each key in 'lower'case and in 'shift'.

(x) The key-codes for the 'function mode' are in the table from ØØCC to ØØF2.

(xi) The key-codes for the 'graphics mode' are in the table from ØØF3 to Ø11Ø.

(xii) The command table is at Ø111 to Ø1FB. Each keyword is listed with its last letter inverted.

(xiii) The 'update routine' at Ø1FC to Ø2Ø6 is used by the LOAD and SAVE command routines.

(xiv) The routines from Ø2Ø7 to Ø2BA are used to produce the T.V. display.

(xv) The keyboard scanning routine at Ø2BB to Ø2E6 is a very useful routine. Each key of the keyboard gives a unique key-value in the HL register pair. No key pressed gives the value FFFF.

(xvi) The SAVE command routine is at Ø2F6 to Ø33F.

(xvii) The LOAD command routine is at Ø34Ø to Ø3A7.

(xviii) The routine at Ø3CB to Ø3E4 is the RAM integrity check routine that is carried out upon initialisation and following a NEW command.

(xix) The main initialisation routine starts at Ø3E5, and is followed by the operating system routines for handling the 'cursor' and forming LISTings.

(xx) The main command routine for the running of a BASIC program is from Ø63E to Ø6DF.

(xxi) The keyboard decode routine at Ø7B4 to Ø7DB is also very useful as it converts the key-values (in BC now) to the values 1–78 and forms the appropriate address, in HL, for a given key in the main key table. (see note ix).

(xxii) The routine at Ø7F1 to Ø868 is the character printing routine used by RST ØØ1Ø. (see note iii.)

(xxiii) The routine at Ø8F5 to Ø94A is concerned with expanding the display file, in the case of a 'collapsed' display file. The routine in effect sets the system variable 'DF–CC' to a legitimate address.

(xxiv) The CLS command routine is at ØA2A to ØA5F.

(xxv) The PRINT command routine is at ØACF to ØBAE.

(xxvi) The PLOT/UNPLOT command routine is at ØBAF to ØC0D. The difference between the commands being dependant on the current value of T–ADDR.

(xxvii) The SCROLL command routine is at ØC0E to ØC28.

(xxciii) The main syntax tables are at ØC29 to ØCB9. The first

part being a pointer table and the second part the actual syntax table that gives the required syntax for each command and the address of the 'command routine'.

(xxix) The BASIC interpreter starts at ØCBA.

(xxx) The FAST command routine is at ØF2Ø to ØF27 and can be simply called using 'CALL ØF2Ø' to enter FAST mode, or ensure the presence in FAST mode.

(xxxi) The SLOW command routine is at ØF28 to ØF2E and can likewise be called by 'CALL ØF28'.

(xxxii) The 'Expression Evaluator' starts at location ØF52.

(xxxiii) The LET command routine is at 131D to 14Ø4.

(xxxiv) The DIM command routine is at 14Ø5 to 1483.

(xxxv) The routines between 14CA and 1913 are concerned with handling 'floating-point' numbers. e.g. the routine 'Evaluate to integer' is at 1586. Print 'Last value' is at 15D7, etc.

(xxxvi) The function table for the 'floating-point calculator' is at 1914 to 199B.

(xxxvii) The 'floating-point calculator' is at 199C to 1AA8.

(xxxviii) The various function routines are at 1AA9 to 1DFF. e.g. CHR$ is at 1B8E to 1BA2, COS is at 1D3D to 1D47, etc.

(xxxix) The 'character generator' is at 1EØØ to 1FFF. This part of the 8K ROM holds the 8*8 formats of the 64 characters that can appear on the T.V. display.

Program Aids

A number of BASIC programs can be written to assist in the examination of the Monitor, and particularly the data tables.

HEX DISPLAY

This program displays the contents of Monitor addresses in hexadecimal starting at a specified address:

```
 5 DIM H$(4)
1Ø PRINT "START=";
2Ø INPUT S
25 PRINT S
3Ø FOR A=S TO 8191 STEP 8
35 SCROLL
```

```
40 LET C=A
50 GO SUB 500
60 PRINT AT 5,0;H$;"bbb";
70 FOR B=A TO A+7
80 LET C=PEEK(B)
90 GO SUB 500
100 PRINT H$(3 TO 4);"b";
110 NEXT B
120 PRINT
130 NEXT A
140 STOP
500 LET D1=C
510 FOR I=4 TO 1 STEP -1
520 LET D2=INT(D1/16)
530 LET H$(I)=CHR$(D1-16*D2+28)
540 LET D1=D2
550 NEXT I
560 RETURN
```

This works in 1K – for a 16K system change the PRINT AT statement at line 60 to give a larger screen display.

CHARACTER DISPLAY

This program displays the contents of Monitor addresses as characters – useful for some data tables.

```
10 PRINT "START=";
20 INPUT S
25 PRINT S
30 FOR A=S TO 8191
40 SCROLL
50 PRINT AT 15,0;A;"bbb";CHR$ (PEEK A)
60 NEXT A
```

The program is very handy for displaying the Key Table (locations 126 to 272) and the following Command Table (locations 273 to 507). As described in the previous section the Key Table holds codes for the keyboard keys in 'lower' case, in shifted form, in function mode and finally in graphics mode. RUN the program with start address equalling 126 and the appropriate keyboard values will be shown. In the Command

Table we find each keyword with the last letter held in inverse form. To show this, run the program with a start address of 273, or simply let it run on after the Key Table.

CHARACTER GENERATOR DISPLAY

The last data table in the Monitor is the character generator held in locations 7680 to 8191. This holds the formats for each of the 64 characters used on the ZX81 by means of eight bytes per character, each byte consisting of 0's and 1's representing unshaded and shaded portions respectively.

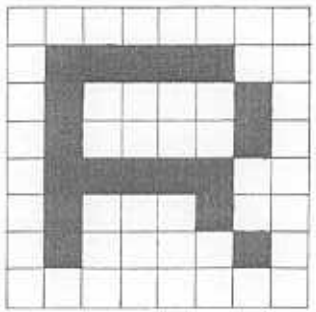
For example the letter R has character code 55. The portion of the character table holding the format for R is locations 8120 to 8127.

i.e 7680 +(55 x 8) to 7680 + (55 x 8) + 7

The binary patterns in these locations are shown below

Location	Contents
8120	0 0 0 0 0 0 0 0
8121	0 1 1 1 1 1 0 0
8122	0 1 0 0 0 0 1 0
8123	0 1 0 0 0 0 1 0
8124	0 1 1 1 1 1 0 0
8125	0 1 0 0 0 1 0 0
8126	0 1 0 0 0 0 1 0
8127	0 0 0 0 0 0 0 0

This represents



A routine to use the character table to display large characters has already been utilised in Chapter Three, and is shown again below:

To display characters at four times size we use the PLOT statement.

```
 10 PRINT "CHARACTER=";
 20 INPUT A$
 25 LET C=CODE A$
 30 PRINT A$;"bCODE=";C;"ATbLOCb";7680+C*8
 40 FOR H=0 TO 7
 50 LET P=PEEK(7680+C*8+H)
 60 LET V=128
 70 FOR G=0 TO 7
 80 IF P<V THEN GO TO 110
 90 PLOT G,40-H
100 LET P=P-V
110 LET V=V/2
120 NEXT G
130 NEXT H
```

For eight times size we use the PRINT AT statement and this can help illustrate the unshaded portions. We display the shaded portions using "▓" and the unshaded by "▒". Modify the above by

```
 80 IF P<V THEN GO TO 108
 90 PRINT AT H+3, G;"▓"
104 GO TO 110
108 PRINT AT H+3,G;"▒"
```

and the character will appear black on a grey background.

4.2 MONITOR LISTING

The next eleven pages contain a disassembled listing of the ZX81 8K ROM Monitor between addresses 0000 and 0CB9, that is, up to the end of the syntax table. The rest of the Monitor has not been included since much of it consists of the BASIC interpreter which is not particularly interesting or usable.

A description of Monitor routines and tables appears in Section 4.1 and the listing should be studied in conjunction with this.


```
0000  D3 FD      OUT (FD),A
0002  01 FF 7F   LD BC,7FFF
0005  C3 CB 03   JP 03CB
0008  2A 16 40   LD HL,(4016)
000B  22 18 40   LD (4018),HL
000E  18 16      JR 0026
0010  A7         AND A
0011  C2 F1 07   JP NZ,07F1
0014  C3 F5 07   JP 07F5
0017  FF         RST 38
0018  2A 16 40   LD HL,(4016)
001B  7E         LD A,(HL)
001C  A7         AND A
001D  C0         RET NZ
001E  00         NOP
001F  00         NOP
0020  CD 49 00   CALL 0049
0023  18 F2      JR 001C
0025  FF         RST 38
0026  FF         RST 38
0027  FF         RST 38
0028  C3 9C 19   JP 199C
002B  F1         POP AF
002C  08         EX AF
002D  E3         EX (SP),HL
002E  08         EX AF
002F  C9         RET
0030  C5         PUSH BC
0031  2A 14 40   LD HL,(4014)
0034  E5         PUSH HL
0035  C3 84 14   JP 1484
0038  00         NOP
0039  C2 45 00   JP NZ,0045
003C  E1         POP HL
003D  05         DEC B
003E  C8         RET Z
003F  CB 09      SET 3,C
0041  CB 4F      LD B,A
0043  FB         EI
0044  E9         JP (HL)
0045  D1         POP DE
0046  C8         RET Z
0047  18 F8      JR 0041
0049  2A 16 40   LD HL,(4016)
004C  23         INC HL
004D  22 16 40   LD (4016),HL
0050  7E         LD A,(HL)
0051  FE 76      CP 76
0053  C0         RET NZ
0054  18 FA      JR 004E
0056  E1         POP HL
0057  4E         LD L,(HL)
0058  CB 75 00   LD (IY),L
005B  ED 7B 02 40  LD SP,(4002)
005F  CD 07 02   CALL 0207
0062  C3 98 14   JP 1498
0065  FF         RST 38
0066  08         EX AF,AF'
0067  3C         INC A
0068  FA 6D 00   JP M,006D
006B  28 02      JR Z,006F
006D  08         EX AF,AF'
006E  C9         RET
006F  08         EX AF,AF'
0070  F5         PUSH AF
0071  C5         PUSH BC
0072  D5         PUSH DE
0073  E5         PUSH HL
0074  2A 0C 40   LD HL,(400C)
0077  CB FE      SET 7,(HL)
0079  76         HALT
007A  D3 FD      OUT (FD),A
007C  DD E9      JP (IX)
007E
```

```
01FC  23          INC HL
01FD  EB          EX DE,HL
01FE  76 14 40    LD HL,(4014)
0201  37          SCF
0202  ED 52       SBC HL,DE
0204  EB          EX DE,HL
0205  D0          RET NC
0206  E1          POP HL
0207  21 3D 40    LD HL,403D
020A  7E          LD A,(HL)
020B  17          RLA
020C  AE          XOR (HL)
020D  17          RLA
020E  D0          RET NC
020F  3E 7F       LD A,7F
0211  08          EX AF,AF'
0212  06 11       LD B,11
0214  D3 FE       OUT (FE),A
0216  10 FE       DJNZ 0216
0218  D3 FD       OUT (FD),A
021A  08          EX AF,AF'
021B  17          RLA
021C  30 0B       JR NC,0228
021E  CB FF       SET 7,(HL)
0220  F5          PUSH AF
0221  C5          PUSH BC
0222  D5          PUSH DE
0223  E5          PUSH HL
0224  18 03       JR 0229
0226  CB B6       RES 6,(HL)
0228  F9          SET
0229  76 36 40    LD HL,(4036)
022C  2B          DEC HL
022D  7E 7F       LD A,7F
022F  A4          AND H
0230  B5          OR L
0231  7C          LD A,H
0232  20 03       JR NZ,0237
0234  17          RLA
0235  18 02       JR 0239
0237  A4          LD B,(HL)
0238  37          SCF
0239  A7          LD H,A
023A  22 36 40    LD (4036),HL
023D  D0          RET NC
023E  CD DB 02    CALL 02DB
0241  ED 4B 25 40 LD BC,(4025)
0245  2A 25 40    LD (4025),HL
0248  78          LD A,B
0249  C6 02       ADD A,02
024B  ED 42       SBC HL,BC
024D  3A 27 40    LD A,(4027)
0250  B4          OR H
0251  B5          OR L
0252  58          LD E,B
0253  06 0B       LD B,0B
0255  21 3B 40    LD HL,403B
0258  FD 86       RES 0,(IY+1)
025A  20 0B       JR NZ,0264
025C  CB 7E       BIT 7,(HL)
025E  CB CA       SET 0,(HL)
0260  C8          RET Z
0261  05          DEC B
0262  00          NOP
0263  37          SCF
0264  21 27 40    LD HL,4027
0267  3F          CCF
0268  CB 10       RL B
026A  10 FE       DJNZ 026A
026C  46          LD B,(HL)
026D  7B          LD A,E
026E  FE F1       CP F8
0270  9F          SBC A,A
0271  0A 3F       LD B,1F
0273  B6          OR (HL)
0274  A0          AND B
0275  3F          CCF
0276  77          LD (HL),A
0277  D3 F1       OUT (F1),A
0279  2A 0E 40    LD HL,(400E)
027C  CB FC       SET 7,H
027E  ED 52 02    CALL 0292
0281  ED 5F       LD A,R
0283  01 01 19    LD BC,1901
0286  3E F5       LD A,F5
0288  ED E5 02    CALL 02E5
028B  2B          DEC HL
028C  CD 92 02    CALL 0292
028F  E3 29 02    JP 0229
0292  D0 E1       POP IX
0294  FD 4E 28    LD C,(IY+28)
0297  FD CB 30 7E  BIT 7,(IY+30)
029B  28 0C       JR Z,02A9
029D  79          LD A,C
029E  ED 44       NEG
02A0  3C          INC A
02A1  08          EX AF,AF'
02A2  D3 FE       OUT (FE),A
02A4  E1          POP HL
02A5  01          POP BC
02A6  C5          PUSH BC
02A7  F1          POP AF
02A8  C9          RET
02A9  3E FC       LD A,FC
02AB  06 04       LD B,04
02AD  CD E5 02    CALL 02E5
02B0  2B          DEC HL
02B1  E3          EX (SP),HL
02B2  E3          EX (SP),HL
02B3  DD E9       JP (IX)
02B5  ED 4F       LD R,A
02B7  3E 00       LD A,00
02B9  FB          EI
02BA  E9          JP (HL)
02BB  21 FF FF    LD HL,FFFF
02BE  01 FE FE    LD BC,FEFE
02C1  ED 78       IN A,(C)
02C3  F6 01       OR 01
02C5  F6 E0       OR E0
02C7  57          LD D,A
02C8  2F          CPL
02C9  EE 01       XOR 01
02CB  9F          SBC A,A
02CC  A5          AND L
02CD  6F          LD L,A
02CE  7C          LD A,H
02CF  A2          AND D
02D0  67          LD H,A
02D1  CB 00       RLC B
02D3  ED 78       IN A,(C)
02D5  38 FD       JR C,02D5
02D7  1F          RRA
02D8  1F          LD L,A
02D9  CB 14       RL H
02DB  17          RLA
02DC  17          RLA
02DD  17          RLA
02DE  9F          SBC A,A
02DF  E6 10       AND 10
02E1  C6 1F       ADD A,1F
02E3- 32 2B 40    LD (402B),A
```



```
02E6  C9          RET
02E7  FD CB 30 7E  BIT 7,(IY+30)
02EB  C8          RET Z
02EC  76          HALT
02ED  D3 FD       OUT (FD),A
02EF  FD CB 30 BE  RES 7,(IY+30)
02F3  C9          RET
02F4  CF          RST 8
02F5  0E C0       LD C,C0
02F7  A8          XOR B
02F8  03          INC BC
02F9  38 F9       JR C,02F4
02FB  EB          EX DE,HL
02FC  11 CB 12    LD DE,12CB
02FF  CD 43 0F    CALL 0F43
0302  30 2E       JR NC,0332
0304  10 FE       DJNZ 0304
0306  1B          DEC DE
0307  7A          LD A,D
0308  B3          OR E
0309  20 F4       JR NZ,02FF
030B  CD 3E 03    CALL 033E
030E  CB 7E       BIT 7,(HL)
0310  23          INC HL
0311  28 FB       JR Z,030E
0313  21 0F 40    LD HL,400F
0316  CD 3E 03    CALL 033E
0319  CD FC 01    CALL 01FC
031C  10 F8       JR 0316
031E  5E          LD E,(HL)
031F  37          SCF
0320  CB 13       RL E
0322  C8          RET Z
0323  9F          SBC A,A
0324  E6 05       AND 05
0326  C6 04       ADD A,04
0328  4F          LD C,A
0329  D3 FF       OUT (FF),A
032B  06 23       LD B,23
032D  10 FE       DJNZ 032D
032F  CD 43 0F    CALL 0F43
0332  30 72       JR NC,03A6
0334  06 1E       LD B,1E
0336  10 FE       DJNZ 0336
0338  0D          DEC C
0339  20 FE       JR NZ,0329
033B  A7          AND A
033C  10 FD       DJNZ 033B
033E  18 E0       JR 0320
0340  CD A6 03    CALL 03A6
0343  CB 12       RL D
0345  CB 0A       RRC D
0347  CD 4C 03    CALL 034C
034A  18 FB       JR 0347
034C  0E 01       LD C,01
034E  06 00       LD B,00
0350  3E 7F       LD A,7F
0352  DB FE       IN A,(FE)
0354  03 FF       OUT (FF),A
0356  1F          RRA
0357  30 A9       JR NC,0302
0359  17          RLA
035A  17          RLA
035B  3B 28       JR C,0385
035D  10 F1       DJNZ 0350
035F  F1          POP AF
0360  0A          LD A,(BC)
0361  B2 F5 03    OR D
0364  A2          AND D
0365  A0          AND B
0366  CB 4C 03    CALL 034C
0369  CB 7A       BIT 7,D
```

```
036C  79          LD A,C
036D  20 03       JR NZ,0371
036F  EE          CP (HL)
0370  20 0A       JR NZ,0347
0372  23          INC HL
0373  17          RLA
0374  30 F1       JR NC,0366
0376  FD 34 15    INC (IY+15)
0379  21 09 40    LD HL,4009
037C  50          LD D,B
037D  CD 4C 03    CALL 034C
0380  71          LD (HL),C
0381  CD FC 01    CALL 01FC
0384  18 FA       JR 0380
0386  05          PUSH DE
0387  1E F4       LD E,F4
0389  06 1A       LD B,1A
038B  1D          DEC E
038C  06 FE       IN A,(FE)
038E  17          RLA
038F  CB 7B       BIT 7,E
0391  7B          LD A,E
0392  38 F5       JR C,0389
0394  10 F5       DJNZ 038B
0396  D1          POP DE
0397  20 04       JR NZ,039D
0399  FE 5A       CP 5A
039B  30 B2       JR NC,034F
039D  3F          CCF
039E  CB 13       RL E
03A0  38 A0       JR NC,0342
03A2  E9          SET
03A3  7A          LD A,D
03A4  A2          AND A
03A5  28 DB       JR Z,0381
03A7  CF          RST 8
03A8  0C          INC C
03A9  CD 52 0F    CALL 0F52
03AC  3A 01 40    LD A,(4001)
03AF  87          ADD A,A
03B0  FA 9A 0B    JP M,0B9A
03B3  E1          POP HL
03B4  D0          RET NC
03B5  E5          PUSH HL
03B6  CD E7 02    CALL 02E7
03B9  CD F4 13    CALL 13F4
03BC  42          LD B,D
03BD  4B          LD L,E
03BE  0D          DEC C
03BF  F8          RET M
03C0  09          ADD HL,BC
03C1  CB FE       SET 7,(HL)
03C3  E9          RET
03C4  CD E7 02    CALL 02E7
03C7  ED 4B 04 40 LD BC,(4004)
03CB  0B          DEC BC
03CC  40          LD B,B
03CD  69          LD L,C
03CE  3E 3F       LD A,3F
03D0  56 03       LD (HL),03
03D2  20          RET NZ
03D3  EC          CP H
03D4  24 FA       JR NZ,03D0
03D6  A7          AND A
03D7  ED 42       SBC HL,BC
03D9  09          ADD HL,BC
03DA  25          DEC H
03DB  30 0A       JR NC,03E7
03DD  55          DEC (HL)
03DE  28 03       JR Z,03E3
03E0  2B F3       DEC HL
03E2  18 EB       JR 03CF
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03E2  22 04 40     LD (4004),HL
03E5  2A 04 40     LD HL,(4004)
03E8  2B           DEC HL
03E9  36 3E        LD (HL),3E
03EB  2B           DEC HL
03EC  F9           LD SP,HL
03ED  2B           DEC HL
03EE  2B           DEC HL
03EF  22 02 40     LD (4002),HL
03F2  3E 3E        LD A,3E
03F4  ED 47        LD I,A
03F6  ED 56        IM1
03F8  FD 21 00 40  LD IY,4000
03FC  FD 36 3B 40  LD (IY+3B),40
0400  21 7D 40     LD HL,407D
0403  22 0C 40     LD (400C),HL
0406  06 19        LD B,19
0408  3A 7A        LD (HL),7A
040A  23           INC HL
040B  10 FB        DJNZ 0408
040D  22 10 40     LD (4010),HL
0410  CD 96 14     CALL 1496
0413  CD A9 14     CALL 14A9
0416  CD 07 02     CALL 0207
0419  CD 3A 0A     CALL 0A3A
041C  2A 0A 40     LD HL,(400A)
041F  ED 5B 25 40  LD DE,(4025)
0423  A7           AND A
0424  ED 52        SBC HL,DE
0426  EB           EX DE,HL
0427  30 04        JR NC,042D
0429  19           ADD HL,DE
042A  22 25 40     LD (4025),HL
042D  CD 00 09     CALL 0900
0430  28 01        JR Z,0433
0432  EB           EX DE,HL
0433  CD 3E 07     CALL 073E
0436  FD 35 3E     DEC (IY+3E)
0439  20 37        JR NZ,0472
043B  2A 0A 40     LD HL,(400A)
043E  CD DB 09     CALL 09DB
0441  2A 1A 40     LD HL,(401A)
0444  37           SCF
0445  ED 52        SBC HL,DE
0447  21 23 40     LD HL,4023
044A  30 0B        JR NC,0457
044C  EB           EX DE,HL
044D  7E           LD A,(HL)
044E  23           INC HL
044F  ED A0        LDI
0451  12           LD (DE),A
0452  18 C5        JR 0419
0454  21 06 40     LD HL,4006
0457  5E           LD E,(HL)
0458  23           INC HL
0459  56           LD D,(HL)
045A  E5           PUSH HL
045B  EB           EX DE,HL
045C  23           INC HL
045D  CD 00 09     CALL 0900
0460  CD FD 05     CALL 05FD
0463  E1           POP HL
0464  FD CB 20 AE  BIT 5,(IY+20)
0468  20 08        JR NZ,0472
046A  72           LD (HL),D
046B  2B           DEC HL
046C  73           LD (HL),E
046D  18 00        JR 0419
046F  CD A9 14     CALL 14A9
0472  2A 14 40     LD HL,(4014)
0475  7E           LD A,(HL)
0476  FE 7E        CP 7E
0478  20 00        JR NZ,047A
047A  01 86 00     LD BC,0086
047D  CD A0 0A     CALL 0AA0
0480  18 F3        JR 0475
0482  FF 7A        CP 7A
0484  23           INC HL
0485  20 EE        JR NZ,0475
0487  CD 37 05     CALL 0537
048A  CD 1F 0A     CALL 0A1F
048D  2A 14 40     LD HL,(4014)
0490  FD 3A 00 FF  LD (IY),FF
0494  CD A6 07     CALL 07A6
0497  FD CB 00 7E   BIT 7,(IY)
049B  20 24        JR NZ,04C1
049D  3A 22 40     LD A,(4022)
04A0  FE 10        CP 10
04A2  30 10        JR NC,04C1
04A4  3C           INC A
04A5  32 22 40     LD (4022),A
04A8  47           LD B,A
04A9  0E 01        LD C,01
04AB  CD 18 09     CALL 0918
04AE  54           LD D,H
04AF  50           LD E,L
04B0  7E           LD A,(HL)
04B1  2B           DEC HL
04B2  BE           CP (HL)
04B3  20 FC        JR NZ,04B1
04B5  23           INC HL
04B6  EB           EX DE,HL
04B7  3A 05 40     LD A,(4005)
04BA  FE 4D        CP 4D
04BC  DC 5D 06     CALL C,065D
04BF  18 C9        JR 048A
04C1  21 00 09     LD HL,0900
04C4  22 18 40     LD (4018),HL
04C7  21 3D 40     LD HL,403D
04CA  CD 7E        BIT 7,(HL)
04CC  EC 29 02     CALL Z,0229
04CF  CB A6        RES 4,(HL)
04D1  20 FC        JR Z,04CF
04D3  ED 4B 25 40  LD BC,(4025)
04D7  CD 48 0F     CALL 0F48
04DA  CD ED 07     CALL 07ED
04DD  30 93        JR NC,0472
04DF  3A 06 40     LD A,(4006)
04E2  3D           DEC A
04E3  FA 9B 05     JP M,059B
04E6  20 0F        JR NZ,04F7
04E8  32 06 40     LD (4006),A
04EB  1D           DEC E
04EC  7B           LD A,E
04ED  FA 27        SUB 27
04EF  30 01        JR C,04F2
04F1  5F           LD E,A
04F2  21 CC 00     LD HL,00CC
04F5  18 0F        JR 0506
04F7  7E           LD A,(HL)
04F8  FE 7A        CP 7A
04FA  28 2F        JR Z,052B
04FC  FE 40        CP 40
04FE  CB FF        SET 7,A
0500  38 19        JR C,051B
0502  21 CF 00     LD HL,00CF
0505  19           ADD HL,DE
0506  18 0D        JR 0515
0508  7E           LD A,(HL)
0509  FD CB 01 56  BIT 2,(IY+01)
050D  20 07        JR NZ,0516
050F  FA C0        JP M,C0
0511  FE E6        CP E6
0513  30 01        JR NC,0516
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0515  3C           INC A
0516  FE F0        CP F0
0518  FA 2D 05     JP M,052D
051B  5F           LD E,A
051C  CD 37 05     CALL 0537
051F  2B           LD A,E
0520  CD 26 05     CALL 0526
0523  E3 72 04     JP 0472
0526  CD 98 09     CALL 0998
0529  12           LD (DE),A
052A  C9           RET
052B  3E 78        LD A,78
052D  5F           LD E,A
052E  21 82 04     LD HL,0482
0531  19           ADD HL,DE
0532  19           ADD HL,DE
0533  4E           LD C,(HL)
0534  23           INC HL
0535  46           LD B,(HL)
0536  E5           PUSH HL
0537  2A 14 40     LD HL,(4014)
053A  FD CB 20 AE  BIT 5,(IY+20)
053E  20 16        JR NZ,0556
0540  FD CB 01 96  RES 2,(IY+01)
0544  7E           LD A,(HL)
0545  FE 7F        CP 7F
0547  C8           RET Z
0548  23           INC HL
0549  CD 04 07     CALL 0704
054C  28 F6        JR Z,0544
054E  FE 26        CP 26
0550  38 F2        JR C,0544
0552  FE DE        CP DE
0554  20 EA        JR Z,0540
0556  FD CB 01 D6  SET 2,(IY+01)
055A  18 E8        JR 0544
055C  01 01 00     LD BC,0001
055F  E3 A0 0A     JP 0AA0
0562  9F           SBC A,A
0563  D5           DEC B
0564  54           LD D,H
0565  04           INC B
0566  76           HALT
0567  05           DEC B
0568  7F           LD A,A
0569  05           DEC B
056A  AF           XOR A
056B  05           DEC B
056C  E4 05 0C     CALL NZ,0C05
056F  06 0B        LD B,0B
0571  05           DEC B
0572  AF           XOR A
0573  05           DEC B
0574  AF           XOR A
0575  05           DEC B
0576  CD 93 05     CALL 0593
0579  7E           LD A,(HL)
057A  36 7F        LD (HL),7F
057C  23           INC HL
057D  18 09        JR 0588
057F  23           INC HL
0580  7E           LD A,(HL)
0581  FE 7A        CP 7A
0583  28 1B        JR Z,059B
0585  36 7F        LD (HL),7F
0587  2B           DEC HL
0588  77           LD (HL),A
0589  18 98        JR 0523
058B  CD 93 05     CALL 0593
058E  CD 5C 05     CALL 055C
0591  18 F4        JR 0589
0593  2B           DEC HL
0594  ED 5B 14 40  LD DE,(4014)
0598  1A           LD A,(DE)
0599  FE 7F        CP 7F
059B  C0           RET NZ
059C  01           POP BC
059D  18 EA        JR 0589
059F  2A 0A 40     LD HL,(400A)
05A2  CD E0 09     CALL 09E0
05A5  EB           EX DE,HL
05A6  CD EB 05     CALL 05EB
05A9  21 06 40     LD HL,4006
05AC  E3 E4 04     JP 04E4
05AF  7B           LD A,E
05B0  E6 07        AND 07
05B2  32 06 40     LD (4006),A
05B5  18 EA        JR 05A1
05B7  EB           EX DE,HL
05B8  11 C2 04     LD DE,04C2
05BB  7E           LD A,(HL)
05BC  E6 E0        AND E0
05BE  20 F7        JR NZ,05B7
05C0  56           LD D,(HL)
05C1  23           INC HL
05C2  5E           LD E,(HL)
05C3  E9           JP (HL)
05C4  CD 1F 0A     CALL 0A1F
05C7  21 6F 04     LD HL,046F
05CA  E5           PUSH HL
05CB  FD CB 20 AE  BIT 5,(IY+20)
05CF  C0           RET NZ
05D0  2A 14 40     LD HL,(4014)
05D3  22 0E 40     LD (400E),HL
05D6  21 21 1B     LD HL,1B21
05D9  22 39 40     LD (4039),HL
05DC  2A 0A 40     LD HL,(400A)
05DF  CD D0 09     CALL 09D0
05E2  CD F0 05     CALL 05F0
05E5  7A           LD A,D
05E6  B3           OR E
05E7  C8           RET Z
05E8  2B           DEC HL
05E9  CD A5 0A     CALL 0AA5
05EC  23           INC HL
05ED  4E           LD C,(HL)
05EE  23           INC HL
05EF  46           LD B,(HL)
05F0  23           INC HL
05F1  ED 5B 0E 40  LD DE,(400E)
05F5  3E 7F        LD A,7F
05F7  12           LD (DE),A
05F8  13           INC DE
05F9  E5           PUSH HL
05FA  21 3D 00     LD HL,003D
05FD  19           ADD HL,DE
05FE  09           ADD HL,BC
05FF  ED 72        SBC HL,SP
0601  E1           POP HL
0602  D0           RET NC
0603  EB D0        LDIR
0605  EB           EX DE,HL
0606  D1           POP DE
0607  CD A2 14     CALL 14A2
060A  18 91        JR 059D
060C  CD 1F 0A     CALL 0A1F
060F  21 72 04     LD HL,0472
0612  FD CB 20 AE  BIT 5,(IY+20)
0616  20 11        JR NZ,0629
0618  2A 14 40     LD HL,(4014)
061B  7E           LD A,(HL)
061C  FE FF        CP FF
061E  28 0A        JR Z,062A
0620  CD E2 08     CALL 08E2
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0623  CD 2A 0A     CALL 0A2A
0626  21 19 04     LD HL,0419
0629  E5           PUSH HL
062A  CD BA 0C     CALL 0CBA
062D  E1           POP HL
062E  CD 37 05     CALL 0537
0631  CD 5E 05     CALL 055E
0634  CD 73 06     CALL 0673
0637  20 15        JR NZ,064E
0639  78           LD A,B
063A  B1           OR C
063B  C2 E0 06     JP NZ,06E0
063E  0B           DEC BC
063F  0B           DEC BC
0640  ED 43 07 40  LD (4007),BC
0644  FD 36 22 02  LD (IY+22),02
0648  ED 5B 0C 40  LD DE,(400C)
064C  18 13        JR 0661
064E  FE 76        CP 76
0650  28 12        JR Z,0664
0652  ED 4B 30 40  LD BC,(4030)
0656  CD 18 09     CALL 0918
0659  ED 5B 29 40  LD DE,(4029)
065D  FD 36 22 02  LD (IY+22),02
0661  DF           RST 18
0662  FE 76        CP 76
0664  CA 13 04     JP Z,0413
0667  FD 36 01 80  LD (IY+01),80
066B  EB           EX DE,HL
066C  22 29 40     LD (4029),HL
066F  EB           EX DE,HL
0670  CD 4D 00     CALL 004D
0673  CD C1 0C     CALL 0CC1
0676  FD CB 01 8E  RES 1,(IY+01)
067A  3E C0        LD A,C0
067C  FD 77 19     LD (IY+19),A
067F  CD A3 14     CALL 14A3
0682  FD CB 2D AE  RES 5,(IY+2D)
0686  FD CB 00 7E  BIT 7,(IY)
068A  28 22        JR Z,06AE
068C  2A 29 40     LD HL,(4029)
068F  A6           AND (HL)
0690  20 1C        JR NZ,06AE
0692  56           LD D,(HL)
0693  23           INC HL
0694  5E           LD E,(HL)
0695  ED 53 07 40  LD (4007),DE
0699  23           INC HL
069A  5E           LD E,(HL)
069B  23           INC HL
069C  56           LD D,(HL)
069D  23           INC HL
069E  EB           EX DE,HL
069F  19           ADD HL,DE
06A0  CD 46 0F     CALL 0F46
06A3  38 C7        JR C,066C
06A5  21 00 40     LD HL,4000
06A8  CB 7E        BIT 7,(HL)
06AA  28 02        JR Z,06AE
06AC  36 0C        LD (HL),0C
06AE  FD CB 38 7E  BIT 7,(IY+38)
06B2  CC 71 08     CALL Z,0871
06B5  01 21 01     LD BC,0121
06B8  CD 18 09     CALL 0918
06BB  3A 00 40     LD A,(4000)
06BE  ED 4B 07 40  LD BC,(4007)
06C2  3C           INC A
06C3  28 0C        JR Z,06D1
06C5  FE 09        CP 09
06C7  20 01        JR NZ,06CA
06C9  03           INC BC
06CA  ED 43 2B 40  LD (402B),BC
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06CE  20 01        JR NZ,06D1
06D0  0B           DEC BC
06D1  CD EB 07     CALL 07EB
06D4  3E 18        LD A,18
06D6  D7           RST 10
06D7  CD 98 0A     CALL 0A98
06DA  CD AF 14     CALL 14AF
06DD  C3 C1 04     JP 04C1
06E0  ED 43 0A 40  LD (400A),BC
06E4  2A 16 40     LD HL,(4016)
06E7  EB           EX DE,HL
06E8  21 13 04     LD HL,0413
06EB  E5           PUSH HL
06EC  2A 1A 40     LD HL,(401A)
06EF  ED 52        SBC HL,DE
06F1  E5           PUSH HL
06F2  C5           PUSH BC
06F3  CD E7 02     CALL 02E7
06F6  CD 2A 0A     CALL 0A2A
06F9  E1           POP HL
06FA  CD D8 09     CALL 09D8
06FD  20 06        JR NZ,0705
06FF  CD F2 09     CALL 09F2
0702  CD 60 0A     CALL 0A60
0705  C1           POP BC
0706  79           LD A,C
0707  3D           DEC A
0708  B0           OR B
0709  C8           RET Z
070A  C5           PUSH BC
070B  03           INC BC
070C  03           INC BC
070D  03           INC BC
070E  03           INC BC
070F  2B           DEC HL
0710  CD 9E 09     CALL 099E
0713  CD 07 02     CALL 0207
0716  C1           POP BC
0717  C5           PUSH BC
0718  13           INC DE
0719  2A 1A 40     LD HL,(401A)
071C  2B           DEC HL
071D  ED B8        LDDR
071F  2A 0A 40     LD HL,(400A)
0722  EB           EX DE,HL
0723  C1           POP BC
0724  70           LD (HL),B
0725  2B           DEC HL
0726  71           LD (HL),C
0727  2B           DEC HL
0728  73           LD (HL),E
0729  2B           DEC HL
072A  72           LD (HL),D
072B  C9           RET
072C  FD CB 01 CE  SET 1,(IY+01)
0730  CD A7 0E     CALL 0EA7
0733  78           LD A,B
0734  E6 3F        AND 3F
0736  67           LD H,A
0737  69           LD L,C
0738  22 0A 40     LD (400A),HL
073B  CD D8 09     CALL 09D8
073E  1E 00        LD E,00
0740  CD 45 07     CALL 0745
0743  18 FB        JR 0740
0745  ED 4B 0A 40  LD BC,(400A)
0749  CD EA 09     CALL 09EA
074C  16 92        LD D,92
074E  28 05        JR Z,0755
0750  11 00 00     LD DE,0000
0753  CB 13        RL E
0755  FD 73 1E     LD (IY+1E),E
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0758  7E           LD A,(HL)
0759  FE 40        CP 40
075B  C1           POP BC
075C  D0           RET NC
075D  C5           PUSH BC
075E  CD A5 0A     CALL 0AA5
0761  23           INC HL
0762  7A           LD A,D
0763  D7           RST 10
0764  23           INC HL
0765  23           INC HL
0766  22 16 40     LD (4016),HL
0769  FD CB 01 C6  SET 0,(IY+01)
076D  ED 4B 18 40  LD BC,(4018)
0771  2A 16 40     LD HL,(4016)
0774  A7           AND A
0775  ED 42        SBC HL,BC
0777  20 03        JR NZ,077C
0779  3E B8        LD A,B8
077B  D7           RST 10
077C  2A 16 40     LD HL,(4016)
077F  7E           LD A,(HL)
0780  23           INC HL
0781  CD B4 07     CALL 07B4
0784  22 16 40     LD (4016),HL
0787  28 E4        JR Z,076D
0789  FE 7F        CP 7F
078B  28 10        JR Z,079D
078D  FE 76        CP 76
078F  28 5D        JR Z,07EE
0791  CB 77        BIT 6,A
0793  28 05        JR Z,079A
0795  CD 4B 09     CALL 094B
0798  18 D3        JR 076D
079A  D7           RST 10
079B  18 D0        JR 076D
079D  3A 06 40     LD A,(4006)
07A0  06 AB        LD B,AB
07A2  A7           AND A
07A3  20 05        JR NZ,07AA
07A5  3A 01 40     LD A,(4001)
07A8  06 B0        LD B,B0
07AA  1F           RRA
07AB  1F           RRA
07AC  E6 01        AND 01
07AE  80           ADD A,B
07AF  CD F5 07     CALL 07F5
07B2  18 B9        JR 076D
07B4  FE 7E        CP 7E
07B6  C0           RET NZ
07B7  23           INC HL
07B8  23           INC HL
07B9  23           INC HL
07BA  23           INC HL
07BB  23           INC HL
07BC  C9           RET
07BD  16 00        LD D,00
07BF  CB 28        SRA B
07C1  9F           SBC A,A
07C2  F6 26        OR 26
07C4  2E 05        LD L,05
07C6  95           SUB L
07C7  85           ADD A,L
07C8  37           SCF
07C9  CB 19        RR C
07CB  38 FA        JR C,07C7
07CD  0C           INC C
07CE  C0           RET NZ
07CF  48           LD C,B
07D0  2D           DEC L
07D1  2E 01        LD L,01
07D3  20 F2        JR NZ,07C7
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07D5  21 7D 00     LD HL,007D
07D8  5F           LD E,A
07D9  19           ADD HL,DE
07DA  37           SCF
07DB  C9           RET
07DC  7B           LD A,E
07DD  A7           AND A
07DE  F8           RET M
07DF  18 10        JR 07F1
07E1  AF           XOR A
07E2  09           ADD HL,BC
07E3  3C           INC A
07E4  38 FC        JR C,07E2
07E6  ED 42        SBC HL,BC
07E8  3D           DEC A
07E9  28 F1        JR Z,07DC
07EB  1E 1C        LD E,1C
07ED  83           ADD A,E
07EE  A7           AND A
07EF  28 04        JR Z,07F5
07F1  FD CB 01 86  RES 0,(IY+01)
07F5  D9           EXX
07F6  E5           PUSH HL
07F7  FD CB 01 4E  BIT 1,(IY+01)
07FB  20 05        JR NZ,0802
07FD  CD 08 08     CALL 0808
0800  18 03        JR 0805
0802  CD 51 08     CALL 0851
0805  E1           POP HL
0806  D9           EXX
0807  C9           RET
0808  57           LD D,A
0809  ED 4B 39 40  LD BC,(4039)
080D  79           LD A,C
080E  FE 21        CP 21
0810  28 1A        JR Z,082C
0812  3E 76        LD A,76
0814  BA           CP D
0815  28 30        JR Z,0847
0817  2A 0E 40     LD HL,(400E)
081A  BE           CP (HL)
081B  7A           LD A,D
081C  20 20        JR NZ,083E
081E  0D           DEC C
081F  20 19        JR NZ,083A
0821  23           INC HL
0822  22 0E 40     LD (400E),HL
0825  0E 21        LD C,21
0827  05           DEC B
0828  ED 43 39 40  LD (4039),BC
082C  78           LD A,B
082D  FD BE 22     CP (IY+22)
0830  28 03        JR Z,0835
0832  A7           AND A
0833  20 DD        JR NZ,0812
0835  2E 04        LD L,04
0837  C3 58 00     JP 0058
083A  CD 9B 09     CALL 099B
083D  EB           EX DE,HL
083E  77           LD (HL),A
083F  23           INC HL
0840  22 0E 40     LD (400E),HL
0843  FD 35 39     DEC (IY+39)
0846  C9           RET
0847  0E 21        LD C,21
0849  05           DEC B
084A  FD CB 01 C6  SET 0,(IY+01)
084E  C3 18 09     JP 0918
0851  FE 76        CP 76
0853  28 1C        JR Z,0871
0855  4F           LD C,A
0856  3A 38 40     LD A,(4038)
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08C2  EA 3F      AND 3F
08C4  FE 5C      CP 5C
08C6  4F         LD L,A
08C7  26 40      LD H,40
08C9  CC 7E 08   CALL Z,0878
08CC  71         LD (HL),C
08CD  2C         INC L
08CE  FD 75 3B   LD (IY+3B),L
08D1  C9         RET
08D2  16 8A      LD D,8A
08D4  2A 0C 40   LD HL,(400C)
08D7  23         INC HL
08D8  18 05      JR 08DF
08DA  16 01      LD D,01
08DC  21 3C 40   LD HL,403C
08DF  CD E7 02   CALL 02E7
08E2  E5         PUSH HL
08E3  C5         PUSH BC
08E4  AF         XOR A
08E5  5F         LD E,A
08E6  ED FB      OUT (FB),A
08E8  E1         POP HL
08E9  CD 43 0F   CALL 0F43
08EC  30 05      JR C,08F3
08EE  1F         RRA
08EF  ED FB      OUT (FB),A
08F1  EF         RST 28
08F2  0E         INC C
08F3  DB FB      IN A,(FB)
08F5  B7         AND A
08F6  FA 0E 08   JP M,080E
08F9  30 EE      JR NC,08E9
08FB  E5         PUSH HL
08FC  D5         PUSH DE
08FD  7A         LD A,D
08FE  FE 07      CP 07
0900  9F         SBC A,A
0901  A3         AND E
0902  07         RLCA
0903  A3         AND E
0904  57         LD D,A
0905  4E         LD C,(HL)
0906  79         LD A,C
0907  23         INC HL
0908  FE 7A      CP 7A
090A  28 24      JR Z,0930
090C  E5         PUSH HL
090D  FE 77      SUB A
090F  87         ADD A,A
0910  87         ADD A,A
0911  26 0F      LD H,0F
0913  CB 14      RL D
0915  83         ADD A,E
0916  6F         LD L,A
0917  CB 11      RL C
0919  9F         SBC A,A
091A  AE         XOR (HL)
091B  4F         LD C,A
091C  66 00      LD H,00
091E  7A         LD A,D
091F  CB 01      RLC C
0921  1F         RRA
0922  A7         LD H,A
0923  DB FB      IN A,(FB)
0925  1F         RRA
0926  30 FB      JR NC,0923
0928  7E         LD A,H
0929  D3 FB      OUT (FB),A
092B  10 F1      DJNZ 091E
092D  E1         POP HL
092E  10 05      JR 0935
0930  DB FC      IN A,(FC)
0932  AF         XOR A
0933  D3 FC      OUT (FC),A
0935  D1         POP DE
0936  C1         POP BC
0937  E1         POP HL
0938  C9         RET
0939  1F         RRA
093A  30 FB      JR NC,0937
093C  7A         LD A,D
093D  0F         RRCA
093E  D3 FB      OUT (FB),A
0940  D3         DOF DE
0941  1C         INC E
0942  CD 5E      BIT 3,F
0944  20 AF      JR Z,08F5
0946  C1         POP BC
0947  15         DEC D
0948  20 A0      JR NZ,08EA
094A  3E 04      LD A,04
094C  D3 FB      OUT (FB),A
094E  CD 07 02   CALL 0207
0951  C1         POP BC
0952  21 5C 40   LD HL,405C
0955  36 7A      LD (HL),7A
0957  06 20      LD B,20
0959  2B         DEC HL
095A  36 00      LD (HL),00
095C  10 FB      DJNZ 0959
095E  7B         LD A,L
095F  CB FF      SET 7,A
0961  32 38 40   LD (4038),A
0964  C9         RET
0965  3E 17      LD A,17
0967  90         SUB B
0968  38 00      JR C,096A
096A  FD BE 22   CP (IY+22)
096D  DA 35 08   JP C,0835
0970  3C         INC A
0971  47         LD B,A
0972  3E 1F      LD A,1F
0974  91         SUB C
0975  20 FD      JR Z,0974
0977  91         SUB C
0978  32 38 40   LD (4038),A
097B  C9         RET
097C  ED 43 3F 40   LD (403F),BC
0980  2A 10 40   LD HL,(4010)
0983  51         LD D,C
0984  3E 22      LD A,22
0986  91         SUB C
0987  4F         LD C,A
0988  3E 7A      LD A,7A
098A  04         INC B
098B  2B         DEC HL
098C  BE         CP (HL)
098D  20 FC      JR NZ,098B
098F  10 FA      DJNZ 098B
0991  23         INC HL
0992  ED 01      OUTW
0994  3E 0E 40   LD (400E),HL
0997  37         SCF
0998  F0         RET P0
0999  15         DEC D
099A  F8         RET Z
099B  E5         PUSH HL
099C  CD 98 09   CALL 0998
099F  C1         POP BC
09A0  41         LD B,C
09A1  62         LD H,D
09A2  6B         LD L,E
09A3  3A 00      LD (HL),00
09A5  2B         DEC HL
09A6  10 FD      DJNZ 09A5
09A8  EB         EX DE,HL
09A9  23         INC HL
09AA  72         LD (HL),D
09AB  2B         DEC HL
09AC  73         LD (HL),E
09AD  C9         RET
09AE  FD CB 01 C6   SET 0,(IY+01)
09B2  E3 F5 07   JP 07F5
09B5  E5         PUSH HL
09B6  21 11 01   LD HL,0111
09B9  CB 3F      BIT 7,A
09BB  28 02      JR Z,09BF
09BD  E6 3F      AND 3F
09BF  FE 43      CP 43
09C1  30 10      JR NC,09D3
09C3  47         LD B,A
09C4  04         INC B
09C5  CB 7E      BIT 7,(HL)
09C7  23         INC HL
09C8  28 FB      JR Z,09C5
09CA  10 F9      DJNZ 09C5
09CC  CB 77      BIT 6,A
09CE  20 02      JR NZ,09D2
09D0  FE 10      CP 10
09D2  3F         CCF
09D3  44         LD B,H
09D4  4D         LD C,L
09D5  E1         POP HL
09D6  00         GET HC
09D7  0A         LD A,(BC)
09D8  E6 E4      AND A,E4
09DA  C9         RET
09DB  08 01 00   LD BC,0001
09DE  E5         PUSH HL
09DF  CD E5 0E   CALL 0EE5
09E2  E1         POP HL
09E3  CD AB 09   CALL 09AB
09E6  26 1C 40   LD HL,(401C)
09E9  EB         EX DE,HL
09EA  ED B8      LDDR
09EC  C9         RET
09ED  F5         PUSH AF
09EE  E5         PUSH HL
09EF  21 0C 40   LD HL,400C
09F2  3E 09      LD A,09
09F4  5E         LD E,(HL)
09F5  23         INC HL
09F6  56         LD D,(HL)
09F7  E3         EX (SP),HL
09F8  A7         AND A
09F9  ED 52      SBC HL,DE
09FB  10 FD      DJNZ 09FA
09FD  EB         EX DE,HL
09FE  E3         EX (SP),HL
09FF  30 09      JR NC,0A0A
0A01  D5         PUSH DE
0A02  EB         EX DE,HL
0A03  09         ADD HL,BC
0A04  E5         EX (SP),HL
0A05  72         LD (HL),D
0A06  2B         DEC HL
0A07  73         LD (HL),E
0A08  23         INC HL
0A09  D1         POP DE
0A0A  23         INC HL
0A0B  3D         DEC A
0A0C  20 EB      JR NZ,09F9
0A0E  EB         EX DE,HL
0A0F  D1         POP DE
0A10  F1         POP AF
0A11  A7         AND A
0A12  ED 52      SBC HL,DE
0A14  44         LD B,H
0A15  4D         LD C,L
0A16  03         INC BC
0A17  19         ADD HL,DE
0A18  EB         EX DE,HL
0A19  C9         RET
0A1A  E5         PUSH HL
0A1B  21 7D 40   LD HL,407D
0A1E  54         LD D,H
0A1F  5D         LD E,L
0A20  C1         POP BC
0A21  CD EA 09   CALL 09EA
0A24  D0         RET NC
0A25  C5         PUSH BC
0A26  CD F2 0F   CALL 0FF2
0A29  E0         EX (SP),HL
0A2A  18 F4      JR 0A20
0A2C  7E         LD A,(HL)
0A2D  E0         CP 0
0A2E  C0         RET NZ
0A2F  23         INC HL
0A30  7E         LD A,(HL)
0A31  2B         DEC HL
0A32  B9         CP C
0A33  C9         RET
0A34  E5         PUSH HL
0A35  7E         LD A,(HL)
0A36  FE 40      CP 40
0A38  38 17      JR C,0A51
0A3A  CB AF      BIT 5,A
0A3C  28 14      JR Z,0A52
0A3E  B7         AND A,A
0A3F  FA 01 06   JP M,0A01
0A42  3F         CCF
0A43  01 05 00   LD BC,0005
0A46  30 02      JR NC,0A4A
0A48  0E 11      LD C,11
0A4A             RLA
0A4B  23         INC HL
0A4C  7E         LD A,(HL)
0A4D  30 FD      JR NC,0A4C
0A4F  18 04      JR 0A55
0A51  23         INC HL
0A52  23         INC HL
0A53  4F         LD C,(HL)
0A54  23         INC HL
0A55  46         LD B,(HL)
0A56  23         INC HL
0A57  09         ADD HL,BC
0A58  E1         POP HL
0A59  C9         RET
```

```
0A1A  44        LD B,H
0A1B  4D        LD C,L
0A1C  19        ADD HL,DE
0A1D  EB        EX DE,HL
0A1E  C9        RET
0A1F  FD A6 22  LD B,(IY+22)
0A22  C5        PUSH BC
0A23  CD 2C 0A  CALL 0A2C
0A26  E1        POP HL
0A27  05        DEC B
0A28  18 02     JR 0A2C
0A2A  06 10     LD B,10
0A2C  FD CB 01 96  RES 2,(IY+01)
0A30  0E 21     LD C,21
0A32  C5        PUSH BC
0A33  CD 18 09  CALL 0918
0A36  C1        POP BC
0A37  3A 05 40  LD A,(4005)
0A3A  FE 4D     CP 4D
0A3C  38 14     JR C,0A52
0A3E  FD CB 3A FE  SET 7,(IY+3A)
0A42  AF        XOR A
0A43  CD F5 07  CALL 07F5
0A46  2A 39 40  LD HL,(4039)
0A49  7D        LD A,L
0A4A  B4        OR H
0A4B  E6 3E     AND 3E
0A4D  20 E3     JR NZ,0A32
0A4F  E3 3B 09  JP 093B
0A52  54        LD D,H
0A53  5D        LD E,L
0A54  2B        DEC HL
0A55  4B        LD C,B
0A56  06 00     LD B,00
0A58  ED B8     LDDR
0A5A  2A 10 40  LD HL,(4010)
0A5D  CD 12 0A  CALL 0A12
0A60  C5        PUSH BC
0A61  7B        LD A,B
0A62  2F        CPL
0A63  47        LD B,A
0A64  79        LD A,C
0A65  2F        CPL
0A66  4F        LD C,A
0A67  03        INC BC
0A68  CD AD 09  CALL 09AD
0A6B  EB        EX DE,HL
0A6C  E1        POP HL
0A6D  19        ADD HL,DE
0A6E  E5        PUSH DE
0A6F  ED B8     LDDR
0A71  E1        POP HL
0A72  C9        RET
0A73  2A 14 40  LD HL,(4014)
0A76  CD 4D 00  CALL 004D
0A79  DF        RST 18
0A7A  FB CB 2D AE  BIT 5,(IY+2D)
0A7E  C0        RET NZ
0A7F  21 5D 40  LD HL,405D
0A82  22 3F 40  LD (403F),HL
0A85  CD 44 15  CALL 1544
0A88  CD 96 15  CALL 1596
0A8B  38 04     JR C,0A91
0A8D  21 F0 0D  LD HL,0DF0
0A90  09        ADD HL,BC
0A91  DA 9A 0D  JP C,0D9A
0A94  DF        RST 18
0A95  C3 0B 14  JP 140B
0A98  D5        PUSH DE
0A99  E5        PUSH HL
0A9A- AF        XOR A

0A9B  20 20     JR NZ,0ABF
0A9E  A8        LD H,B
0A9F  A9        LD L,C
0AA0  1E FF     LD E,FF
0AA2  18 08     JR 0AAC
0AA4  D5        PUSH DE
0AA5  5A        LD D,(HL)
0AA6  23        INC HL
0AA7  5E        LD E,(HL)
0AA8  E5        PUSH HL
0AA9  EB        EX DE,HL
0AAA  1E 00     LD E,00
0AAC  01 40 FC  LD BC,FC40
0AAF  CD E1 07  CALL 07E1
0AB2  01 9C FF  LD BC,FF9C
0AB5  CB F1 07  CALL 07F1
0AB8  0E FA     LD C,FA
0ABA  CB F1 07  CALL 07F1
0ABD  7B        LD A,E
0ABE  CB EB 07  CALL 07EB
0AC1  E1        POP HL
0AC2  D1        POP DE
0AC3  C9        RET
0AC4  CD A6 0D  CALL 0DA6
0AC7  E1        POP HL
0AC8  C8        RET Z
0AC9  E9        JP (HL)
0ACA  FD CB 01 CE  SET 1,(IY+01)
0ACE  7E        LD A,(HL)
0ACF  FE 76     CP 76
0AD1  CA B4 0D  JP Z,0DB4
0AD4  D6 1A     SUB 1A
0AD6  CE 00     ADC A,00
0AD8  20 A9     JR NZ,0A83
0ADA  FE A7     CP A7
0ADC  20 1D     JR NZ,0AFB
0ADE  EF        RST 28
0ADF  CD 92 0D  CALL 0D92
0AE2  FE 1A     CP 1A
0AE4  D2 9A 0D  JP NC,0D9A
0AE7  EF        RST 28
0AE8  CD 92 0D  CALL 0D92
0AEB  CD 4E 0B  CALL 0B4E
0AEE  FF        RST 38
0AEF  D1 34 CD  LD DE,CD34
0AF2  F5        PUSH AF
0AF3  0F        DEC BC
0AF4  0F        RRCA
0AF5  CD F5 00  CALL 00F5
0AF8  38 36     JR 0B30
0AFA  FE A0     CP A0
0AFC  20 33     JR NZ,0B31
0AFE  F7        RST 30
0AFF  CD 92 0D  CALL 0D92
0B02  CD 4E 0B  CALL 0B4E
0B05  CD 02 0C  CALL 0C02
0B08  C2 A0 0F  JP NZ,0EA0
0B0B  E6 1F     AND 1F
0B0D  4F        LD C,A
0B0E  FD CB 01 4E  BIT 1,(IY+01)
0B12  28 0A     JR Z,0B1E
0B14  FD 7E 38  LD A,(IY+38)
0B17  EE FF     SET 7,A
0B19  C6 3C     ADD A,3C
0B1B  D4 71 0B  CALL NC,0B71
0B1E  FD 86 3F  ADD A,(IY+3F)
0B21  FE 21     CP 21
0B23  3A 3A 40  LD A,(403A)
0B26  DE 01     SBC A,01
0B28  CD FA 0B  CALL 0BFA
0B2B  FD CB 01 C6  SET 0,(IY+01)
0B2F  18 0A     JR 0B37
```



```
0B31  CD 55 0B  CALL 0B55
0B34  DF        RST 18
0B35  D6 1A     SUB 1A
0B37  CE 00     ADC A,00
0B39  28 0A     JR Z,0B44
0B3B  CD 1D 0D  CALL 0D1D
0B3E  C5 B4 0B  JP 0BB4
0B41  D4 BB 0B  CALL NC,0BBB
0B44  E7        RST 20
0B45  FE 76     CP 76
0B47  C8        RET Z
0B48  C3 B5 0A  JP 0AB5
0B4B  CD AA 0D  CALL 0DAA
0B4E  C0        RET NZ
0B4F  E1        POP HL
0B50  18 E2     JR 0B34
0B52  CD C5 0A  CALL 0AC5
0B55  FD CB 01 76  BIT 6,(IY+01)
0B59  CC F4 13  CALL Z,13F4
0B5C  28 0A     JR Z,0B68
0B5E  C3 07 15  JP 1507
0B61  3E 0F     LD A,0B
0B63  D7        RST 10
0B64  ED 5B 10 40  LD DE,(4010)
0B68  79        LD A,C
0B69  B1        OR C
0B6A  08        DEC BC
0B6B  C8        RET Z
0B6C  1A        LD A,(DE)
0B6D  13        INC DE
0B6E  ED 53 10 40  LD (4010),DE
0B72  CB 27     RLA A,A
0B74  DB EB     JR Z,0B66
0B76  FE E0     CP E0
0B78  28 E7     JR Z,0B64
0B7A  C5        PUSH BC
0B7B  CD 40 09  CALL 0940
0B7E  C1        POP BC
0B7F  18 E3     JR 0B67
0B81  CD C5 0A  CALL 0AC5
0B84  3E 7A     LD A,7A
0B86  D7        RST 10
0B87  C9        RET
0B88  CD C5 0A  CALL 0AC5
0B8B  FD CB 01 CA  SET 0,(IY+01)
0B8F  AF        XOR A
0B90  D7        RST 10
0B91  ED 4B 39 40  LD BC,(4039)
0B95  79        LD A,C
0B96  FD CB 01 4E  BIT 1,(IY+01)
0B9A  28 05     JR Z,0BA1
0B9C  3E 50     LD A,50
0B9E  FD 96 38  SUB (IY+38)
0BA1  0E 11     LD C,11
0BA3  B9        CP C
0BA4  30 02     JR NC,0BA8
0BA6  0E 01     LD C,01
0BA8  CD 0B 09  CALL 090B
0BAB  C9        RET
0BAC  CD F5 0B  CALL 0BF5
0BAF  ED 43 3A 40  LD (403A),BC
0BB3  3F 20     LD A,20
0BB5  90        SUB B
0BB6  DA A0 0E  JP C,0EA0
0BB9  47        LD B,A
0BBA  3C 04     LD A,01
0BBC  CB 20     SRA B
0BBE  30 02     JR NC,0BC2
0BC0  3E 04     LD A,04
0BC2  CB 27     SRA C
0BC4  30 08     JR NC,0BCA
0BC6  07        RLCA
```

```
0BC7  07        RLCA
0BC8  07        RLCA
0BC9  07        RLCA
0BCA  F5        PUSH AF
0BCB  CD F5 0B  CALL 0BF5
0BCE  7E        LD A,(HL)
0BCF  07        RLCA
0BD0  FE 10     CP 10
0BD2  30 06     JR NC,0BDA
0BD4  0F        RRCA
0BD5  30 02     JR NC,0BD9
0BD7  EE BF     XOR BF
0BD9  47        LD B,A
0BDA  11 9C 0C  LD DE,0C9C
0BDD  3A 30 40  LD A,(4030)
0BE0  93        SUB E
0BE1  FA C9 0B  JP M,0BC9
0BE4  F1        POP AF
0BE5  2F        CPL
0BE6  A0        AND B
0BE7  18 02     JR 0BEB
0BE9  F1        POP AF
0BEA  B0        OR B
0BEB  FE 08     CP 08
0BED  38 02     JR C,0BF1
0BEF  EE BF     XOR BF
0BF1  B9        EXX
0BF2  D7        RST 10
0BF3  D9        EXX
0BF4  C9        RET
0BF5  CD 02 0C  CALL 0C02
0BF8  47        LD B,A
0BF9  C5        PUSH BC
0BFA  CD 02 0C  CALL 0C02
0BFD  59        LD E,C
0BFE  E1        POP HL
0BFF  51        LD D,C
0C00  4F        LD C,A
0C01  C9        RET
0C02  CD C9 15  CALL 15C9
0C05  DA A0 0E  JP C,0EA0
0C08  0E 01     LD C,01
0C0A  C8        RET Z
0C0B  0E FF     LD C,FF
0C0D  C9        RET
0C0E  FD A6 22  LD B,(IY+22)
0C11  0E 21     LD C,21
0C13  CD 18 09  CALL 0918
0C16  CD 9E 09  CALL 099E
0C19  7E        LD A,(HL)
0C1A  12        LD (DE),A
0C1B  FD 34 3A  INC (IY+3A)
0C1E  2A 0C 40  LD HL,(400C)
0C21  23        INC HL
0C22  54        LD D,H
0C23  5D        LD E,L
0C24  ED B1     CPIR
0C26  C3 5D 0A  JP 0A5D
0C29  00        NOP
```

```
00 20 3F 01 11 75
5F 49 42 20 57 1F 27 52 45 0F 4D 20 44 20 5A 20
4F 45 00 52 5A 4D 15 6A 01 14 67 0A 00 01 0F 0A
0E 05 4D 00 04 00 05 0E 00 0E 0C 04 E0 0E 04 14
0A 0F 0A 05 09 00 04 00 2F 0E 05 FF 0A 01 00 E0
0F 05 05 14 05 7A 00 00 C3 03 03 AF 01 07 30 07
06 1A 04 00 97 0F 03 4E 0E 05 40 01 05 F6 07 00
3E 0F 00 96 14 00 7A 00 0A 1A 06 00 AF 0F 0A 1A
06 00 AF 0F 00 0E 0F 0C 00 2E 0F 00 20 0F 00 20
0F 00 A9 00 05 E0 0A 03 2E 07
```

SOLUTIONS TO EXERCISES

Chapter 1

1(a)
```
10 FOR X = 63 TO 0 STEP -1  ... use 59 for 1K ZX81's
20 FOR Y = 43 TO 0 STEP -1
30 PLOT X,Y
40 NEXT Y
50 NEXT X
```

1(b)
```
10 FOR X = 10 TO 30
20 FOR Y = 5 TO 25
30 PLOT X,Y
40 NEXT Y
50 NEXT X
```

1(c) For 16K Machines:—

```
10 FOR X = 0 TO 63
20 PLOT X,0
30 GO SUB 500
40 UNPLOT X,0
50 NEXT X
60 FOR Y = 0 TO 43
70 PLOT 63,Y
80 GO SUB 500
90 UNPLOT 63,Y
100 NEXT Y
110 FOR X=63 TO 0 STEP -1
120 PLOT X,43
130 GO SUB 500
140 UNPLOT X,43
150 NEXT X
160 FOR Y=43 TO 0 STEP -1
170 PLOT 0,Y
180 GO SUB 500
190 UNPLOT 0, Y
200 NEXT Y
210 STOP
500 PAUSE 10
510 POKE 16437,255
520 RETURN
```


For 1K ZX81's the boundaries of the display will need to be reduced.

Alternatively try this. (Substitute Y=15 for Y=0 for 1K):

```
10 LET X=0
20 LET Y=0
30 PLOT X,Y
40 PAUSE 10        ) or  40 FOR A=1 TO 20
50 POKE 16437,255)       50 NEXT A
60 UNPLOT X,Y
70 LET X=X+(Y=0)-(Y=43)-(X=63 AND Y=0) + (X=0 AND
   Y=43)
80 LET Y=Y-(X=0)+(X=63)-(Y=43 AND X=63) + (Y=0 AND
   X=0)
90 GO TO 30
```

1(d)
```
10 FOR A=0 TO 90 STEP 5
20 LET M=TAN(A*2*PI/360)
30 FOR X=0 TO 63 (use 40 for 1K)
40 LET Y=INT (M*X)
50 IF Y>43 THEN GO TO 80
60 PLOT X,Y
70 NEXT X
80 NEXT A
```

1(e) A line through the point (32,22) with gradient m can be calculated since the slope $\frac{y-22}{x-32} = m$

so $y = m(x-32)+22$

Use values of m from −5 to 5 in steps of one half

```
10 FOR M=-5 TO 5 STEP 0.5
20 FOR X=0 TO 63
30 LET Y=INT(M*(X-32)+22)
40 IF Y>43 OR Y<0 THEN GO TO 60
50 PLOT X,Y
60 NEXT X
70 NEXT M
```

1(f) Equation is $x^2 + y^2 = 40^2$

so $x = 40 \cos \theta$
and $y = 40 \sin \theta$
and we PLOT it for the angle θ between 0° and 90°.

```
10 FOR Q = 0 TO 90
20 LET P=Q*PI/180
30 PLOT 40*COS P,40*SIN P
40 NEXT Q
```

Chapter 2

2(a) Add the following instruction

```
55 IF A$(I)="–" OR A$(I)="b" THEN GO TO 70
```

2(b)
```
10 DIM S$(40)
20 PRINT "ENTERbSENTENCE:"
30 INPUT S$
40 PRINT S$
50 FOR I=1 TO 37
60 IF S$(I TO I+2)="THE" THEN GO TO 100
70 NEXT I
80 PRINT "DOESbNOTbCONTAINbTHE."
90 STOP
100 PRINT "DOESbCONTAINbTHE"
```

Notice this accepts any word containing, T,H,E, e.g. PATHETIC

Chapter 3

3(a) No solution specified: the subject area is open to the reader's choice.

3(b)
```
71 LET V=0
72 FOR J=1 TO 8
73 IF CODE (W$(I,J))>128 THEN LET V=V+1
74 NEXT J
75 IF V<>1 THEN GO TO 70
```

V counts the number of inverse characters in the word.

3(c) ABS is included so that the **relative** values of N and R are compared effectively, i.e. it is unimportant which is the larger. Without ABS we have for example:

```
190 IF N–R>5 THEN GO TO 220
```

If R was 50 and N was 44 the test would not be satisfied since –6 is not greater than 5.

3(d) Try it and see!

3(e)
```
30 LET A$(I)=CHR$(INT(RND*11)+28)
```

3(f) There is not a way of crashing the program at the input stage that we have found!

3(g) Add the following line

```
105 IF N=M AND D>SQR M THEN GO TO 120
```

3(h) Line 260 terminates with an error if DF is zero. Add the following:

```
253 IF DF<>0 THEN GO TO 260
255 PRINT "NObSOLUTIONbPOSSIBLE"
257 STOP
```

3(i) Line 360 detects a response which is shorter than the answer keyword, and which is therefore obviously wrong.

APPENDIX
PROGRAM DESIGN AND DEVELOPMENT

Introduction

This section has been written to show the reader how a games program has been built up from first ideas into a fully working and documented program.

The writing of programs can generally be split into a number of steps:

1. Defining the problem
2. Outlining the solution
3. Selecting and representing algorithms
4. Coding (or writing the program)
5. Debugging
6. Testing and validating
7. Documentation
8. Maintaining the program

It is vital that a considerable amount of planning and design for a program takes place before the user touches the keyboard. In particular the aim and format of the program must be clearly specified, since ambiguities at this stage will cause problems later. When defining the method of solution (or **algorithm**) is it helpful to write this down as a series of separate steps in a block-structured form, as shown in earlier chapters. Some programmers like to use **flowcharts** (example later) but the author thinks these are not vital if the algorithm is written down in a structured way. All later stages of the implementation of the program are based upon this stage and it can be helpful to specify the names and meanings of variables here. Certainly a list of variables must be kept as the program is written to avoid confusion or duplication of names. Even when tracking down errors or program **bugs**, the structured method can be traced through to show any logic errors. Although it can be frustrating for the user with a good idea for a program to wait for an hour or so following this method before getting on the ZX81, he will find it saves a great deal of time later: there will be much fewer errors and those present will be easier to find.

This approach, while certainly the best, does present problems for those beginning to program, since such users will not have all their ideas at the beginning of the design process. The remainder of this section

represents an alternative of gradually improving upon an initial simple program.

Sample Specification

Step One, defining the problem means "What is the Program to do" or "What is its specification". Here is the specification of the program which will be covered in this section:

"The program is to draw a large block on the screen which represents a thick dungeon wall. A prisoner under the user's control has to dig himself out from one end to the other. However parts of the wall are of made of hard rock, which he must dig round. If he takes too long a Warder will come looking for him and if he is found he will be taken back and the tunnels he has dug filled in. The object is for the prisoner to escape."

Those people without 16K expansions will realise that (without using machine code) it will not be possible for their ZX81's to handle such a program. Even so the first part of this section is just as applicable to 1K as to 16K, so continue reading.

The specification has given us three main problems:

1. We have to be able to move a character representing the prisoner round the screen.
2. Parts of the screen have to be designated "No-Go" areas which the prisoner must go round, and
3. We have to make a second character follow the paths made by the "Prisoner" while looking for him.

PROBLEM ONE – MOVING A CHARACTER ROUND THE SCREEN

As described earlier in the book there are two ways of printing a character on the screen, "PRINT AT" and "PLOT". We will use "PRINT AT" because any character can be displayed by this statement. Since it is not necessary to input the co-ordinates for every move and since we do not want the program to stop while waiting for an input we will use the 'INKEY$" statement. The following program shows briefly how this can be done.

```
 5  REM PROGRAM 1
10  LET X=5
20  LET Y=1
30  IF INKEY$="8" THEN LET Y=Y+1
40  PRINT AT X,Y;"P"
50  GO TO 30
```

Y is the horizontal position which is incremented everytime the "Right Arrow" or "8" key is pressed thus drawing a line towards the right. Note that the line continues for as long as the "Right Arrow" key is pressed. If we can move in one direction like this then we can move in any direction by incorporating the other arrow keys in the program. One fault with the above program is that once the line reaches a certain length it crashes with an error message B/40 which means that the value of "Y" in line 40 is too large. The computer has tried to draw off the screen,to prevent this happening insert the following line:

```
35  IF Y>30 THEN LET Y=Y-1
```

The line will now no longer be drawn past column 30.

When the above technique is used to draw a line in all directions it becomes a very versatile method of drawing on the screen. The following "Sketcher" program demonstrates this. It makes the ZX81 imitate a childs Etch-A-Sketch machine. Movement and character changing are shown below:

5–8	Left, Down, Up, Right
D	Change character to a dot
B	Change character to a blank
S	Scroll whole picture
A	Change character back to black square
C	Press to insert your own character

```
 5 REM SKETCHER PROGRAM
10 LET X=10
20 LET Y=12
30 LET P$=CHR$(128)
40 LET X=X-(INKEY$="7")+(INKEY$="6")
50 LET Y=Y-(INKEY$="5")+(INKEY$="8")
60 IF INKEY$="C" THEN GO SUB 300
70 IF INKEY$="A" THEN LET P$=CHR$(128)
80 IF INKEY$="D" THEN LET P$="."
```



```
 90 IF INKEY$="B" THEN LET P$="b"
100 IF INKEY$="S" THEN SCROLL
110 IF Y>31 THEN LET X=X+1
120 IF Y>31 THEN LET Y=0
130 IF Y=0 THEN LET Y=Y+1
140 IF X=0 THEN LET X=X+1
150 IF X>20 THEN LET X=0
160 IF X=0 THEN LET Y=Y+1
170 PRINT AT X,Y;P$
180 GO TO 40
300 PRINT AT 1,1;"CHARACTER="
310 INPUT P$
320 PRINT AT 1,1;"bbbbbbbbb"
330 RETURN
```

Lines 10 to 30	Sets up coordinates and character to be printed.
Lines 40 and 50	Change the character co-ordinates, compare with Line 30 in Program 1.
Lines 60 to 90	Allow character to be changed.
Lines 110 to 160	Stop the character from going off the screen.
Lines 300 to 330	Allow the user to change the character to any other character or string.

We have not totally achieved our objective as the Sketcher Program and Program 1 are drawing lines round the screen rather than moving a character. To create the illusion of movement we must erase the character everytime it moves. To do this we must store the old co-ordinates and print a blank on them. Insert the following lines into Program 1:–

```
25  LET S=X
27  LET T=Y
45  PRINT AT S,T;"b"
50  GO TO 25
```

Note how the character flashes – this is because it is constantly rubbing itself out. Try and work out how to stop the flashing (answer at the end of this section) and try to incorporate this technique into the Sketcher Program.

The two programs above both fit into a 1K ZX81 although memory full errors may occur with the Sketcher Program as the screen begins to fill

up. For the second problem below (defining parts of the screen as No-Go areas) a 16K expansion must be used.

PROBLEM TWO: DEFINING "NO-GO" AREAS ON SCREEN

By the expression "No-Go Areas" is meant a part of the screen which a program such as Sketcher cannot draw on and must go round to pass. This means that the ZX81 must know what is being displayed on the screen. The easiest way of doing this is to store the screen contents in an array. This is why a 16K expansion is needed. The array will be dimensioned as 21x31 (the number of "PRINT AT" positions) so that every time a character is printed on the screen a corresponding digit should be placed at the correct position in the array. For example if a "3" is printed on the screen at 5,7 then a "3" is stored in the array at 5,7.

```
PRINT AT X,Y;"3"
LET A(X,Y)=3
```

To create No-Go areas on the screen therefore all we have to do is place values in the array. If we try to draw a character in a No-Go screen position then we have to move the character back to its old position.

This BLOCK program gives a demonstration of the No-Go Areas, as well as a moving (self-erasing) character. Move the character by using the "Arrow" keys.

```
  5 REM BLOCK PROGRAM
 10 DIM A(21,31)
 20 FOR S=1 TO 21
 30 FOR T=1 TO 31
 40 LET X=INT(RND*10+1)
 45 IF X>8 THEN PRINT AT S,T;"■"
 50 IF X>8 THEN LET A(S,T)=7
 60 NEXT T
 70 NEXT S
100 LET X=10
110 LET Y=1
120 LET S=X
130 LET T=Y
140 LET X=X-(INKEY$="7")+(INKEY$="6")
150 LET Y=Y-(INKEY$="5")+(INKEY$="8")
```



```
160 IF A(X,Y)=7 THEN GO SUB 200
170 PRINT AT X,Y;"O"
180 PRINT AT S,T;"b"
190 GO TO 120
200 LET X=S
210 LET Y=T
220 RETURN
```

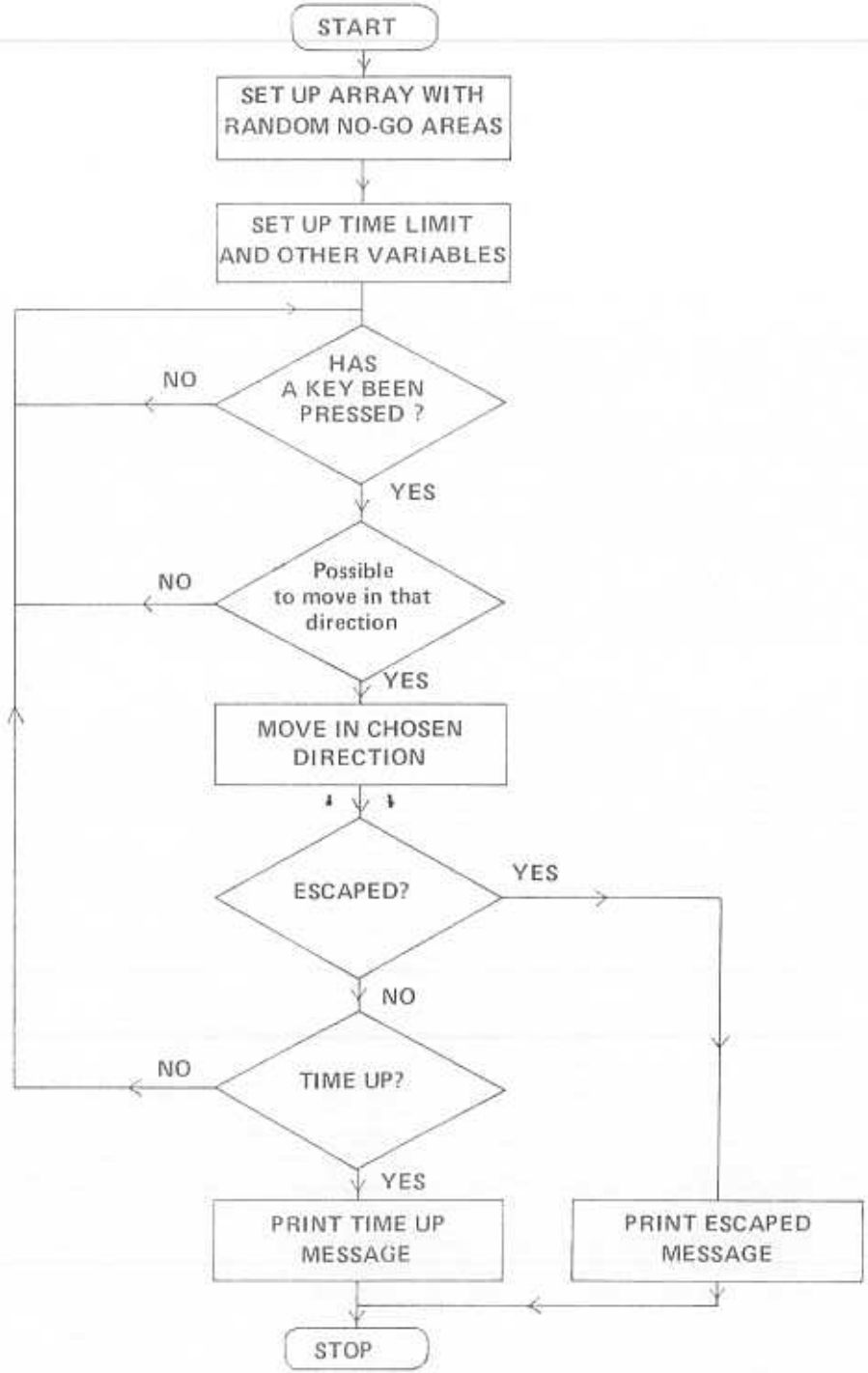
This program produces a screen full of random black squares. Once the flashing "O" has appeared, move about by using the arrow keys. No matter how hard you try you will be unable to move the "O" through a black square. This is how the program works.

Line 10	Sets up the two dimensional array.
Lines 20 to 70	Fills randomly chosen parts of the array with 7 and prints out the corresponding position on the screen.
Lines 100 to 110	Set up the starting position of the flashing "O".
Lines 120 to 130	Store the previous position of the flashing "O".
Lines 140 to 150	Input the new position for the "O" to go to.
Line 160	Finds out whether the new position of the "O" is a No-Go Area by looking at the corresponding position in the array.
Lines 170 to 190	Print the "O" and erase the old "O".
Lines 200 to 220	Return the flashing "O" to its old position if it is trying to pass a No-Go Area.

An interesting alteration to liven this program up can be made as follows:—

```
200 LET X=S-2
210 LET Y=T-2
```

Now everytime the flashing "O" reaches a No-Go Area it will bounce away from it. As we now have the two main techniques which form the basis of the game program we can now begin work on it. The diagram on the next page shows a general algorithm for the game in the form of a flowchart. It is around this that we shall write the Game Program.



This flowchart is not an algorithm for the complete game because we want a "Warder" to be able to chase the "Prisoner" through the "tunnels" and capture him. However this part of the program can be added later at the "Print Time Up" box. Box 1 carries out the same functions as lines 10 to 100 in the block program and can be broken down into the following sections.

a) Set up array
b) Set up initial variables (co-ordinates etc.)
c) Fill array with random flags (No-go areas)
d) Print out picture
e) Set up time limit

Up to this point we have reached Step 3, in the program – writing procedure, that is we have:–

DEFINED THE PROBLEM, this was our specification.

OUTLINED THE SOLUTION, the techniques needed to write the program, i.e. character movement and No-go Areas.

SELECTED AND REPRESENTED ALGORITHMS, such as the flow-chart and the sketch and block programs.

We have also carried out some coding, debugging and documentation in the process of outlining the solution. Coding of the actual game program can now be done as all of the boxes in the flowchart have been covered already.

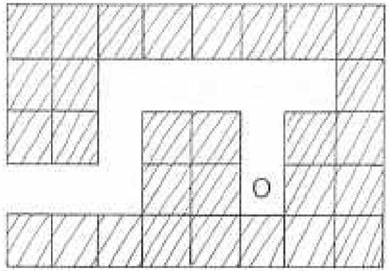
```
 10 REM ESCAPE GAME
 20 REM INITIALISE
 30 FAST
 40 DIM A(20,22)
 50 LET X=10
 60 LET Y=2
 70 LET C=0
 80 LET A$="O"
 90 REM FILL ARRAY
100 FOR I=1 TO 100
110 LET V=INT(RND*20+1)
120 LET D=INT(RND*20+1)
130 LET A(V,D)=7
140 NEXT I
150 REM PRINT PICTURE
```

```
160 SLOW
170 CLS
180 FOR I=1 TO 20
190 PRINT "bb▒▒▒▒▒▒▒▒▒▒▒▒▒▒▒▒▒▒▒▒
    ▒"
200 NEXT I
210 REM SETUP TIME LIMIT
220 LET TIME = INT(RND*200+1)
230 REM MOVING PRISONER
240 LET C=C+1
250 IF C>TIME THEN GO TO 500
260 LET K=X
270 LET P=Y
280 LET X=X-(INKEY$="7")+(INKEY$="6")
290 LET Y=Y-(INKEY$="5")+(INKEY$="8")
295 IF Y>20 THEN GO TO 400
300 IF A(X,Y)=7 THEN LET X=K
310 IF A(X,Y)=7 THEN LET Y=P
320 PRINT AT K,P;"b"
330 LET A(X,Y)=8
340 PRINT AT X,Y;A$
350 GO TO 230
400 PRINT AT 1,20;"YOUbHAVE"
410 PRINT AT 3,20;"ESCAPED"
420 GO TO 700
500 PRINT AT 1,20;"YOUbARE"
510 PRINT AT 3,20 ;"CAUGHT"
700 STOP
```

When this program is run the screen will clear for about five seconds while the initialisation and array-filling take place (lines 10 to 140). A large black square is then drawn on the left of the T.V. screen with a flashing "O" at the left edge. The flashing "O" represents the prisoner and the black square shows the ground through which he must dig to make his escape. Escape is achieved when he reaches the right hand side. You may have noticed that this program uses a slightly different method of filling the array than does the block program. In this program the density of No-Go areas can be chosen (here 100) by the size of the FOR NEXT loop in line 100. The "Tunnel" effect is created by the printing of blanks in line 320 which also causes the "O" to flash. Try making changes to the program, for example to the density of No-Go areas, the time limit, or adding boundaries to the top, bottom and left of the screen so that the program does not crash with a 3/300 error if

you go off the edge.

This game provides a good springboard for further expansions, however we said that it was our aim to incorporate a "Warder" to capture the prisoner. The warder has to either follow the exact course taken by the prisoner or work his way through the tunnels by following the array. Let us look at the second method first. The array used by this program so far contains 3 numbers; 0, 7, 8, which correspond to the screen display as shown below.



7	7	7	0	0	7	0	0
0	0	8	8	8	8	8	7
0	7	8	7	7	8	7	0
8	8	8	0	0	8	0	0
0	0	0	0	0	0	0	7

SCREEN DISPLAY

8 = Passage taken by "Prisoner"
7 = No go areas
0 = Areas which can be passed through

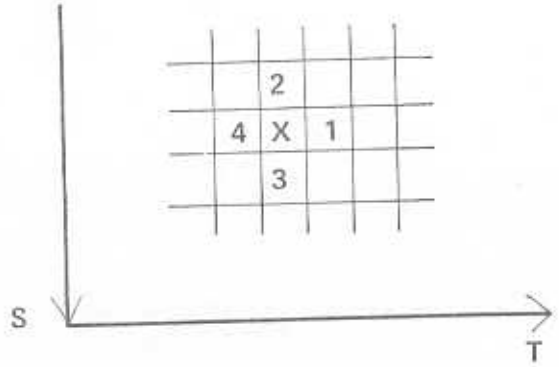
As the ZX81 will use the array to locate the position of the "Prisoner" the array must show where he is! This can be done by adding the line.

```
245 IF C>TIME THEN LET A(X,Y) = 9
```

Now as soon as the prisoners time is up his position is marked in the array by a "9".

The ZX81 (or warder) can now search from a starting position along the trail of "8"s in the array for the "9" (prisoners position). The computer not only has to search for the "9" but also "8"s so that it can follow a route made by the prisoner. To do this the computer has to search for an "8" or "9" in the squares adjacent to its present position.

Assume the "Warder" is at square X – he will search in the following way:



So to search from

X to 1	T = T + 1
1 to 2	S = S – 1 & T = T – 1
2 to 3	S = S + 2
3 to 4	T = T – 1 & S = S – 1

So that when the ZX81 has found an adjacent "8" it moves onto it and starts the search procedure again. Because this order of searching has been chosen, the "Warder" will tend to move right and up, rather than down and left. The coding to do this will look like this

```
500 REM CHASING WARDER
510 LET D = 7
520 LET S=10
530 LET T=1
540 LET F=S
550 LET G=T
560 LET T=T+1
570 IF A(S,T)<D THEN GO TO 1000
580 LET S=S–1
590 LET T=T–1
600 IF A(S,T)>D THEN GO TO 1000
610 LET S=S+Z
620 IF A(S,T)>D THEN GO TO 1000
630 LET S=S–1
640 LET T=T–1
650 IF A(S,T)>D THEN GO TO 1000
660 GO TO 560
1000 PRINT AT S,T;"X"
```



```
1010 PRINT AT F,G;"b"
1020 IF A(S,T)=9 THEN GO TO 1100
1030 GO TO 540
1100 PRINT AT 1,23;"GOT"
1110 PRINT AT 3,23;"YOU"
```

Because the same order of search is used by the "Warder" (right, up, down, left) it will occasionally become trapped. To prevent this from happening the search order can be randomised, though the "Warder" should be more inclined to move forward than to move backwards.

INDEX

(Program names in Italics)