June/July 1983

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SINCLAIR PROJECTS

THE MAGAZINE FOR THE SERIOUS SINCLAIR USER

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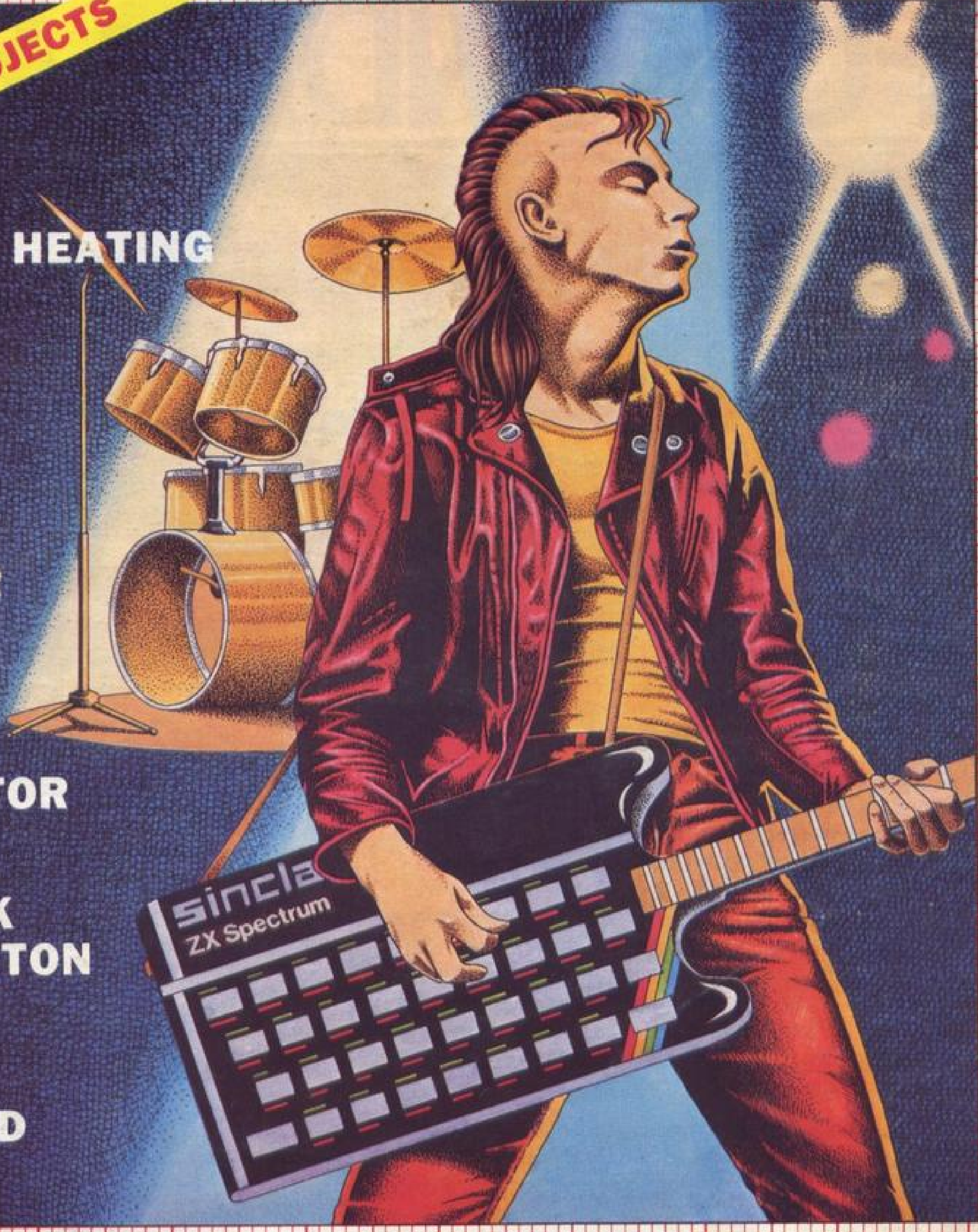

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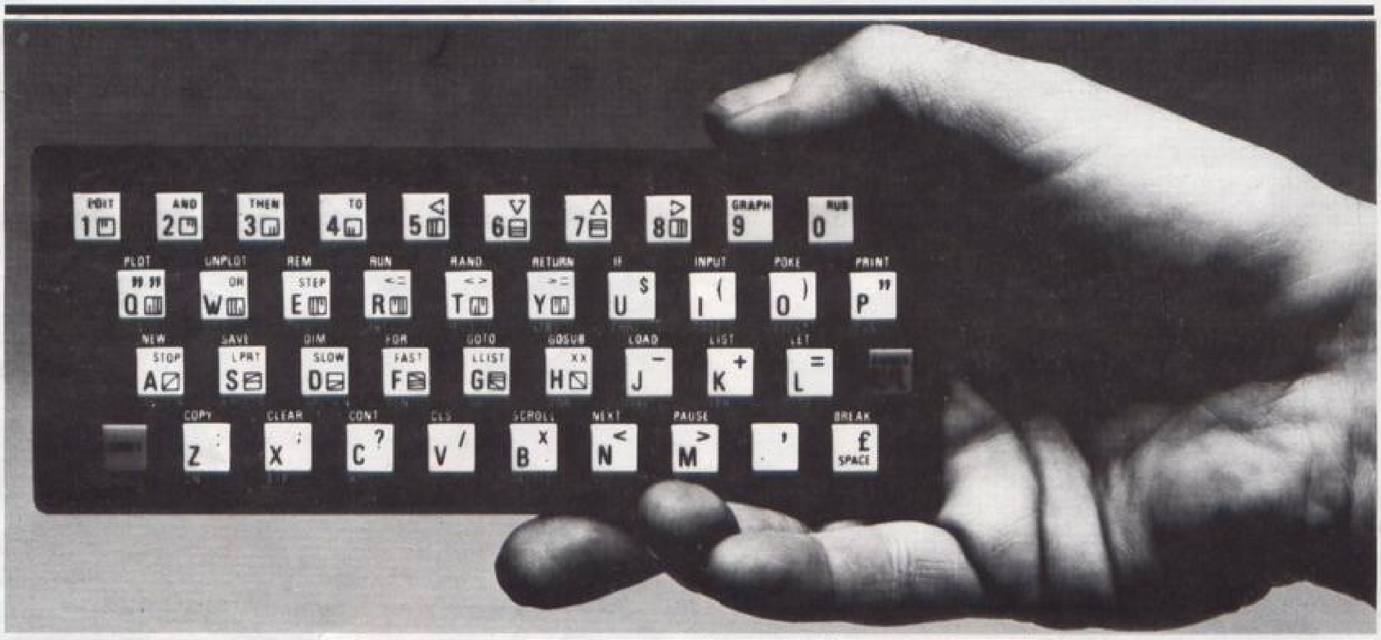

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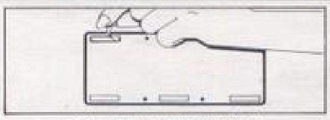
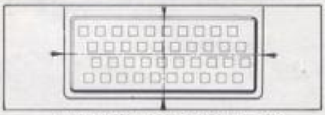


3. So all you do is remove the protective backing.



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SINCLAIR PROJECTS

FROM THE EDITOR

A VARIED collection of projects this month should appeal to a wide range of enthusiasts. At the simple level is the small load and save device from Trevor Hainsworth which should be a great help to all ZX-81 users who find difficulty with that most critical area of using the machine.

For people who prefer to expand the uses of their machine by software rather than hardware peripherals, we have a feature on graph plotting on the Spectrum. The program occupies 5K and can fit easily into the smaller Spectrum and allows a wide range of mathematical equations to be displayed in graph form.

The difficulty increases with three of our articles which are continuations from previous issues. John Mellor has provided two of them. The first is the second in his series on decoding, intended to give users a more thorough understanding of how their machines work so that they have more confidence in making their own projects. He has also written the second in the series on controlling your central heating with the ZX-81 on the Watchdog circuit.

For those who were looking for the project to be workable after this issue we thought it better to include the article before telling you how to link-up the full system for safety reasons.

As Mellor says in his article, when the ZX-81 is being used to control central heating it has to operate for long periods, thus increasing the danger of the microprocessors failing. If that happened, a fail-safe system is imperative to prevent damage to a central heating system.

The third continuation is the adding of the fire button to the joystick, one of the features in our first issue. The project, which adds a five-button pad to the joystick, can also be made as a separate unit.

Our sixth project improves the sound capabilities of the Spectrum. Many users have found the beep irritating. Now we show how a far wider range of notes and sounds can be achieved without too much difficulty.

In addition we have the regular pages of news, letters and problems answered by our expert writers.

We are always interested in what readers think of the magazine and the way it is developing. We have had a number of teething troubles but we will always be willing to help to solve difficulties which arise from our articles.

We are also interested in ideas for projects and articles. Anyone who wishes to submit articles should read the outline feature which offers guidance on how to present your work.

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NEWS

AGF interface can expand joystick use

AGF has now modified its joystick interface to accept standard Atari joysticks. The interface allows you to simulate the cursor keys on a Spectrum or ZX-81 plus a second set of keys for a second player.

Much software uses cursor keys and AGF provides some demonstration software with each unit so you can look for the cheapest joysticks which can be used on Ataris — there is a range from Le Stick to Competition Pro.

AGF sells the interface at £20 and the address is 26 Van Gough Place, Bognor Regis, West Sussex PO22 9BY. You should indicate which machine you have.

Improved printer

THE ZX Printer Spool solves a problem which bedevils Sinclair users. The aluminium spindle and two end-pieces are fitted to the paper roll and allow it to turn easily. The plastic ends on the printer are often loose and cause it to wander from side to side, preventing the printer motor pulling through the paper.

It solved the problem but only after tapping one end of the paper reel on a hard surface to get it back into line.

The results are much better printout, both for graphics and text, plus a great saving in printer paper.

The ZX Printer Spool costs £4 and can be obtained from Sadlers Developments, Sadlers, Vicarage Lane, Send, Woking, Surrey GU23 7JN.

Telford service

FOR £42.40, Telford Electronics and Computing will fit your ZX-81 into a Fuller 42-key keyboard and case. It will also add reverse video switch, re-set button, repeat key — on a separate key — and power-on LED. The price includes fitting and postage.

Optional extras include a monitor socket, joysticks and fitting the power pack and 16K RAM inside the case.

For more details, contact TEC at 26a Bradford Street, Shifnal, Shropshire TF11 8AU. Tel: 0952-46008.

New angle on Sinclairs

WARP FACTOR EIGHT sells the Hi-Stak, plastic blocks to raise a ZX-81 or Spectrum to an angle suitable for typing. They raise the Spectrum by about 30 degrees and stick on the bottom of the case at the back by double-sided sticky pads. They are a little expensive at £3.95 inc. VAT and postage but if you want to have style and do not wish to add anything at the back — the edge connector finishes 1½in. off the table and can cause wobble — use it.

Warp Factor Eight is at 6 Pelham Road, Braughing, Ware, Herts SG11 2QU. Tel: 01-452 7782.

NEWS

Keyword for better printing

LPRINT is not only a Sinclair keyword but the name of a printer interface for the Spectrum. The small black box, 2½in. by 2in., plugs into the expansion port on the Spectrum. Thereafter all LLIST and LPRINT commands are converted to a Centronics parallel interface on the back. By plugging-in a standard 20-way cable to its pins a standard plain-paper printer can be used.

Any Centronics printer can be used, as any graphics, user-defined characters and the like have to be programmed in by the user — each printer has ways of doing graphics and special characters. The instructions are so simple that they are printed on the bottom of the unit.

The same firm can also supply a tape with a program for using the COPY command. GP100 was used to reproduce every dot on the screen using a routine of only 76 bytes stored above RAMTOP.

A modification must be made before using LPRINT, as the printer would normally output a new line after every carriage return — ENTER — character. That facility must be removed so that it gives a new line only when the printer interface tells it to do so. The printer manual will undoubtedly cover that and there is a warning built into the COPY program. Sometimes all that is required is to throw a switch or insert a wire between two terminals.

The LPRINT graphics routine for COPYing the screen is its best feature. Its worst is that you cannot set the line length on LLIST, so it prints the line until it reaches the end of the line or exceeds the length of the printer paper.

The other thing about LLIST and LPRINT is that it ignores graphics and other non-recognisable characters. So a string with three graphics characters will print as an empty string — no spaces. It would be much better to print a space so that the graphics could be filled-in later by hand.

All the control for the printer is stored in a 2K ROM inside the box along with seven ICs. No user RAM is used unless the COPY command is required.

The LPRINT module costs £41.40, plus the printer cable at £12.08. The COPY tape costs £5. Euro-electronics is at 29 Clarence Square, Cheltenham, Gloucester. Tel: 0242-582009.

Filesixty buttons can improve the keyboard

THE FILESIXTY button set is cheaper than a real keyboard and yet offers the same advantages. The keys move and the Sinclair keyboard has a positive keypress. The button set is the same size as the Sinclair keyboard and is stuck over the top of it with double-sided sticky tape. It does not invalidate the guarantee, require soldering, or need you to go inside the case.

The buttons have on the underside a nylon flap with a knob on it. The knob is centred over the Sinclair key and when not being pressed holds the button above the keyboard. When the button is pressed the key moves down about 2mm. and the knob strikes the keypad. That works very well.

The keyboard has a black surround to blend with the ZX-81 and the keys are nearly all white with black lettering, making them easy to see. The number keys are coloured blue, SHIFT and NEWLINE keys orange. The keys are only 8mm. square, which makes them easy to use.

The graphics on the keys, however, have been changed, so that solid blocks of black are represented by lines indicating the area covered. That and the fact that some of the key symbols have been changed may create initial difficulty but should be no problem after use for a week or so. The cost of the Filesixty button set is £10 and it should last as long as the Sinclair keyboard. Filesixty can be obtained from Fox Electronics, 141 Abbey Road, Basingstoke, Hampshire RG21 9ED and some shops.

NEWS

Spectrum Centronics interface

KEMPSTON MICRO-ELECTRONICS has produced a Centronics printer interface which plugs on the back of the Spectrum. There is nothing spectacular in the box as it is an 8255 chip used as a port to access the printer cable.

The printer cable is a full 35-way type and is about one metre long. The plug at the end which fits on the printer seemed a little too thick to put the securing clips around but it was a tight fit in the socket.

All the hard work is done in 650 bytes of machine code stored above RAMTOP; a different program is provided for each computer. That may seem a great deal but the accompanying Basic program allows you to specify a number of options on the printer. Once those options are set, the program will save the machine code only to allow you to use all the rest of the RAM yourself.

Line length, changing the character codes for individual characters, special features such as the line feed and carriage return, can be set in software. All those commands effect only LPRINT and LLIST as COPY is ignored.

Any of the options can be ignored by pressing ENTER in response to the question. In that way a printing routine can be personalised and if, say, the line length is limited to 32,LLIST would produce a duplicate of that listed on the screen.

Hilderbay, the company which produced it, must be congratulated on providing a fine, easy-to-use piece of software.

The only way to COPY a screen suggested in the instructions is to use the Basic Point command in a loop to assemble the required graphic bytes to put out to the printer. That is useful but slow and the routine applies only to Epson printers. Looking through the printer manual is the only answer if you do not have one of those.

A machine code program for at least two of the popular printers to simulate, if not use the COPY command, would have been useful. That seems preferable to the LPRINT, as it allows you control of the printer with as much ease as possible.

The printer interface costs £45 and is available from Kempston Microelectronics, 180a Bedford Road, Kempston, Bedford MK42 8BL.

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LETTERS

Radio-teleprinters need for Spectrum

Our previous issues have generated plenty of interest and many queries. In this month's letters page David Buckley answers some of the problems you have had.

I HAVE been reading the article in the second edition of *Sinclair Projects* covering the use of the ZX-81 as a radio-teleprinter. As I will soon be the owner of a 48K Spectrum, I am interested in using this set-up.

P Hollingsworth,
Warrington,
Cheshire.

● *The conversion is too lengthy to detail on the letters page but if anybody wishes to submit on article on the changes necessary, please contact the Editor.*

Lack of detail

I BOUGHT *Sinclair Projects* for the radio teleprinter article. Although no expert in electronics, I have been successful in constructing items for the ZX-81 but I was disappointed as there seems to be a lack of detail compared to other projects. In particular, I am having problems with:

Audio to logic level conversion — the article does not explain how it is to be constructed but merely refers to another publication. I felt somewhat let down by that discovery, as I did not expect to have to buy another magazine to complete the project.

In figure three, for what are the optional ICs 74365?

There are no details of wiring and layout of connections on the Veroboard.

In my opinion your magazine is a useful addition to the market but I feel that the projects will have to be set out in more detail if they are to appeal to the majority of Sinclair users.

C E Davis,
Maidenhead,
Berkshire.

● *The circuitry required to convert the incoming audio tones into logic levels would be a complete project in itself and many libraries hold back issues of technical and hobbyist magazines which may be photocopied for personal use.*

Issue 2 page 8 gave the reason for the optional 74365 ICs. The interchip wiring on the Veroboard is a little more complex than a few straight links but can easily be carried-out using insulated wire, in the manner of the Latch Card project in issue one and by following the circuit diagram, figure seven.

Combination

WITH REFERENCE to the ZX-81 projects on pages 12 and 34 of the February/March issue, will you please consider combining them in a future issue to show how a teleprinter can be used as a printer for the ZX-81?

Such information is available for the Nascom, UK-101, Superboard, Triton and Acorn Atom computers.

R Idiens,
Marlow, Bucks.

● *Has anybody done this who is willing to write about it?*

Keep it simple

I AM interested in *Sinclair Projects* but two matters bother me. First, how technical are the projects? Do they need test equipment to set up before operating? I can solder and would call myself handy at DIY projects but with little technical background — only O level physics.

Second, how many projects are solely for the Spectrum, which I own, as I have seen projects for the ZX-80 and ZX-81 which can be adapted but I want easy-to-follow projects for the Spectrum, with no adaptations.

I J Le Tissier,
St Sampsons,
Guernsey, CI.

● *We intend to keep the projects within the abilities of the average hobbyist, so the only test equipment needed, if at all, for the majority of projects will be a simple multimeter. We hope to maintain a balance between projects for the ZX-81 and for the Spectrum and, because of the higher cost of the Spectrum, most of them will simply plug in the back.*

Latch card

IN YOUR Latch Card article, Dave Buckley wrote that the address is 36850 but I think that is only for the ZX-81 with a 64K RAM pack. I have only the ZX-81 with a 16K RAM pack and I cannot POKE the address 36850.

Mike Werner,
Dortmund,
West Germany.

● *The Latch Card will work with either the standard ZX-81 with 1K RAM or expanded with up to 19K RAM. It will not work with a 64K RAM pack. See the reply to Martin Hunt regarding updates to the Latch Card article.*

Error pinned

IN YOUR first issue I was interested to see a project for a Latch Card. Even though I am something of a novice at electronics I decided to try this circuit and then to build the Power Card circuit to go with it.

I have bought most of the components for the circuit but when I looked more closely at the ZX-81 wiring schedule it says to connect pin 9 of the 74LS133 to pin 15 of the 74LS04; the 74LS04 only has 14 pins on it.

As you had not printed a proper circuit diagram for the project I had no way of knowing what the wiring schedule should be.

Apart from that unfortunate error I found the articles on how to solder, and on tools to use, very interesting and informative.

Martin Hunt,
York.

LETTERS

• You found an error nobody else seems to have noticed. Pin 15 should, of course, read Pin 13. Issue 2, pages 47 and 48, and Issue 3, page 17, contain some updates to the Latch Card and Power Card projects.

ZX printer

I FOUND the article on the ZX printer of interest but would like to point out that the pin-out list is incorrect. The only connections are D0, D1, D2, D6, D7, A2, IOREQ, RD, WR, 0V, +5V, +9V; the main point to note is that the printer is addressed with "out 251" which is accomplished with by address line "A2" being taken low; any out address which takes A2 low will operate the printer.

With the joystick controller, addressing makes use of lines A5, A6, A7, for "out 255".

While using the controller I also had a ZX printer connected, with strange results. Out 251 from ROM command to printer also puts A5, A6, A7, high operating joystick.

D7 on printer receives squarewave which tells the stylus when to print. D7 on joystick also gives out a square wave on D7 and in spite of one being on a read cycle and one on a write cycle, the joystick seems to operate the stylus print.

That can be cured by changing any joystick address lines to A2 — high joystick, low printer.

R M Moore,
Romford, Essex.

Logic circuit

I BELIEVE your magazine is an excellent idea for the computer hobbyist. I am sure that many amateurs like myself find logic circuits and circuits using ICs confusing, especially when many IC pins are shown unconnected.

I feel that a Digital Electronics for Beginners series would prove extremely popular.

Jack Anderson,
London NW2.

• If any readers feel that they are able to write for Sinclair Projects *on this or any other suitable project, please read the author guide in issue 3 page 45 and write to the editor with an outline of your idea.*

Graphic board

AT THE BEGINNING of August, 1982 I bought a ZX-81; two months later I bought the Memotech 16K RAM pack.

I bought the December/January issue of *Sinclair Projects,* in which it describes how to make and attach a user-definable graphics board. A friend qualified in electronics built and attached it. After following the instructions carefully he put the computer on — no cursor appeared — and the screen flashed and jolted rapidly.

According to the magazine nothing was wrong. The magazine says, 'The ROMCS line-pin 23B of edge connector — must be connected to the ROMCS input of the CHR$ logic circuit'. He thinks that is incorrect. Also when it says 'The ROMCS output from the CHR$ logic circuit must be connected to the ROM ROMCS terminal-pin 20 of the ROM 1C,' he wonders if that pin should be isolated.

Paul Carpenter,
Harrow Weald,
Middlesex.

• See the suggestions on page 16 of the April/May issue.

Joystick

I HAVE decided to build the Spectrum joystick control. I have one or two queries:

Is figure five (edge connections) correct? In the Sinclair manual IORQ is shown at pin 17 and RD is shown at pin 18, not as you show; which is correct? Are the rest of the pins correct? They appear so.

Is the overlay in figure four correct?

Is the Vero cutting drawing correct?

In figure 2b, should pins b & c be transposed?

B. Walton,
Whitley Bar,
Tyne and Wear.

• In figure five, IORQ and RD are transposed; the correct edge connect or diagrams are always given at the back of the magazine.

The Vero cutting diagram is correct but the numbering along the top should read 30 to 1 rather than 1 to 30. Using the printed numbering there is an indistinct track break at row 13 column 22.

The component overlay needs some corrections. To do this, first draw in all the grid lines, using a pencil. IC1 should be moved down half a row. The link in column 11 from row 1 should stop at row 2. The bottom ends of R3 and R4 should stop at row 14 and the top ends of C3 and C4 should go up to row 14.

In figure 2b, pin 'b' is incorrectly labelled pin 'c' and vice versa. Pin 'c' should then be moved three holes to the right and pin 'a' half a hole to the right.

RAM project

I HAVE recently completed the Spectrum Joystick project and, having used your demonstration program, find that it works exactly as it should.

My problem, however, is when trying to use it in existing programs I have a few queries.

When using lines 10–60 and subroutine 1100 and 1130, as in your given program, is it necessary to delete any existing movement routines?

When using the joystick program, will it work only with a simple command, i.e., if INKEYS $="5" THEN LET A=A+1 or will it work with complex routines, such as LET UX =UX+(U$="8" AND UX(29)−U$="5" AND UX=>2)?

I have tried it in some programs with and without existing movement routines; sometimes the program crashes and at other times I get the report of E — OUT OF DATA 20:1 (READ n: POKE a, n).

B Walton,
Whitley Bay,
Tyne and Wear.

• Lines 10 to 60 POKE a machine code routine into RAM starting at address a=32550. It is important that this area of RAM is first protected from Basic by entering CLEAR 32549. When lines 10 to 60 have been run they have served their purpose and may be deleted. The machine code may be SAVEd to tape by SAVE "name" CODE

LETTERS

32550, 43. The machine code routine is called from Basic by USR 32550 in line 1100 of the 1000 to 1130 subroutine. The joystick X position is left in the variable b and the y position is left in the variable c. Variable a is also used.

After the program returns from the subroutine, it is for you to decide what to do with the variables b and c; for example, you may use them as values in a PLOT statement to draw lines.

If you receive the out of data error message, you must have omitted one of the numbers in the DATA statements. Lines 40 to 60 should contain 43 numbers.

RS232

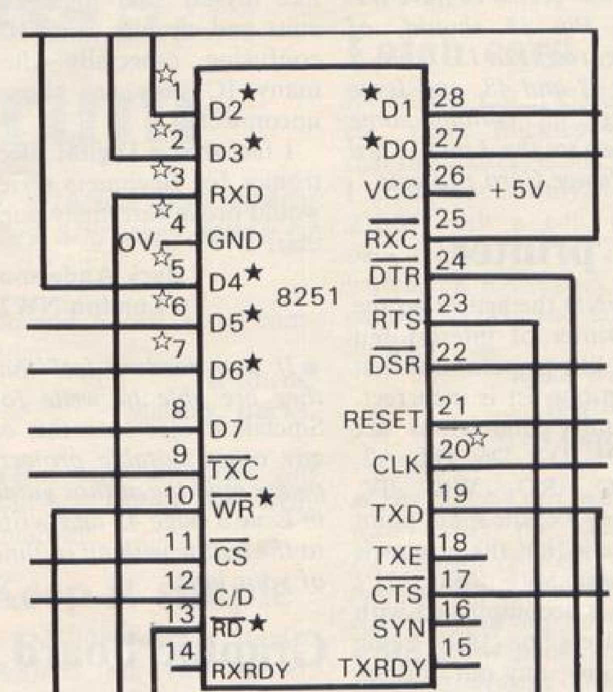
BECAUSE I am working in this field for a PhD unfortunately the circuit diagram for the Spectrum RS232 is not good enough for me

In figure two, page 30–31, I could not understand where we should connect points D0-D7 and Ck, $\overline{RD}$, ..., 20 and also $\overline{A6}$, $\overline{A7}$, $\overline{IORQ}$ & $\overline{A5}$.

H. Jahankhani,
London NW11.

● *D0–D7, CK, $\overline{RD}$, $\overline{WR}$, $\overline{IORQ}$, RESET, A7, A6, A5 should go to the edge connector which plugs in the back of the Spectrum. The numbered connection points 2, 5, 6, 7, 3, 4, 20, 1 go to those numbered pins in the D type connector. See also the Updates section.*

Detail Spectrum RS232



UPDATE

Second impressions

February/March, **Money Maker,** page 7.

220 GOTO 220 + 5* (INKEY $ = "Y") − 130 * (INKEY$ = "N")

930 PRINT , , N $, , , P $, , , , , "OPTIONS: − " , , , "1. REPEAT PRINTOUT",,,"2. SAVE ON TAPE" , , , "3. MODIFY THE DATA" , , , "4. STOP"

February/March, **Machine Code Guide,** page 30.

The machine code numbers which should have appeared in figure one are:

0,0,38,64,46,130,126,35,166,119,201

In figure four, there are some repeated lines which might cause confusion. Two errors are:

210 GOSUB 4300
405 GOSUB 4300

Two additional changes are required to the program in listing 2 for use on the Spectrum; they are:

1050 LET X = 16 * (CODEZ $ − (7 * (Z $ (1) > "9") + 48)) + CODEZ $ (2) − (7 * (Z $ (2) > + 48)

1120 LET H = INT(X/16):LET L = X − 16 * H: LET Z $ = CHR $ (H + 48 + 7 * (H > 9)) + CHR $ (L + 48 + 7 * (L > 9))

April/May, **Central heating article:** Diagram, pages 24 and 25:

IC7 74LS132 should be 74LS138; IC1 ZN477 should be ZN447; IC1 which should be ZN447 is variously referred to as ZN477 and ZN447.

Spectrum RS232: diagram, page 31— ¼ 7400 should have an open circle at pin 3 to denote signal inversion and a & in the box to signify an AND gate. Page 30: PORT 73F = CMND (A7 + A6 + A5) should read PORT 73F → CMND ($\overline{A7, A6, A5}$). PORT 71F = DATA (A7 + A6 + A5) should read PORT 71F → DATA ($\overline{A7, A6, A5}$). A6,A7 by ¼7432 should read $\overline{A6}$, $\overline{A7}$, ¼7432 blocks should both have 1 in the block to signify an OR gate.

Page 31: all ¼75188 blocks should have a & in the block to signify an AND gate; 75189 power connections are omitted — pin 14 +5V, pin 7 0V; 75188 power connections are omitted and pin numbering is incorrect — pins 1, 2, 3 should read 13, 12, 11 respectively — pin 1 −9V, pin 14 +12V, pin 7 0V.

Decoder: page 39, figure six: Inside SLC should be title of figure. Page 40, figure five: At 48K, 2000 should read C000; 49252 should read 40151; at 16K, 1683 should read 16383; at 8K the lower 8192 should read 8191.

GRAPH PLOTTER

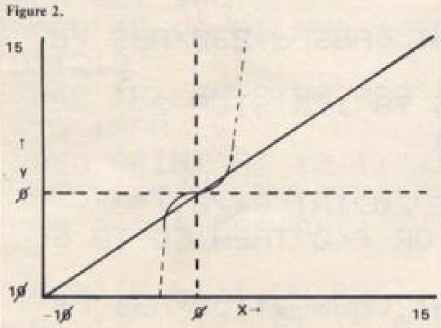
Using the Spectrum as a display aid for complex graphs

The Spectrum graphics allow it to plot realistic graphs of mathematical equations. Brian Lee has prepared this program which allows a wide range of equations and values to be represented in an easy-to-understand form.

FOR O LEVEL mathematics students, or anyone with a general interest in mathematics, the reasonably high screen resolution of the Spectrum makes it possible to plot realistic graphs of mathematical equations.

A program to do this is listed. It requires 5K of memory plus about 1.2K for the variables, so will fit easily in the 16K Spectrum. The program will plot graphs of the form $y=f(x)$, i.e., $y=\mathrm{Sin}\ x$, $y=3x^2+2x-4$, and the like. It will handle virtually any function over a wide range of x values, both positive and negative, and will scale the x and y values independently to make full use of the screen area available. The x and y axes are drawn in their appropriate positions and the maximum and minimum values labelled. If desired, a second graph may be plotted over the first, to the same scale. For trigonometric functions the user may enter the required range of x in radians as PI, multiples of PI, or any fraction of PI down to PI/16—but not PI/3—

Figure 2.

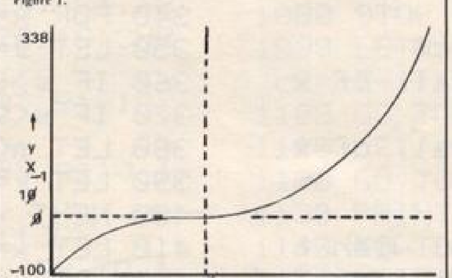


and the axis will be labelled accordingly.

After typing-in the program and before running it, save it on tape using SAVE "name" LINE 1500. The program will then run automatically after loading but to run it for the first time after typing it in, first GOTO 1500.

On running the program you are

Figure 1.



first asked to enter f(x) and since the Spectrum becomes confused when faced with evaluating such things as x↑2 where x is negative, it is always better to use the form x*x and the like. The range of x is next established by entering the minimum and maximum values as prompted.

If a second graph is required, enter the function of x when requested. Due to the slow Basic, the screen will remain blank for a short time before the graph is plotted, the time depending on the complexity of your equation. If a second function is entered, another delay will occur before the graph appears.

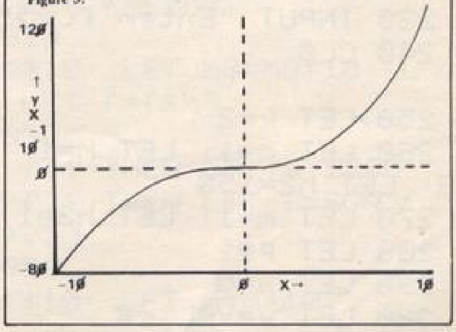
The shape of the graph is accurate to one pixel in any direction, that being the limit of the Spectrum system. Obviously if there was a higher screen resolution, the graph shape could be made much more accurate. In calculating the maximum and minimum values of y, some compromise is necessary to produce a reasonably accurate result and at the same time label the graph with the results in a neat, presentable manner.

In view of the wide range of values possible with a program of this nature, it is sometimes necessary to scale the values to fit them at the edge of the display and lines 1510 to 1560 of the program, together with the data in line 1500, produce a set of indices from -9 to 9. They are used to label the x and y scales in conventional scientific notation i.e., $y \times 10^2$, as opposed to the E notation of the computer.

It should be borne in mind that when two graphs are to be drawn, the first one entered will determine the x and y scales and the second will be drawn to the same scales. That means, for example, that if the first graph represents $y=x^3$ for $x=-10$ to 15, the result will be as in figure one.

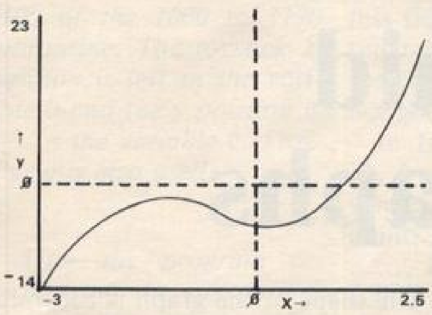
If the second function is $y=x$, that

Figure 3.



GRAPH PLOTTER

Figure 4.



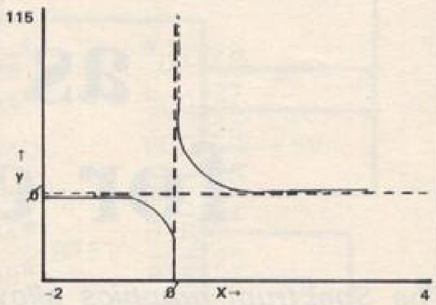
will appear as a horizontal line coincident with the x axis, since the maximum value of y, 15, will not be resolved on a y scale which spans a range of 0 to 3000. Drawing the graphs in the reverse order would result in a display as in figure two. Notice how that has limited the range of y for the x^3 function.

Consider the equation $y = x^3 + 2x^2 - 5$. If that is plotted for $x = -10$ to 10, the result is shown in figure three. That part of the curve running along the x axis could be examined more closely by running the program again for the same equation, but for $x =$ -3 to 2.5 that would result in the curve in figure four.

If you ask the computer to evaluate 1/0 it will report "number too big" because one divided by nought is infinite. Similarly, if you enter $y = 1/x$ as your function over the range $x = 0$ to $x = 4$, you will obtain the same result. Try, however, $y = 1/x$ for $x = -2$ to 4. The result is shown in figure five. Notice the maximum y value of 115 and the minimum value, -58. The values of x which correspond to them are 0.0087 and -0.0172. In other words, the computer has conveniently skipped over the point $x = 0$.

In the program listing it can be seen

Figure 5.



that the range of x (d to e) is divided into equal steps and a value for y calculated at each step. Line 330 gives the step size and it can be seen that it is extremely unlikely that any step of x will be exactly zero, or any integer value. It is for the same reason that it is possible to plot y = Tan x, despite the fact that Tan PI/2 is infinite.

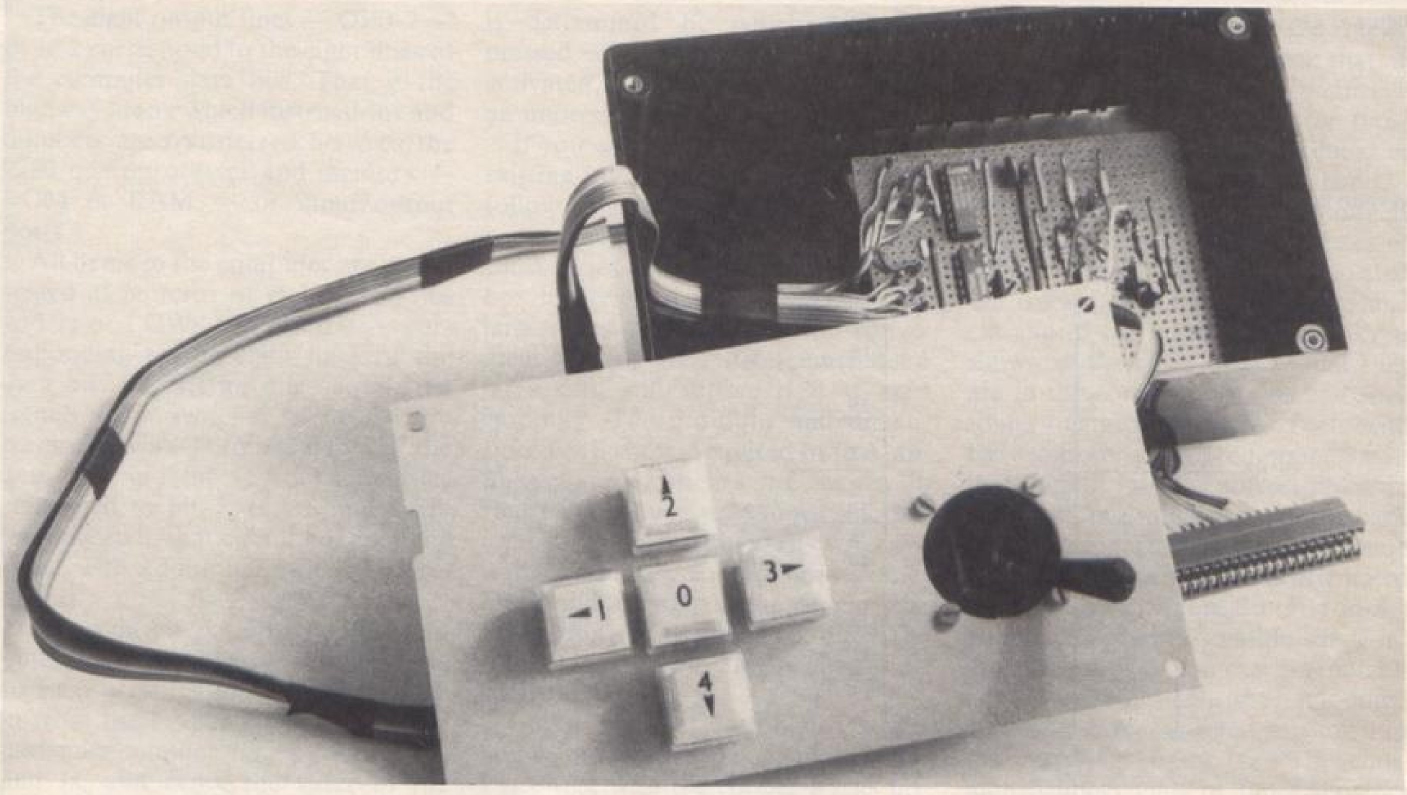
```
 100 CLS
 110 BORDER 0: PAPER 0: INK 7: O
VER 0
 120 DIM n(231)
 130 INPUT "Enter f(x)",c$
 140 INPUT "Enter min. val. of x
",d
 150 INPUT "Enter max. val. of x
",e
 160 LET z=0
 170 PRINT AT 8,2;"Do you wish t
o plot a second";AT 10,6;"functi
on of x ? y/n"
 180 PAUSE 0
 190 IF INKEY$="" THEN GO TO 190
 200 IF INKEY$="n" THEN GO TO 24
0
 210 IF INKEY$="y" THEN CLS : LE
T z=1
 220 LET d2=d: LET e2=e
 230 INPUT "Enter f(x)",m$
 240 CLS
 250>LET k=2
 260 LET c=1: LET h=1: LET c2=15
3: LET h2=153
 270 LET m=1: LET h3=1
 280 LET p=1
 290 LET x=d
 300 LET y=VAL c$
 310 LET f=y: LET g=y
 320 LET n(1)=y
 330 LET s=ABS (e-d)/230
 340 FOR x=d+s TO e STEP s
 350 LET y=VAL c$
 360 IF y>f THEN LET f=y
 370 IF y<g THEN LET g=y
 380 LET n(k)=y
 390 LET k=k+1
 400 NEXT x
 410 LET x=e
 420 LET y=VAL c$
 430 IF y>f THEN LET f=y
 440 IF y<g THEN LET g=y
 450 LET n(231)=y
 460>LET f2=f: LET g2=g
 470 PLOT 24,175: DRAW 0,-159: D
RAW 231,0
 480 IF d>=0 OR e<0 THEN GO TO 5
40
 490 LET a=INT (ABS d*230/ABS (d
-e))+24
 500 FOR b=16 TO 175 STEP 2
 510 PLOT a,b
 520 NEXT b
 530 PRINT AT 20,INT (a/8);"0"
 540 IF g>=0 OR f<0 THEN GO TO 6
10
 550 LET b=INT (ABS g*159/ABS (f
-g))+16
```

GRAPH PLOTTER

```
 560 FOR a=24 TO 255 STEP 2
 570 PLOT a,b
 580 NEXT a
 590 IF b=0 THEN PRINT AT 21,2;"
0"
 600 IF b<>0 THEN PRINT AT INT (
(176-b)/8),2;"0"
 610>LET a=24
 620 FOR k=1 TO 231
 630 LET b=INT (ABS (n(k)-g)*158
/ABS (f-g))+17
 640 IF b>175 THEN LET b=175
 650 PLOT a,b
 660 LET a=a+1
 670 NEXT k
 680 IF e=0 THEN GO TO 730
 690 LET r=e/PI
 700 IF LEN STR$ r<=7 THEN GO TO
 1370
 710 IF ABS e>=1000 THEN GO TO 1
090
 720 IF ABS e<.001 THEN GO TO 11
10
 730 PRINT AT 20,3;d*c
 740 LET t=LEN STR$ e: PRINT AT
20,32-t;e
 750 IF c<>1 THEN PRINT AT 21,12
;"x X 10 ";CHR$ 153;AT 20,18;CHR
$ c2
 760>IF c=1 THEN PRINT AT 21,12;
"x ";CHR$ 153
 765 IF ABS f<.01 AND ABS g>10 T
HEN LET f=0
 770 IF f=0 THEN GO TO 1130
 780 IF ABS f>=1000 THEN GO TO 1
150
 790 IF ABS f<.01 THEN GO TO 117
0
 800 LET g=g*h
 810 IF ABS g>=1000 THEN GO TO 1
190
 820 IF ABS g<.01 AND ABS f>10 T
HEN LET g=0
 830 IF g<.01 AND g<>0 THEN GO T
O 1210
 840 IF LEN STR$ ABS f>3 THEN GO
 TO 1230
 850 PRINT AT 12,1;"y"
 855 LET t=LEN STR$ ABS f: PRINT
 AT 0,3-t;ABS f

 860>IF h<>1 OR h3<>1 THEN PRINT
 AT 13,1;"X";AT 15,0;"10";AT 14,
2;CHR$ h2
 870 IF f>=0 AND g<0 THEN PRINT
AT 18,0;"-"
 880 IF f<0 THEN PRINT AT 12,0;"
-"
 890 PRINT AT 11,1;"^"
 900 IF LEN STR$ ABS g>3 THEN GO
 TO 1300
 910 LET t=LEN STR$ ABS g
 920 PRINT AT 19,3-t;ABS g
 930 IF z<>1 THEN STOP
 940 LET k=1
 950 FOR x=d2 TO e2 STEP s
 960 LET y=VAL m$
 970 LET n(k)=y
 980 LET k=k+1
 990 NEXT x
1000 LET a=24
1010 FOR k=1 TO 231
1020>IF n(k)>f2 OR n(k)<g2 THEN
GO TO 1060
1030 LET b=INT (ABS (n(k)-g2)*15
8/ABS (f2-g2))+17
1040 IF b>175 THEN LET b=175
1050 PLOT a,b
1060 LET a=a+1
1070 NEXT k
1080 STOP
1090 LET e=e/10: LET c=c/10: LET
 c2=c2-1
1100 GO TO 710
1110 LET e=e*10: LET c2=c2+1
1120 GO TO 720
1130 PRINT AT 2,0;"0"
1140 GO TO 810
1150 LET f=f/10: LET h=h/10: LET
 h2=h2-1
1160 GO TO 780
1170 LET f=f*10: LET h=h*10: LET
 h2=h2+1

1180>GO TO 790
1190 LET g=g/10: LET h3=h3/10: L
ET h2=h2-1: LET f=f*h3
1200 GO TO 810
1210 LET g=g*10: LET h3=h3*10: L
ET h2=h2+1: LET f=f*h3
1220 GO TO 830
1230 IF ABS f<1 THEN GO TO 1260
1240 IF ABS f>1 THEN LET f=SGN f
*INT (ABS f+.5)
1250 GO TO 850
1260 LET f=f*10: LET m=m*10
```

GRAPH PLOTTER

```
1270 IF ABS f<1 THEN GO TO 1260
1280 LET f=INT (ABS f+.5)/m*SGN
f
1290 GO TO 850
1300 IF ABS g<1 THEN GO TO 1330
1320 GO TO 910
1330 LET g=g*10: LET p=p*10
1340 IF ABS g<1 THEN GO TO 1330
1350>LET g=SGN g*INT (ABS g+.5)/
p
1360 GO TO 910
1370 LET a=e/PI
1380 LET t=LEN STR$ a
1390 PRINT AT 20,30-t;"PI"
1400 IF d=0 THEN PRINT AT 20,3;d
/PI;"PI"
1410 IF d<>0 THEN PRINT AT 20,3;
d/PI;"PI"
1420 PRINT AT 21,10;"x Rads. ";C
HR$ 153
1430 GO TO 770
1500>DATA 0,0,0,6,9,239,1,14,0,0
,0,6,9,230,9,6,0,0,0,15,1,226,4,
8,0,0,0,6,8,238,9,6,0,0,0,15,8,2
38,1,14,0,0,0,8,8,234,15,2,0,0,0
,14,1,239,1,14,0,0,0,6,9,226,4,1
5,0,0,0,4,4,228,4,4,0,8,4,2,255,
2,4,8,0,0,0,0,0,0,0,0,0,0,96,1
44,32,64,240,0,0,0,224,16,240,16
,224,0,0,0,128,128,160,240,32,0,
0,0,128,128,160,240,32,0,0,0,240
,128,224,16,224,0,0,0,240,128,22
4,16,224,0,0,0,224,128,224,144,9
6,0,0,0,240,16,32,64,128,0,0,0,9
6,144,96,144,96,0,0,0,96,144,112
,16,224

1510 LET a=PEEK 23675+256*PEEK 2
3676
1520 FOR b=a TO a+151
1530 READ d
1540 POKE b,d
1550 NEXT b
1560 GO TO 100
```



Fire button adds new power to our joystick

In our first issue David Sanders built a joystick interface for the Spectrum. In this second article he describes how to add a simple five-key pad to the interface or make it as a separate unit.

THOSE WHO BUILT the joystick interface for the Spectrum described in the first issue of *Sinclair Projects* may have found that some extra functions, such as a FIRE button, would be useful. A simple five-key keypad can be built as a separate unit for around £10 or can be added to an existing joystick interface for less than £5. The circuit, which is simple to build, consists of two integrated circuits, five key switches and a resistor pack, and is powered from the Spectrum power supply via the edge connector.

In functional terms, the keypad consists of two parts — a key switch assembly which generates a code determined by which switches are pressed, and an interface which feeds that code to the computer. The keypad is made from five push-to-make switches arranged in the form of a cross on the box lid — see photograph. One contact of each switch is connected to ground — 0V — and the other is connected via a 4.7kohm resistor to the +5V supply — figure one, switches S0–S4.

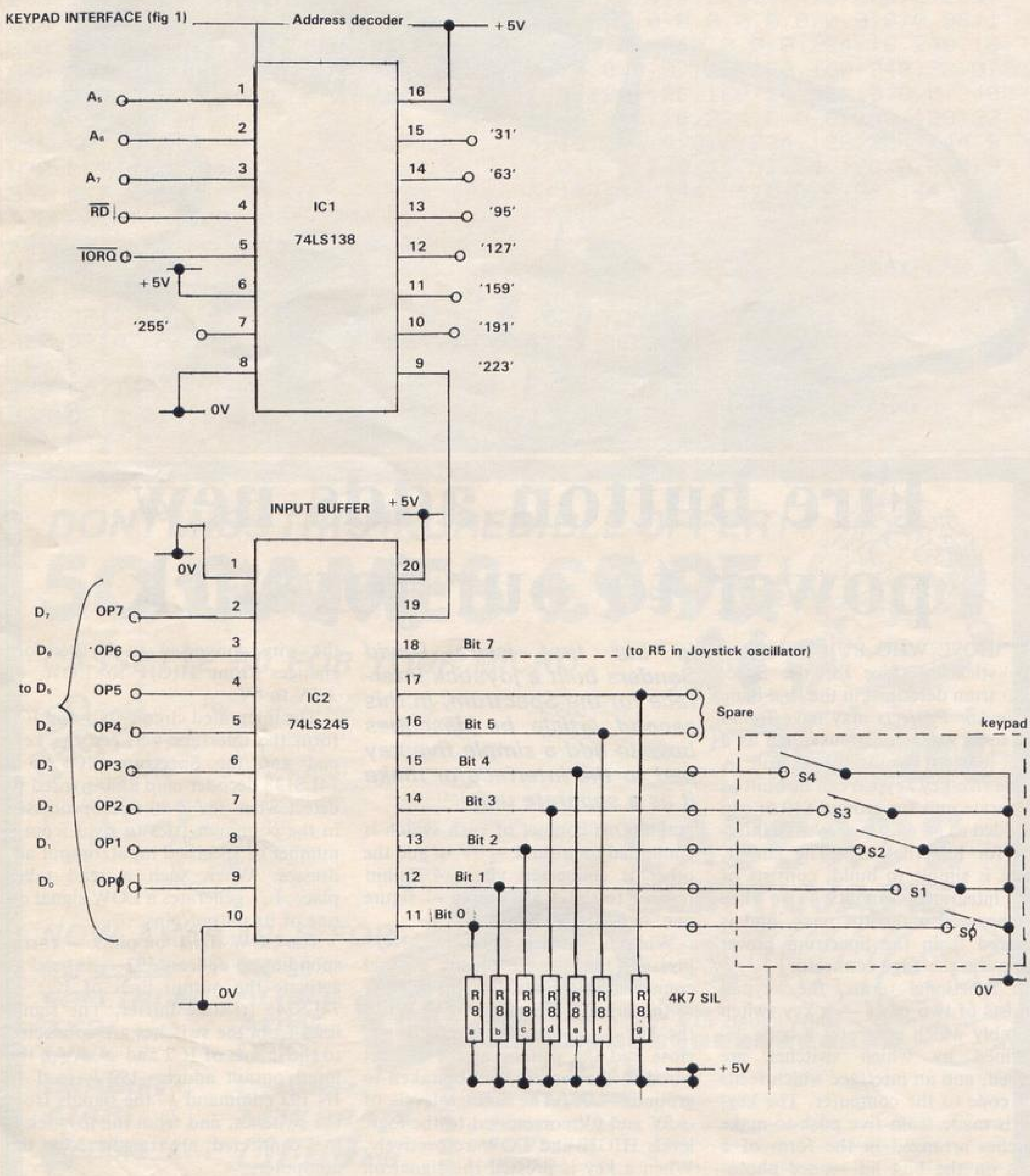
While a switch is open, i.e., NOT pressed, the voltage at the contact connected to the resistor will be close to the supply voltage of +5V. When the key is pressed the contacts will close and the voltage at the contact wired to the resistor will be taken to ground — 0V. The voltage levels of +5V and 0V correspond to the logic levels HIGH and LOW respectively. When a key is pressed the signal on the wire connected to it therefore changes from HIGH to LOW — +5V to 0V.

The integrated circuits IC1 and IC2 form the interface between the keypad and the Spectrum. IC1 is a 74LS138 decoder chip and is wired to detect when the Z-80 microprocessor in the computer tries to read from a number of specified input/output addresses. When such a read takes place, IC1 generates a LOW signal on one of its output pins.

The LOW signal on pin 9 — corresponding to address 192 — is used to activate the output lines of IC2 — 74LS245 tri-state buffer. The signal lines from the switches are connected to the inputs of IC2 and so, when the input/output address 192 is read — IN 192 command — the signals from the switches, and from the joystick if it is connected, are transferred to the computer.

JOYSTICK FIRE BUTTON

Figure 1: Circuit diagram of add-on keypad for the Spectrum.



JOYSTICK FIRE BUTTON

The eight output lines — OP0–7 — of IC2 correspond to the eight lines of the computer data bus. That is the highway along which instructions and numbers are transferred between the Z-80 microprocessor and memory — ROM or RAM — or input/output ports.

All items in the computer are represented as patterns of eight bits — 0s and 1s or LOWs and HIGHs — corresponding to the eight lines of the data bus. As figure one shows, the signals from switches S0 to S4 are connected via IC2 to bits 0 to 4 of the data bus and the joystick circuit is connected to bit 7. Bits 5 and 6 are left unused in that circuit but could be fitted with additional switches if required.

The eight-bit patterns in the computer represent binary numbers and so each combination of signals read in from the keypad corresponds to a particular number. The pattern of 0s and 1s, and hence the value of the number, obtained from the input port is determined by which keys are pressed at the instant the buffer is activated, a pressed key giving a 0 and an unpressed key a 1.

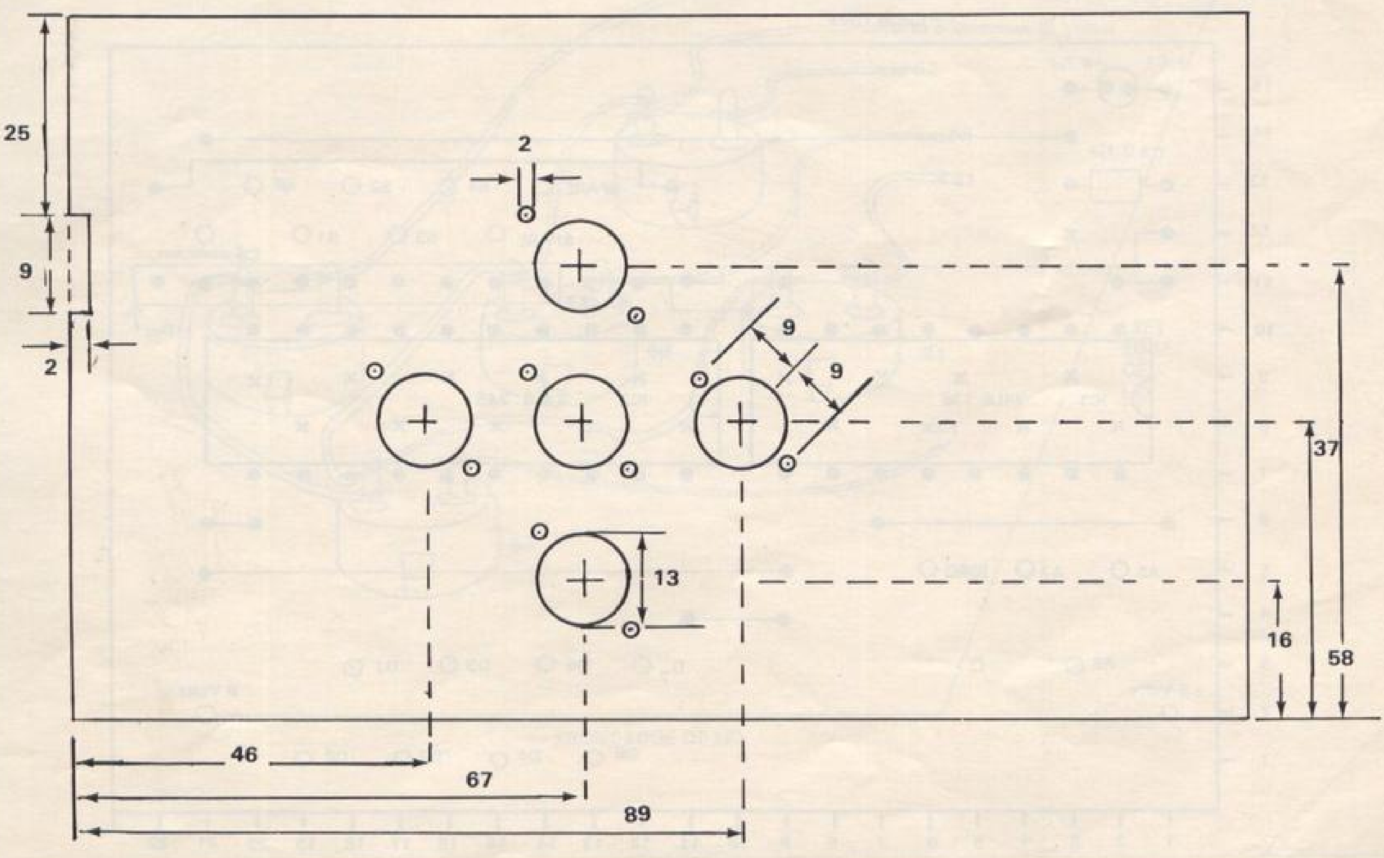
If you wish to add the keypad to an existing joystick interface you should follow the separate construction notes. The first construction step is to cut a series of holes in the lid of the box to accept the key switches. The large holes can be made most conveniently with a sheet metal punch but a large drill will suffice if it is used carefully. The positions and dimensions of the holes required to fit Maplin-type key switches are shown in figure two. If you wish to use another type of switch you obviously will have to determine the correct size of hole. File a shallow slot in the edge of the lid as shown in figure two to allow the ribbon cable from the computer to enter the box.

Cut a piece of Veroboard 1.5in. along the tracks by 2.5in. across. Place that with the copper tracks uppermost and mark on the board the positions of the breaks in the tracks, as shown in figure 3a. Check that all the breaks have been marked correctly and then cut the tracks at those points with either a spot face cutter or a small twist drill held in the hand.

Check that the breaks are complete and clear away any surplus pieces of copper. Turn over the board so that the tracks are on the underside and cut and fit the insulated wire links as shown in figure 3b. Verify that they are in the correct positions and then solder them to the tracks. Then bend the leads of all the components so that they fit into the correct holes.

Mount and solder the resistor pack into position, taking care to ensure that the dot on the pack is orientated as indicated in figure 3b. If you are unable to obtain a suitable single-in-line resistor pack you can use individual 4.7kohm resistors mounted vertically and connected as shown in the sketch in figure 4a. The commoned upper ends of those resistors should be connected to the +5V sup-

Figure 2: Diagram showing how to mark and cut the box lid to accept the five Maplin key switches. All dimensions are in mm.



JOYSTICK FIRE BUTTON

ply rail. Next solder the capacitors into position, taking care to mount the tantalum bead capacitor correctly so that the lead marked with a "+" is connected to the +5V supply line. Fit the integrated circuits and check that the dot or cut-out is to the upper edge of the board — figure 3b. Solder the ICs to the board, taking care not to apply the soldering iron for long periods.

To complete the board, push the Veropins into the holes as shown in figure 3b and solder them to the tracks. Check the underside of the board for dry joints, solder splashes and short circuits.

Using the ribbon cable, wire the Veropins on the left-hand edge of the board to the relevant contacts on the 28-way Spectrum edge connector — see figure 3b and the edge connector pin-out for the Spectrum at the back of this issue. Double-check that you have made the connections correctly.

The final step in construction is to mount the key switches on the box lid and to connect them as shown in figure 4b. Wire together one of the contacts from each switch. Then, using a small length of six-way ribbon cable, wire the commoned contacts to 0V and the other contact of each switch to the relevant Veropin on the right of IC2 — figure 3b. Give the wiring a last check and then put the circuit board in the box — it may be held in place with double-sided sticky pads — and screw the lid into place.

Figure 3a: Diagram of the underside of the circuit board to show the locations of the breaks in the copper tracks.

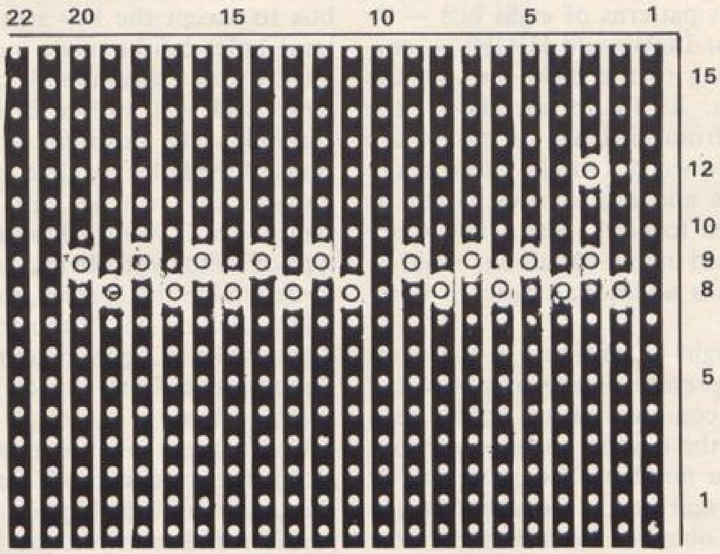
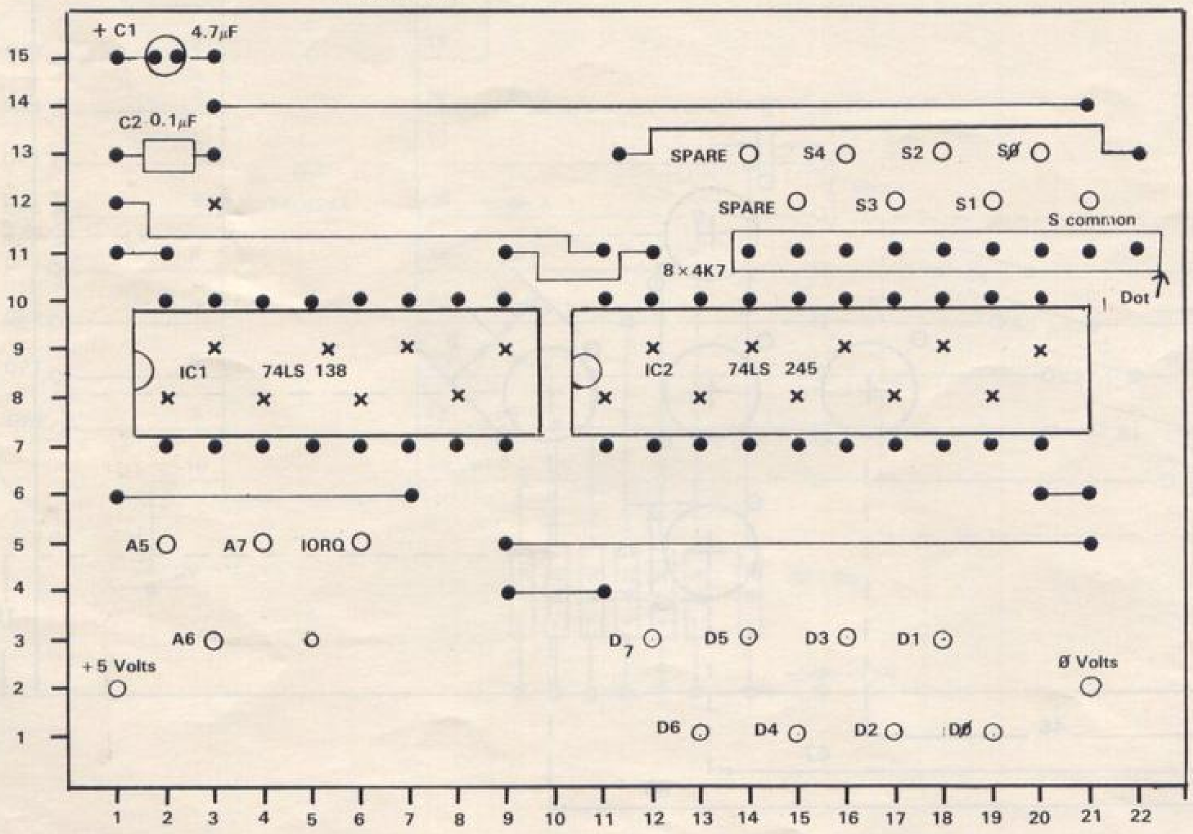


Figure 3b: Diagram showing the layout of the circuit on Veroboard.

(view of component side of board)

o = VEROPIN

× = Cut in Track



JOYSTICK FIRE BUTTON

You are then ready to connect the keypad to your Spectrum and test it.

To add the keypad to an existing joystick, remove the lid from the box and unscrew the joystick. Cut the holes in the lid to accept the switches as described. Increase the depth of the slot at the left-hand edge of the lid to accept an additional piece of ribbon cable. Remove the circuit board from the box and disconnect the link to IC2 from pin 7 on IC1 and connect it to pin 9 on IC1. That changes the address of the joystick from 255 to 223.

Solder the resistor pack into position as shown in figure 3b and add an additional wire from the common pin on the pack — marked with a dot — to the +5V supply line. Fit the extra Veropins to the board as shown in figure 3b. Next take a seven-way length of ribbon cable and connect the extra data lines — D0-6 — from

Figure 4a: Sketch showing method of installing discrete resistors in place of the single-in-line resistor pack if that is not available.

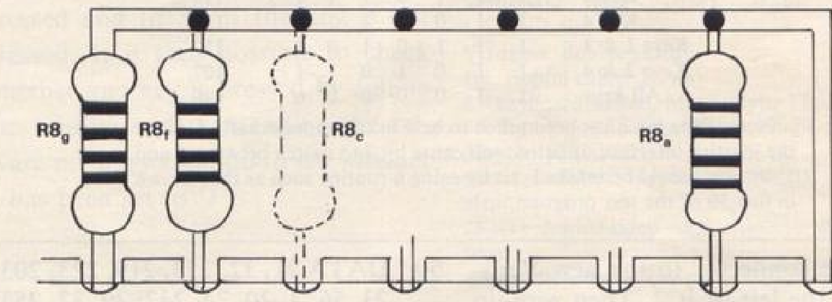
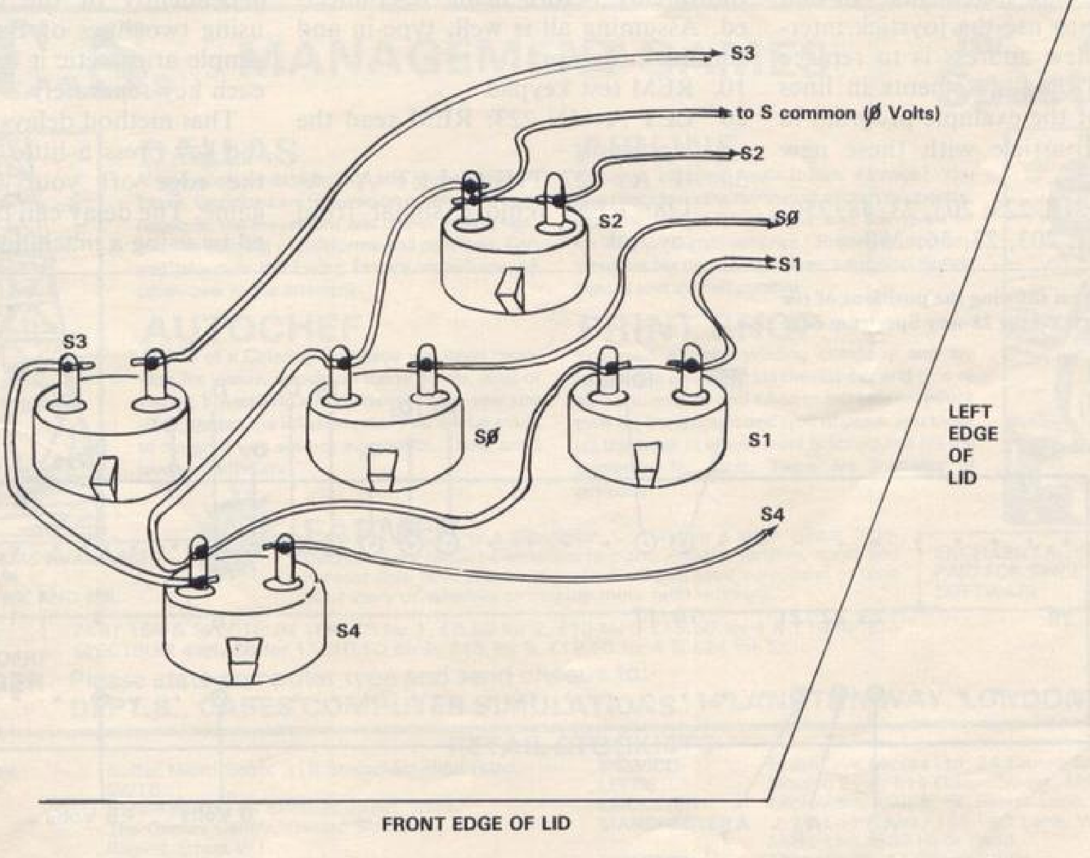


Figure 4b: Sketch of the underside of the box lid showing details of the wiring of the five key switches.



JOYSTICK FIRE BUTTON

Table 1: Values returned from keypad for different key presses

	Binary value							Decimal value
Key No.	–	–	4	3	2	1	0	
Data lines	6	5	4	3	2	1	0	
Key pressed - None	1	1	1	1	1	1	1	127
Key 0	1	1	1	1	1	1	0	126
Key 1	1	1	1	1	1	0	1	125
Key 2	1	1	1	1	0	1	1	123
Key 3	1	1	1	0	1	1	1	119
Key 4	1	1	0	1	1	1	1	111
Keys 1 & 3	1	1	1	0	1	0	1	117
Keys 2 & 4	1	1	0	1	0	1	1	107
All keys	1	1	0	0	0	0	0	96

Note: Data bit 7 has been taken to be 0 in this representation. Since the joystick interface, if fitted, will cause bit 7 to switch between 0 and 1, this bit should be masked out by using a routine such as that shown in line 30 of the test program.

the edge connector to the new Veropins on the left of IC2. Then wire-up the key switches as shown in figure 4b as described. Check all the connections and solder joints and re-assemble the box.

Since the joystick interface is then at a new address — 223 instead of 255 — it is necessary to alter the machine code routine used to read the joystick. The modified code is given in the form of data statements. All that is necessary to use the joystick interface at its new address is to replace the original data statements in lines 45 and 50 of the example program in the joystick article with these new lines:

```
45 DATA 219, 223, 203, 23, 48, 250,
   219, 223, 203, 23, 56, 250
50 DATA 21, 32, 253, 219, 223, 203,
   23, 56, 3, 20, 24, 247, 29, 32, 253,
   219, 223
```

To set up and use the keypad, remove the power plug from the Spectrum, fit the edge connector and re-insert the power plug. The Spectrum should work exactly as before; if there is a difficulty switch-off immediately and disconnect the interface. That should then be checked thoroughly before being re-connected. Assuming all is well, type-in and run this program:

```
10 REM test keypad
20 LET A=IN 223: REM read the
   input port
30 IF A>127 THEN LET A=A-
   128: REM remove signal from
   joystick
40 PRINT A
50 POKE 23692, 2: REM Keep
   scrolling
60 GOTO 20: REM Keep going!
```

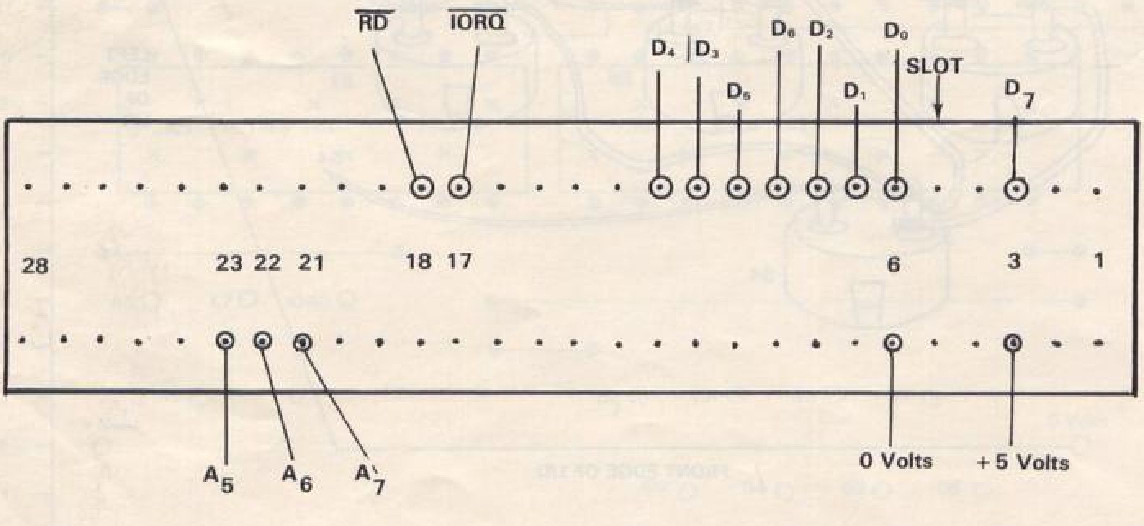
If none of the keys is pressed, the value printed on the screen should be 127. Then try pressing each key in turn and observe the effect it has on the value obtained from the port.

Table one lists the numbers which should be returned when each individual key is pressed and also shows how the binary code for that number is generated from the switches. If you find that a key gives the incorrect value it almost certainly means that the wires to the edge connector or to the switches have been connected to the incorrect Veropins and you will need to re-check the connections.

You will no doubt have realised that pressing more than one key produces a value different from that given when either key is pressed alone — table one. That clearly presents difficulties if you wish to check whether a particular key is down independently of the other keys. By using two lines of Basic to do some simple arithmetic it is possible to test each key separately.

That method delays the response to the key press a little and might take the edge off your Space Invaders game. The delay can largely be avoided by using a machine code routine to

Figure 5: Diagram showing the positions of the required contacts on the 28-way Spectrum edge connector.



JOYSTICK FIRE BUTTON

read the keypad, decode the value obtained, and to set five flags to indicate the state of each of the five keys at the instant the keypad was read.

A suitable machine code routine is given as part of the bigger test program — function key routines. The machine code is contained in the data statements in lines 60, 70 and 80 and is POKEd into memory by lines 10-50. Before loading and running the program, you must remember to enter 'CLEAR 32499 <ENTER> NEW '<ENTER>' to reserve sufficient space for the machine code routines.

The main program illustrates how to use the routine to test the keys. The keyboard is scanned by calling the routine with a 'USR 32508' as in line 1300. If any of the keys is pressed, the routine will return a value of 1 to the USR function, while if none of the keys is pressed the value will be 0. The flags for the keys 0 to 4 are held in the five successive memory locations 32500 to 32504 respectively.

The value of each of those locations is set to '1' if the relevant key is pressed and to '0' if the key is not pressed. It is thus possible to check whether any key is pressed by calling the routine and then testing the relevant memory location to see whether it has been set to '1'.

COMPONENTS

For the complete unit

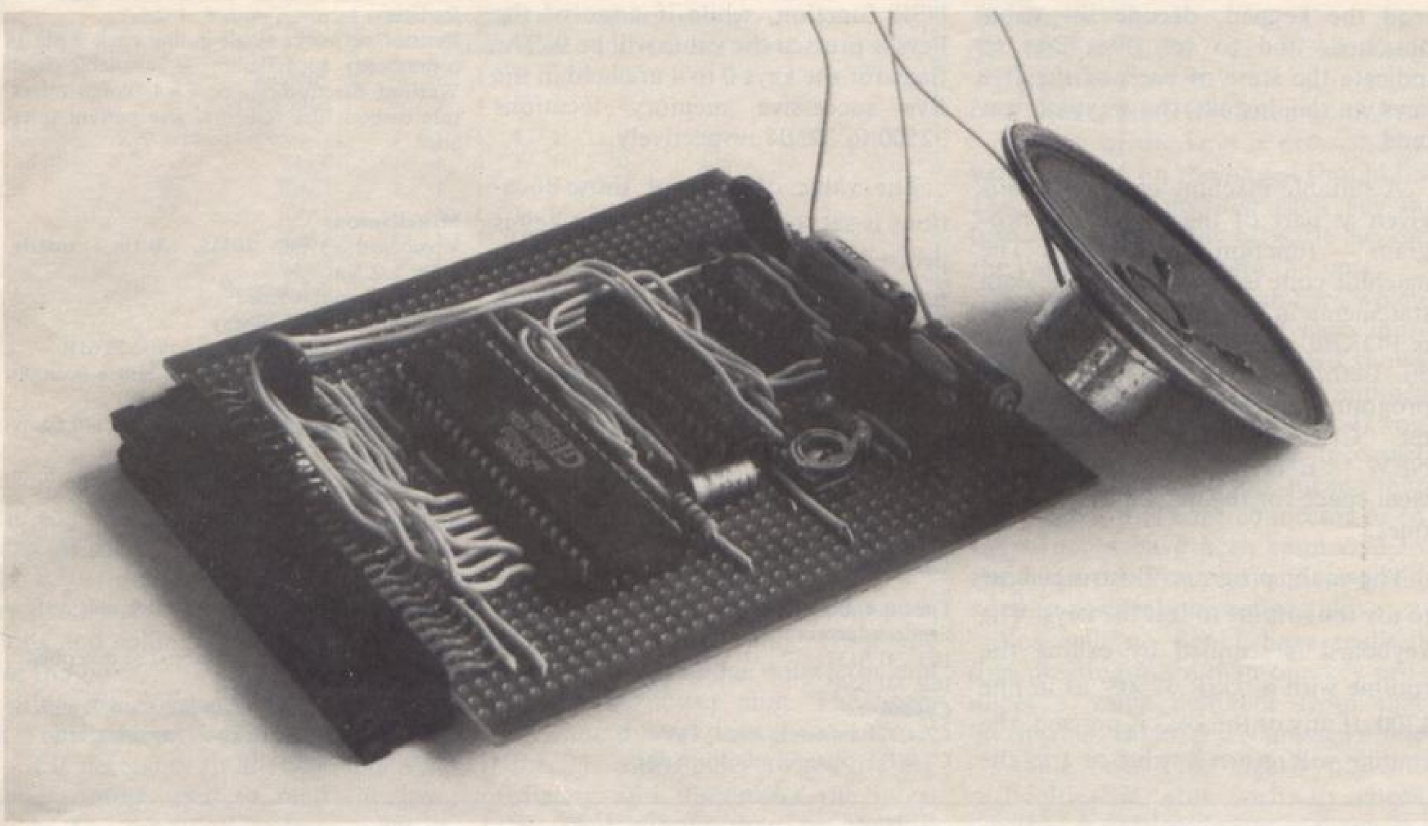
Semiconductors
IC1 74LS138
IC2 74LS245

Capacitors
C1 4.7μF tantalum bead, 16V
C2 0.1μF ceramic miniature disc

Resistors
Resistor network, single-in-line pack 9-pin (8 commoned) 8×4.7kohm — available from Watford Electronics), or 7×4.7kohm miniature carbon film resistors, five percent tolerance.

Miscellaneous
Veroboard type 10345, 0.1in. matrix. 1.5in.×2.5in.
Veropins, double-sided
1m. ribbon cable, 20-way
5×keyboard switch, Maplin type FF61R
5×keytop for above switches, single position, Maplin type FF62S
Metal panel box, Maplin type M4003, or equivalent
28-way double-sided edge connector for Spectrum
4×double-sided sticky pads

As addition to an existing joystick unit
Only the following required:
5×keyboard switches and tops, as described
1m. ribbon cable, 10-way
Single-in-line resistor network 8×4.7kohm or equivalent, discrete resistors, as described
Veropins, double-sided



Getting programmed to generate sound

The Spectrum beep is too quiet for many people. Michael Gorman shows how to improve the sound with an easy-to-build project.

A PROGRAMMABLE sound generator and dual 8-bit ports can easily be added to the Spectrum by using a General Instrument AY-3-8910 integrated circuit.

The circuit shown in figure one can be built on 0.1 Veroboard. Sockets should be used for all the integrated circuits. The connection to the computer is by means of a 28-pin double-sided socket connected to an edge plug which feeds all the connections through to any other external devices. Care must be taken over the Data connections as they do not run in numerical order.

The 8910 has 16 internal registers which may be loaded using the OUT command from the computer. The first six registers (R0-R5) provide for fine and coarse tuning to the three divider chains which divide the external clock to produce the tones. As the lowest note which can be produced is 1/65,025 of the input, the 4MHz clock will yield approximately 60Hz. A separate oscillator can be used to produce more musically-related outputs, of a lower frequency if desired—see figure two.

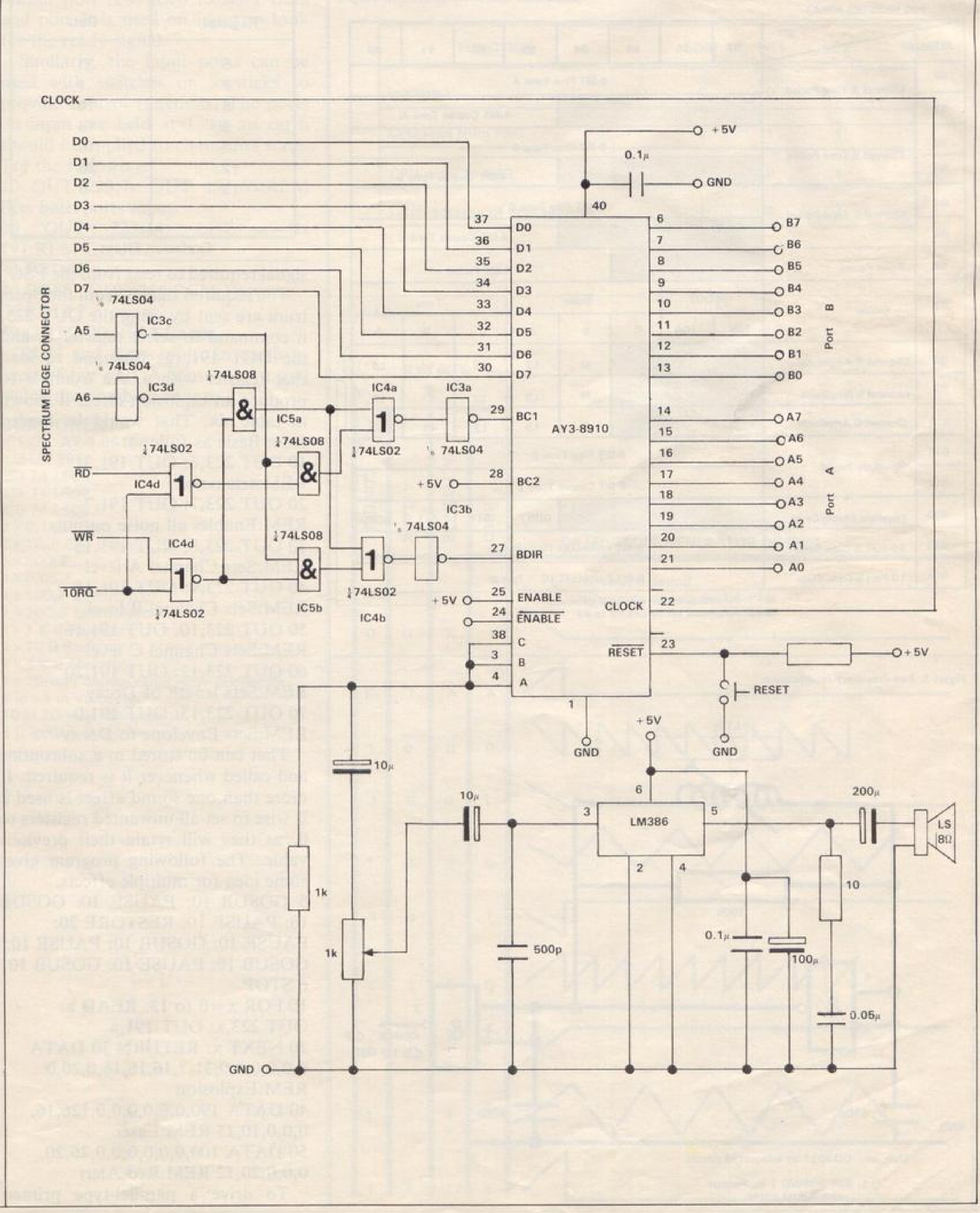
Register 6 controls the noise period. That, too, is related to the clock input. Register 7 is used to enable the tone and voice to the three output channels and the I/O ports. Each bit on the Data lines switches a separate channel—see table one. Loading R7 with 254 decimal (BIN 11111110) enables tone on the A output. Registers 8-10 control the three output levels. Registers 11 and 12 control the envelope period, and register 13 the envelope shape. The possible envelope shapes are shown and expressed in binary form in figure three.

Registers 14 and 15 control the output ports and would be used with joystick controllers and Centronics interfaces.

The $\overline{IORQ}$ and $\overline{WR}$ are gated together by IC4d ($\frac{1}{4}$74LSO2) to form a write allow signal. That is gated by $\overline{A5}$ in IC5b ($\frac{1}{4}$74LSO8) to form the write to PSG signal on BDIR as required on the control line function table in figure four. It is also gated by $\overline{A6}$ in IC5c ($\frac{1}{4}$74LSO8) to form the address latch input to both BDIR and BC1. Similarly the $\overline{IORQ}$ and $\overline{RD}$ are gated by IC4c ($\frac{1}{4}$74LSO2) to form a read signal. That is further gated by the $\overline{A6}$ signal to provide the BC1

SOUND GENERATOR

Figure 1. Circuit diagram.



SOUND GENERATOR

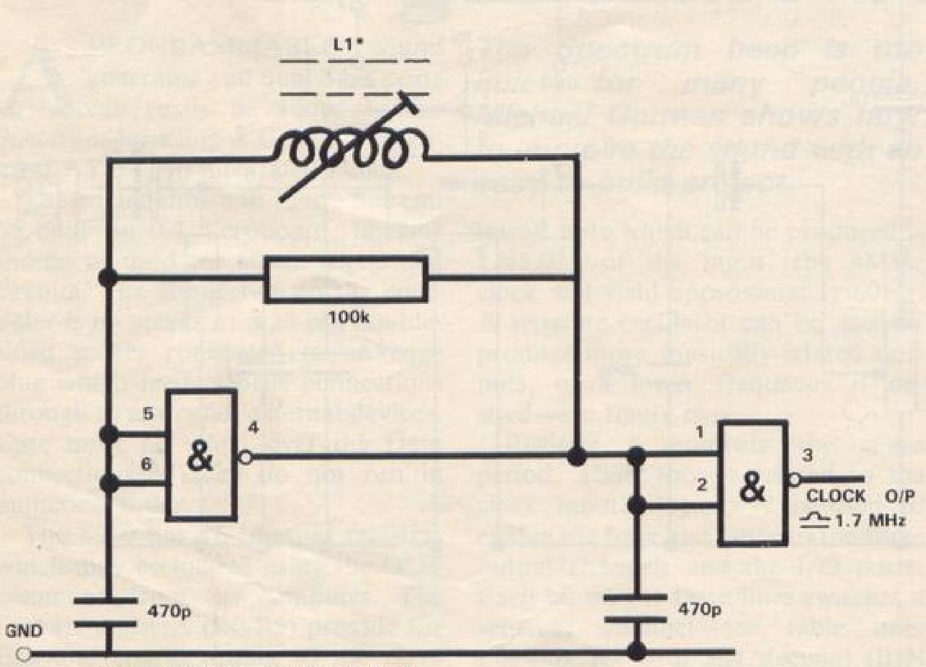
Table 1.

PSG REGISTER ARRAY

REGISTER		B7	B6	B5	B4	B3	B2	B1	B0
R0	Channel A Tone Period	8-BIT Fine Tune A							
R1						4-BIT Coarse Tune A			
R2	Channel B Tone Period	8-BIT Fine Tune B							
R3						4-BIT Coarse Tune B			
R4	Channel C Tone Period	8-BIT Fine Tune C							
R5						4-BIT Coarse Tune C			
R6	Noise Period				5-BIT Period				
R7	Enable (active low)	IN/OUT		Noise (active low)			Tone (active low)		
		10B	10A	C	B	A	C	B	A
R8	Channel A Amplitude				M	L3	L2	L1	L0
R9	Channel B Amplitude				M	L3	L2	L1	L0
R10	Channel C Amplitude				M	L3	L2	L1	L0
R11	Envelope Period	8-BIT Fine Tune E							
R12		8-BIT Coarse Tune E							
R13	Envelope Shape/Cycle					CONT	ATT	ALT	HOLD
R14	10 Port A Data Store	8-BIT PARALLEL 10 Port A							
R15	10 Port B Data Store	8-BIT PARALLEL 10 Port B							

M = 1 Amplitude set by envelope generator
M = Ø Amplitude set by bits BØ to B3

Figure 2. Low-frequency modification.



Use, say, CD4011 as integrated circuit.

*L1: 60T 30SWG ¼ in. Former with 2 dust cores.

Register	Data
6	31
7	7
8	16
9	16
10	16
12	20
13	0

Explosion Effect

signal required to read from the PSG.

The required signals from the Spectrum are sent by using the OUT 223, n command to select register n, and the OUT 191, a command to load that register with a. An example to produce an explosion effect is shown in table six. That would be loaded from Basic as follows:

```
10 OUT 223,6: OUT 191,31
REM:sets noise
20 OUT 223,7: OUT 191,7
REM:Enables all noise outputs
30 OUT 223,8: OUT 191,16
REM:Sets Channel A level
40 OUT 223,9: OUT 191,16
REM:Sets Channel B level
50 OUT 223,10: OUT 191,16
REM:Sets Channel C level
60 OUT 223,12: OUT 191,20
REM:Sets length of Decay
70 OUT 223,13: OUT 191,0
REM:Sets Envelope to Decay
```

That can be stored in a subroutine and called whenever it is required. If more than one sound effect is used it is wise to set all unwanted registers to 0, as they will retain their previous value. The following program gives some idea for multiple effects.

```
5 GOSUB 10: PAUSE 10: GOSUB
10: PAUSE 10: RESTORE 20:
PAUSE 10: GOSUB 10: PAUSE 10:
GOSUB 10: PAUSE 10: GOSUB 10
6 STOP
10 FOR x=0 to 13: READ a:
OUT 223,x: OUT 191,a
20 NEXT x: RETURN 30 DATA
0,0,0,0,0,0,31,7,16,16,16,0,20,0
REM:Explosion
40 DATA 190,0,0,0,0,0,0,126,16,
0,0,0,10,15 REM:Laser
50 DATA 100,0,0,0,0,0,0,26,20,
0,0,0,20,12 REM:Red Alert
```

To drive a parallel-type printer,

output port A is used to send Data and port B is used on input to look for the ready signal.

Similarly, the input ports can be used with switches or joysticks to provide control functions. The ports on input are held at 1, so an earth should be applied to change its state. Try the following:

```
10 OUT 223,7: OUT 191,63:REM Sets both ports input
20 OUT 223,14: LET a=IN 191:REM Get A
30 PRINT a
40 POKE 23692,255:REM Prevents SCROLL? message
50 GOTO 20:REM Loops
```

RUN and then apply an earth to each of the port A pins in turn and watch the numbers change.

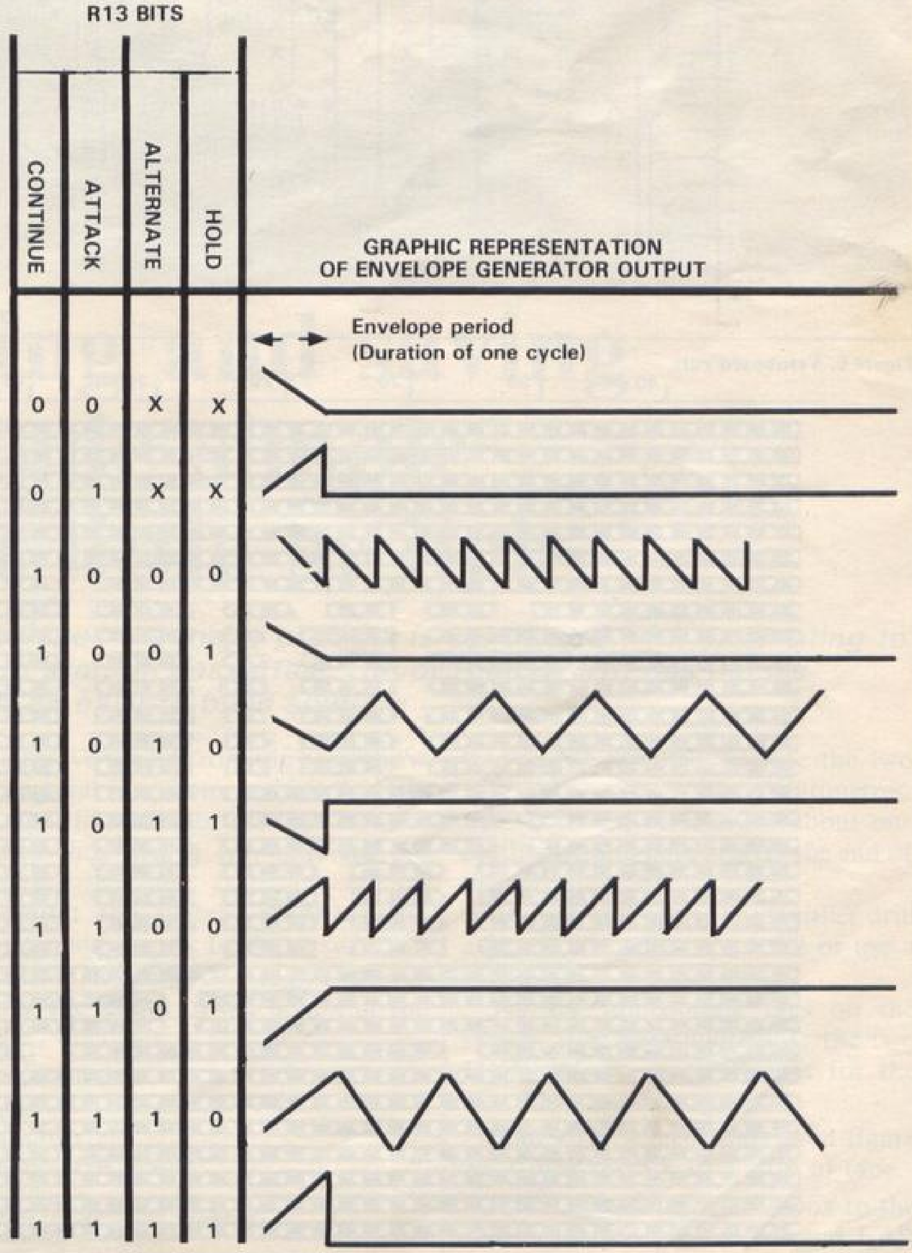
COMPONENTS

IC1 G.I. AY-3-8910
IC2 LM 386
IC3 74 LS04
IC4 74 LS02
IC5 74 LS08
2 × 0.1 μF Cap
2 × 10μF Cap Electrolytic
1 × 500pF
1 × 0.05μF
1 × 100μF Electrolytic
1 × 200μF Electrolytic
1 × 1 K Ω Resistor
1 × 10 Ω Resistor
1 × 1 K Ω Miniature
1 × 28-way double-sided edge connector
4 in × 4 in Veroboard
10 in 20-way ribbon cable
8 Ω loudspeaker

Figure 4. 8910 control line functions.

FUNCTION	BDIR	BC1	BC2
Inactive	0	0	1
CPU read from PSG	0	1	1
CPU write to PSG	1	0	1
Latch address of PSG register	1	1	1

Figure 3.



SOUND GENERATOR

Figure 5. Top of PCB

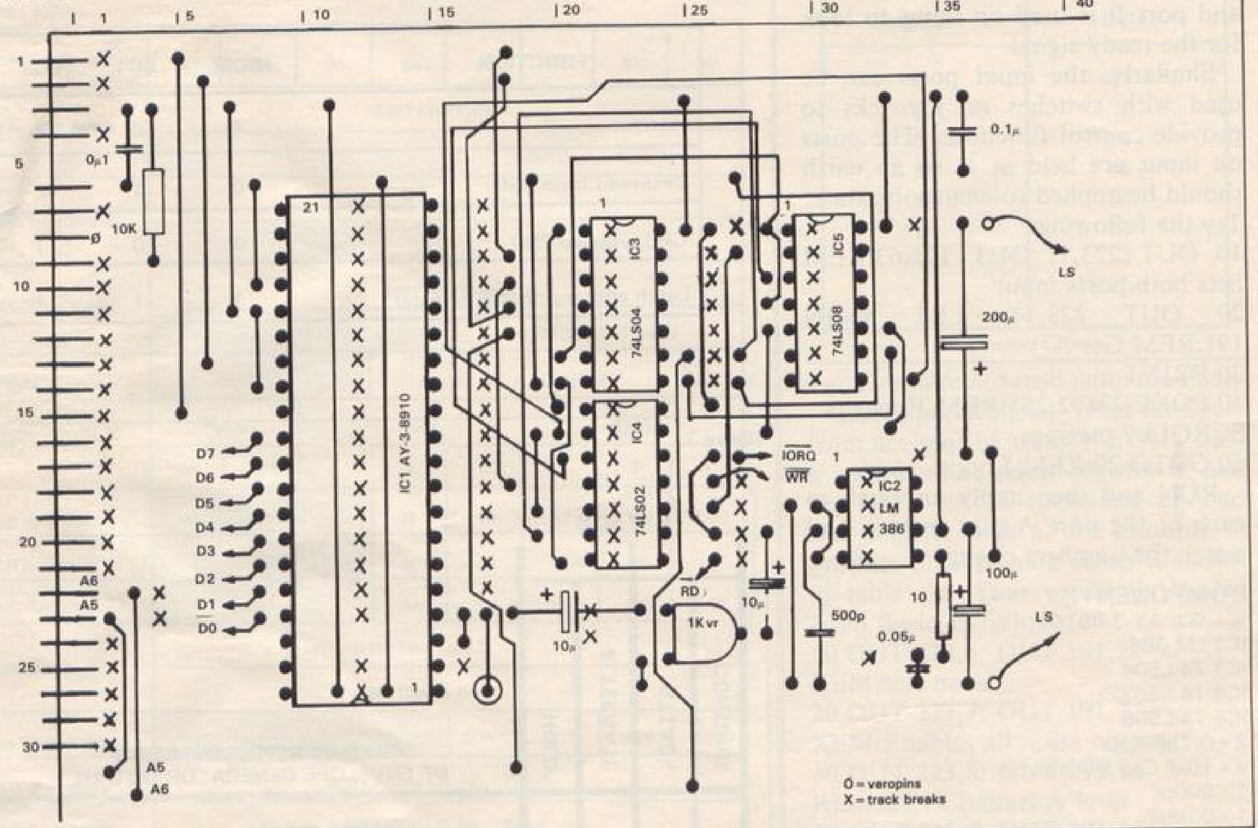
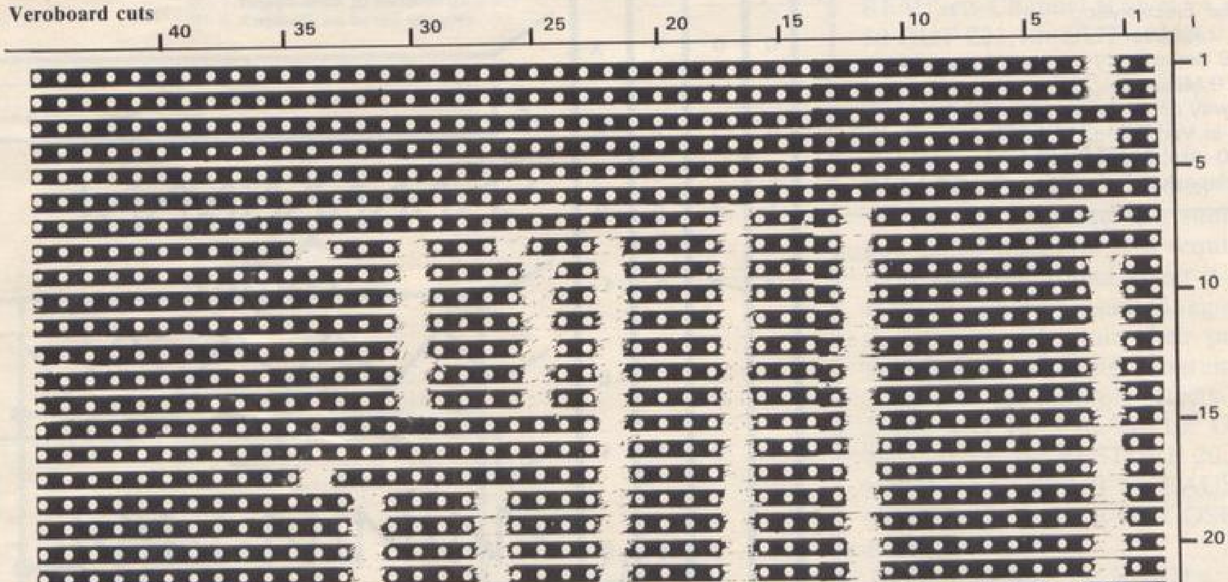
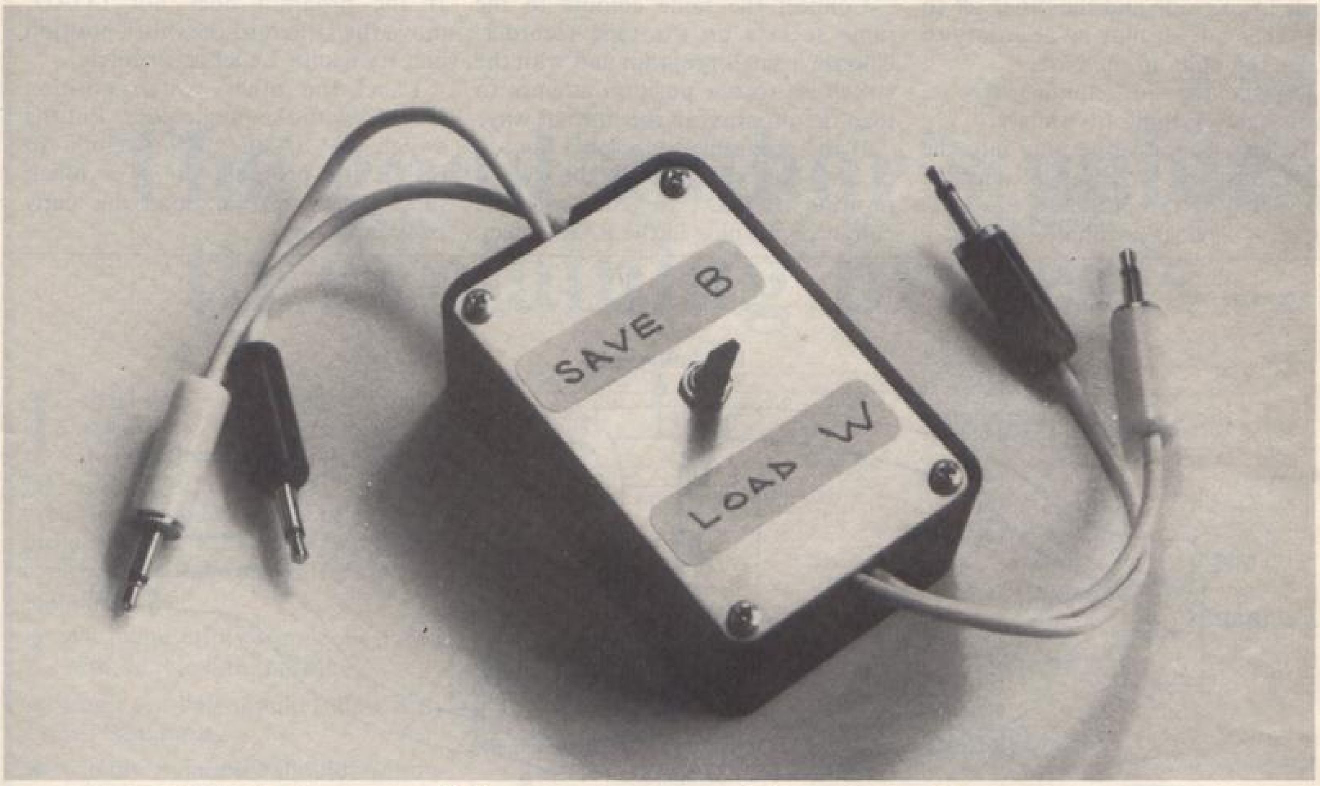


Figure 6. Veroboard cuts





Loading and saving made simple by a little switch

For many users of the Sinclair machines the major problem is concerned with attempting to get information in and out of storage cassettes. Trevor Hainsworth has details of an easy-to-build solution

HERE IT is at last. No more plugging and unplugging of the MIC and EAR plugs of your ZX-81 or Spectrum.

At a cost of £3 and an hour of your time, you can have reliable contacts for loading and saving. The magic box is simply a DPDT switch and an instrument box.

Remove the lid from the box. Draw a diagonal line from each screw-hole to find the centre of the top. Centre-punch then drill a ¼in. hole for the switch.

Mount the switch, adjusting the bottom nut to suit. Lock the switch in position so that the toggle moves along the length of the box. Cut the lead in the middle, separate the two wires for about four centimetres. Bare back the screens for about one centimetre and bare and tin the end of the cores.

At each end of the base, either drill a ¼in. hole at the top centre or use a round file.

Tin the appropriate tags on the switch, then carefully solder the two MIC leads in place. Repeat for the two EAR leads.

Solder the screen leads as in figure 1a. Cover them with a strip of tape.

Offer up the top of the box to the base with one set of MIC and EAR

Figure 1.

Parts required

1 DPDT switch, Tandy 275-663 or similar, cost £1.89.
1 Experimenter box, Tandy 270-230 or similar, cost £1.19.
MIC/EAR leads — use those supplied with ZX-81 or Spectrum.

Tools required

Pliers.
Screwdriver.
Soldering iron/solder.
¼in drill.
Round file or junior hacksaw.
Insulating/pvc tape.

leads to one side and the other set to the other side. It may be necessary to widen the holes in the base.

Replace the lid retaining screws, ensuring everything fits snugly.

To test, connect one plug into the EAR socket on the computer and the other one of the pair into the MIC socket — it does not matter which.

Connect the same colours to the same sockets on the tape recorder. Choose a small program and with the switch set to one position attempt to load the program in the normal way.

If the program loads, label the top of the box adjacent to the switch position 'LOAD', together with the colour of the plug in the EAR socket. If the program does not LOAD, move the switch to the other position and try again. Label accordingly.

Label the other switch position 'SAVE' with the plug colour. Put the switch to SAVE and attempt to SAVE the program on to a blank tape. To be certain, load this copy back in again.

Figure 1a.

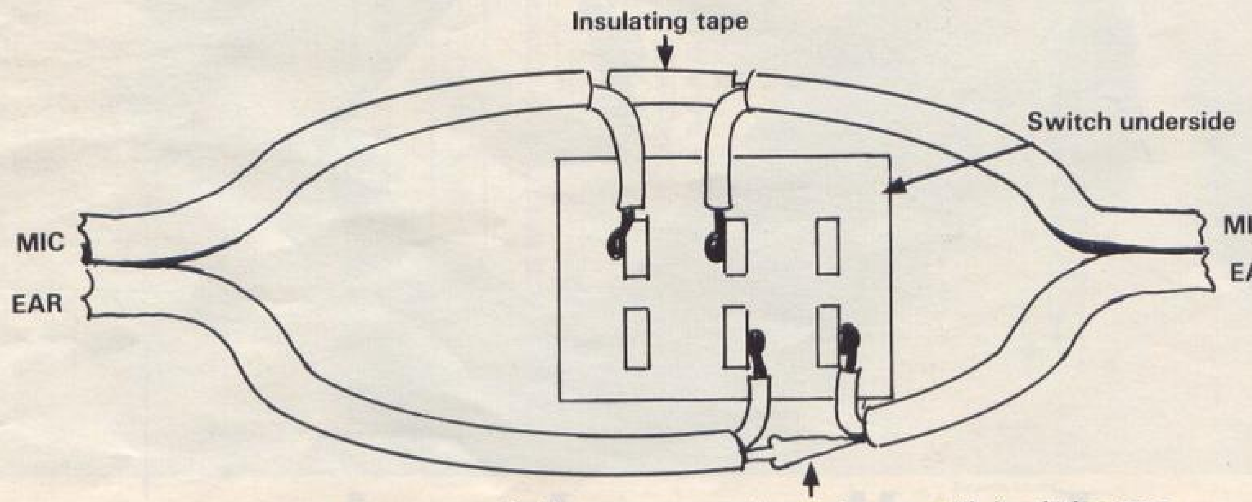
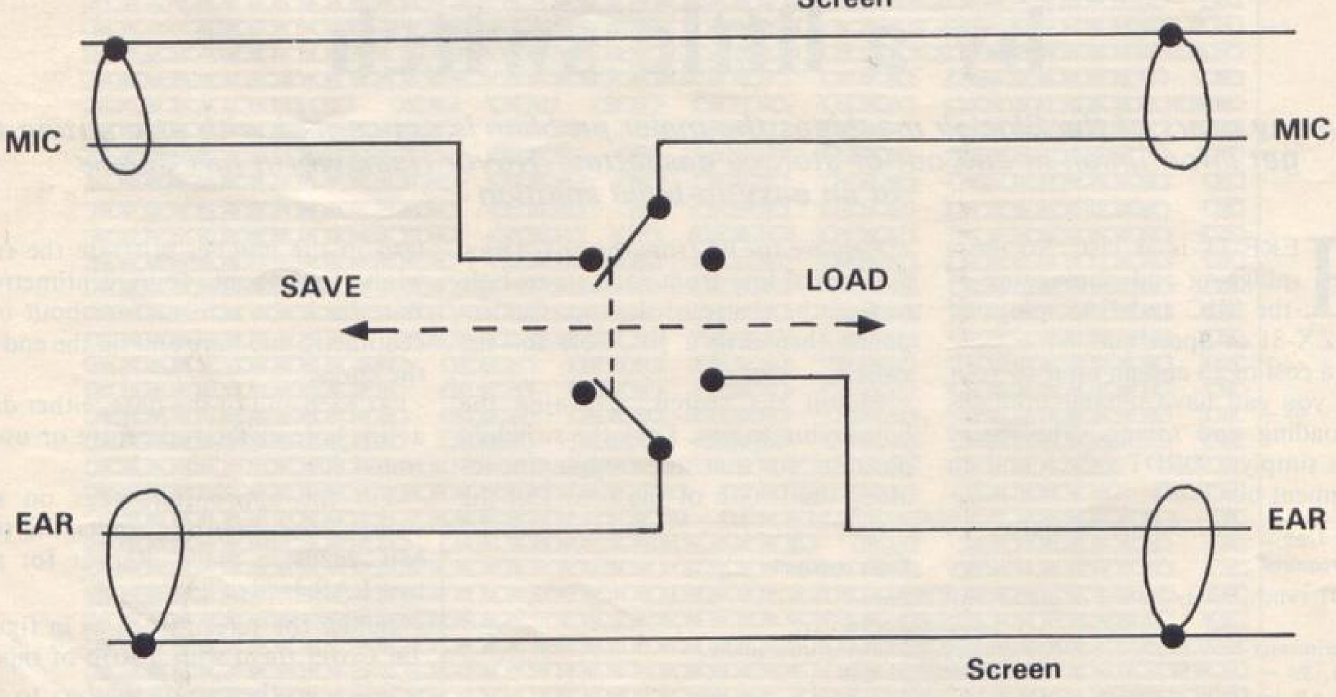


Figure 1b.



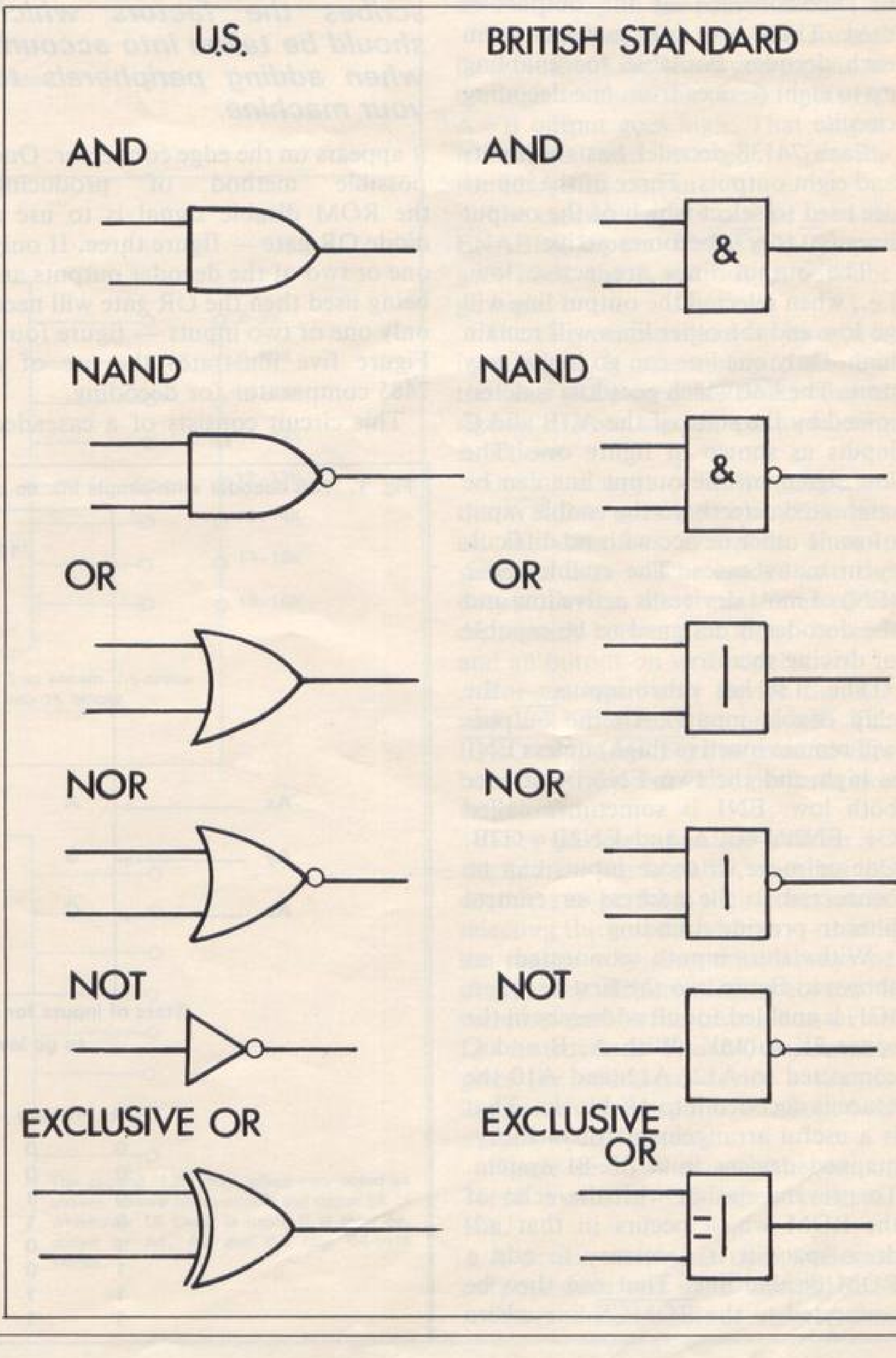
ARTICLE OUTLINE

The good author's guide to explaining projects

IF YOU WISH to submit articles to *Sinclair Projects* we would appreciate it if you adhere to the following rules. Although they are not exclusive it would help us to evaluate projects if there is some element of compatibility between different presentations.

- All manuscripts should be typed with double-line spacing.
- Logic symbols should follow British Standards.
- Circuit symbols should follow British Standards.
- Circuit diagrams should have the values of the components shown, not a reference to a component table.
- Parts of integrated circuits should be designated in this way — $\frac{1}{4}$ 74LS14, not IC5a for example.
- All circuits should be designed for construction using standard Veroboard. Any printed circuit board designs are likely to be returned for conversion. Submission of a project based on a PCB will not exclude future publication.
- Any constructional detail which is unusual or slightly complicated should be illustrated with simple hand-drawn diagrams, showing how it can be implemented.

For those who are unfamiliar with British Standards logic symbols, they are shown here. The reason for using BS symbols is simple, although controversial; they are used extensively in the British educational system and in British industry. As most of our readership is in those areas we use circuit symbols which are most familiar.



Flexible decoding helps ease the limits on input devices

In the last issue John Mellor considered the decoding of the memory. Here he describes the factors which should be taken into account when adding peripherals to your machine.

THE TECHNIQUE of using three to eight line decoders is flexible because of the ability to choose which of the outputs is used. There are eight outputs from each decoder available for enabling up to eight devices from one decoding circuit.

Each 74138 decoder has six inputs and eight outputs. Three of the inputs are used to select which of the output lines ($\overline{y0}$ to $\overline{y7}$) becomes active.

The output lines are active low, i.e., when selected the output line will go low and the other lines will remain high. Only one line can go low at any time. The line which goes low is determined by the state of the A, B and C inputs as shown in figure one. The low signal on the output line can be connected directly to the enable input of some other device with no difficulty in many cases. The enable input (EN) of most devices is active low and the decoder is designed to be capable of driving them.

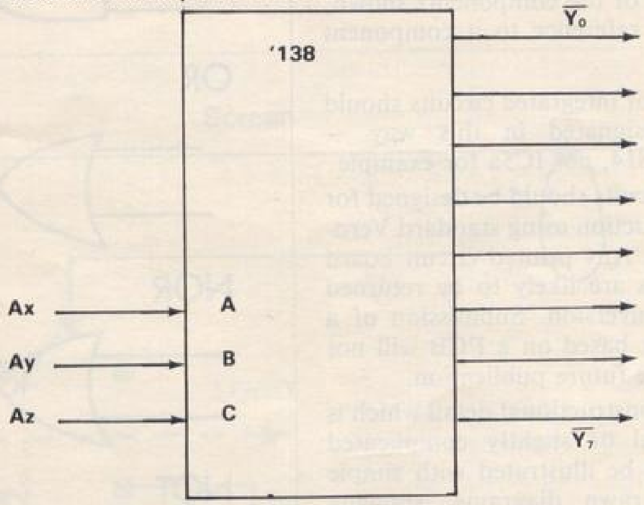
The '138 has other inputs — the chip enable inputs. All the outputs will remain inactive (high) unless EN1 is high and the two EN2 inputs are both low. EN1 is sometimes called G1, EN2A=G2A and EN2B=G2B. One or more of those inputs can be connected to the address or control lines to provide decoding.

With the inputs connected as shown in figure two the first decoder, IC1, is enabled for all addresses in the space 8K to 16K. With A, B and C connected to A12, A11 and A10 the space is decoded into 1K blocks. That is a useful arrangement for memory-mapped devices in a ZX-81 system. To prevent clashes with the echo of the ROM which occurs in that address space it is necessary to add a ROM disable line. That can then be connected to the $\overline{ROMCS}$ line where it appears on the edge connector. One possible method of producing the ROM disable signal is to use a diode OR gate — figure three. If only one or two of the decoder outputs are being used then the OR gate will need only one or two inputs — figure four. Figure five illustrates the use of a 7485 comparator for decoding.

This circuit consists of a cascaded arrangement of four-bit TTL comparators. Each comparator compares a binary word on the four A inputs to the binary word on the B inputs. So that words of greater than four bits may be compared, each IC is provided with cascade inputs and outputs. For example, the A>B output will be high if any of the bits of A is greater than the corresponding bit of B or if the A>B cascade input is high.

The A>B and the A<B inputs of all the comparators are tied low to avoid that situation. To give a total of 12 bits of comparison, three comparators can be used, as shown in figure five, with the A=B input of the first

Fig. 1. '138 decoder with simple I/0: no control lines shown.



State of inputs for output to go low

Ax	Ay	A	Output $\overline{Y}$
0	0	0	0
0	0	1	1
0	1	0	2
0	1	1	3
1	0	0	4
1	0	1	5
1	1	0	6
1	1	1	7

DECODER PART II

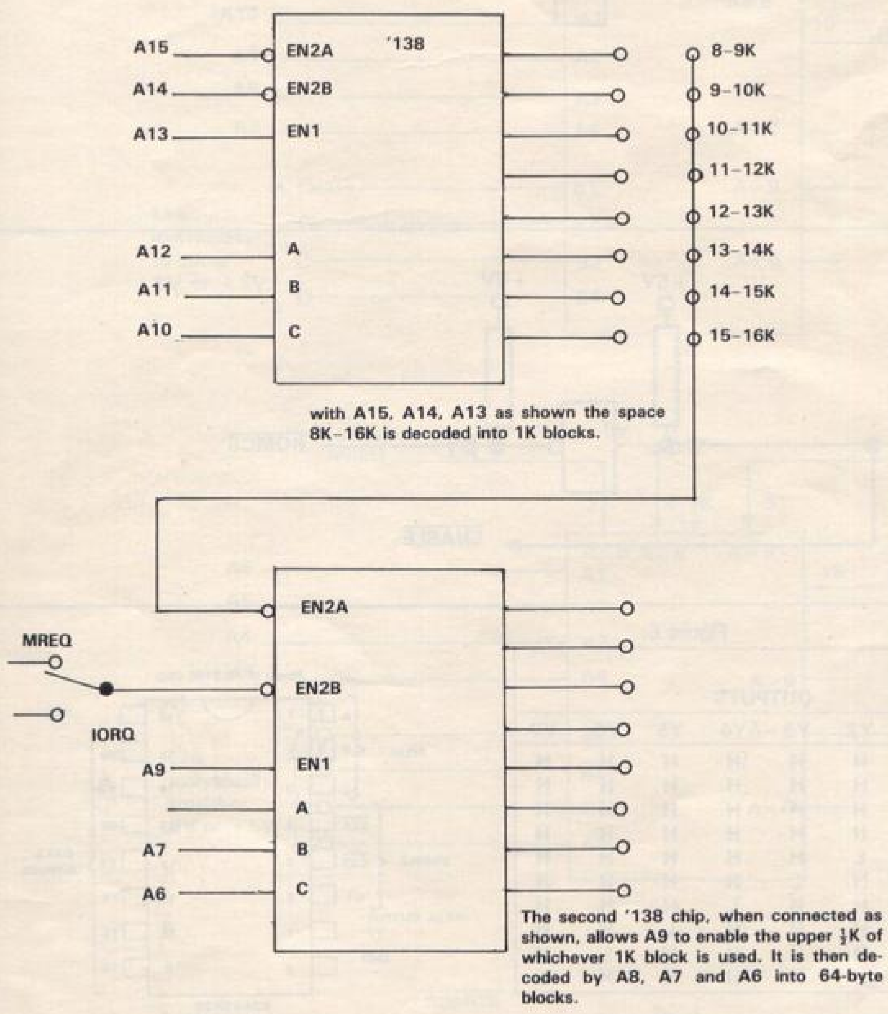
Table 1: Truth table for 4-bit magnitude comparator.

COMPARING INPUTS				CASCADING INPUTS			OUTPUTS		
A3, B3	A2, B2	A1, B1	A0, B0	A>B	A<B	A=B	A>B	A<B	A=B
A3>B3	×	×	×	×	×	×	H	L	L
A3<B3	×	×	×	×	×	×	L	H	L
A3=B3	A2>B2	×	×	×	×	×	H	L	L
A3=B3	A2<B2	×	×	×	×	×	L	H	L
A3=B3	A2=B2	A1>B1	×	×	×	×	H	L	L
A3=B3	A2=B2	A1<B1	×	×	×	×	L	H	L
A3=B3	A2=B2	A1=B1	A0>B0	×	×	×	H	L	L
A3=B3	A2=B2	A1=B1	A0<B0	×	×	×	L	H	L
A3=B3	A2=B2	A1=B1	A0=B0	H	L	L	H	L	L
A3=B3	A2=B2	A1=B1	A0=B0	L	H	L	L	H	L
A3=B3	A2=B2	A1=B1	A0=B0	L	L	H	L	L	H

NOTE: H = High level, L = Low level, X = Irrelevant.

Pinout P0, S5485/N7485 4-bit magnitude comparator.

Figure 2



with A15, A14, A13 as shown the space 8K–16K is decoded into 1K blocks.

The second '138 chip, when connected as shown, allows A9 to enable the upper ½K of whichever 1K block is used. It is then decoded by A8, A7 and A6 into 64-byte blocks.

comparator tied high through the 3K3 resistor. The A = B outputs are connected to the A = B inputs of the following comparator; the final A = B output is thus used to provide the enable signal.

Of the 12 bits being compared, one is the control signal, leaving 11 lines for the address bits. Eleven bits will decode a 16-bit address space into blocks of 32 bytes each. The switches, or links, enable this 32-byte block to be set anywhere in memory — see memory map in the previous issue.

When the address bits and control lines on the A inputs all correspond to the logic levels set on the B inputs the A = B output goes high. That output is buffered and inverted to provide the ENABLE output.

The cascade inputs can be used as ENABLE inputs. If the A < B input goes high, the A = B output will not go high.

The chip enable signal on its own is insufficient. It is necessary to also use the read ($\overline{RD}$) on write ($\overline{WR}$) control signals. Those signals perform two functions:

During a write or output function the $\overline{WR}$ line goes low when the data on the data bus is stable. If not, spurious data will be loaded into the output device; they can be used to distinguish between an input on read and an output on write operation.

For an input-only device the $\overline{RD}$ and $\overline{WR}$ lines may be omitted. The $\overline{IORQ}$ or the $\overline{MREQ}$ line must always be used. Those lines also perform two functions:

They go low when the address on the address bus is stable, enabling the decoders to perform their function of selecting the correct address — that is the reason why they must always be used; they differentiate between a memory read/write instruction or an I/0 instruction. The I/0 instruction gives the addressed device a slightly longer time to respond — about half a clock cycle longer.

Figure seven illustrates the use of 74136 exclusive OR open collector ICs.

A device which has open collector outputs does not have internal load resistors on the output stages, thus

DECODER PART II

Table 2: Result of swapping A12 and A11 using multiple input NAND gate decoding.

	A12	A11			
Binary	1000	1111	1111	1111	
Hex	8	F	F	F	$= 36863_{10}$
Binary	1001	0111	1111	1111	
Hex	9	7	F	F	$= 38911_{10}$

Pinout and truth table for 74136 Quad 2 input exclusive OR gate. Open collector outputs.

	INPUTS A	INPUTS B	OUTPUT Y
$Y = A \oplus B = \overline{A}B + A\overline{B}$	L	L	L
	L	H	H
	H	L	H
	H	H	L

Figure 3. Diode OR gate to provide ROM disable signal.

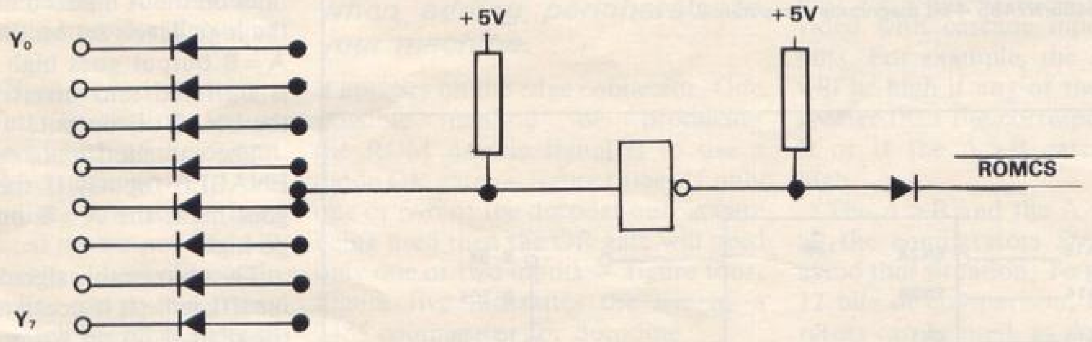


Figure 4. Single output ROM disable circuit.

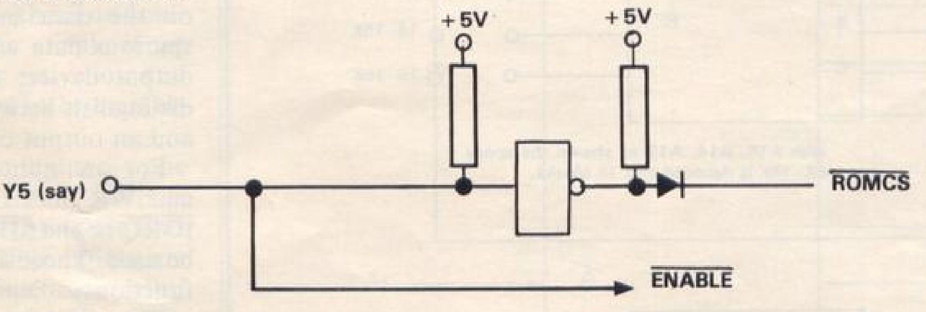
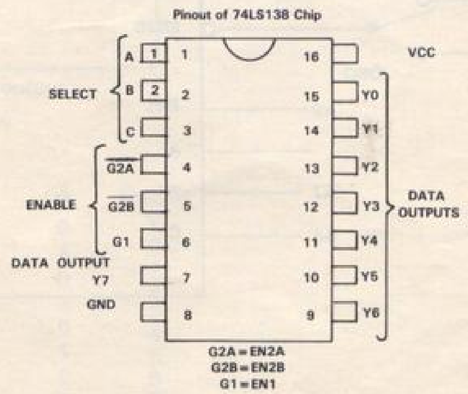


Figure 6:

TRUTH TABLE

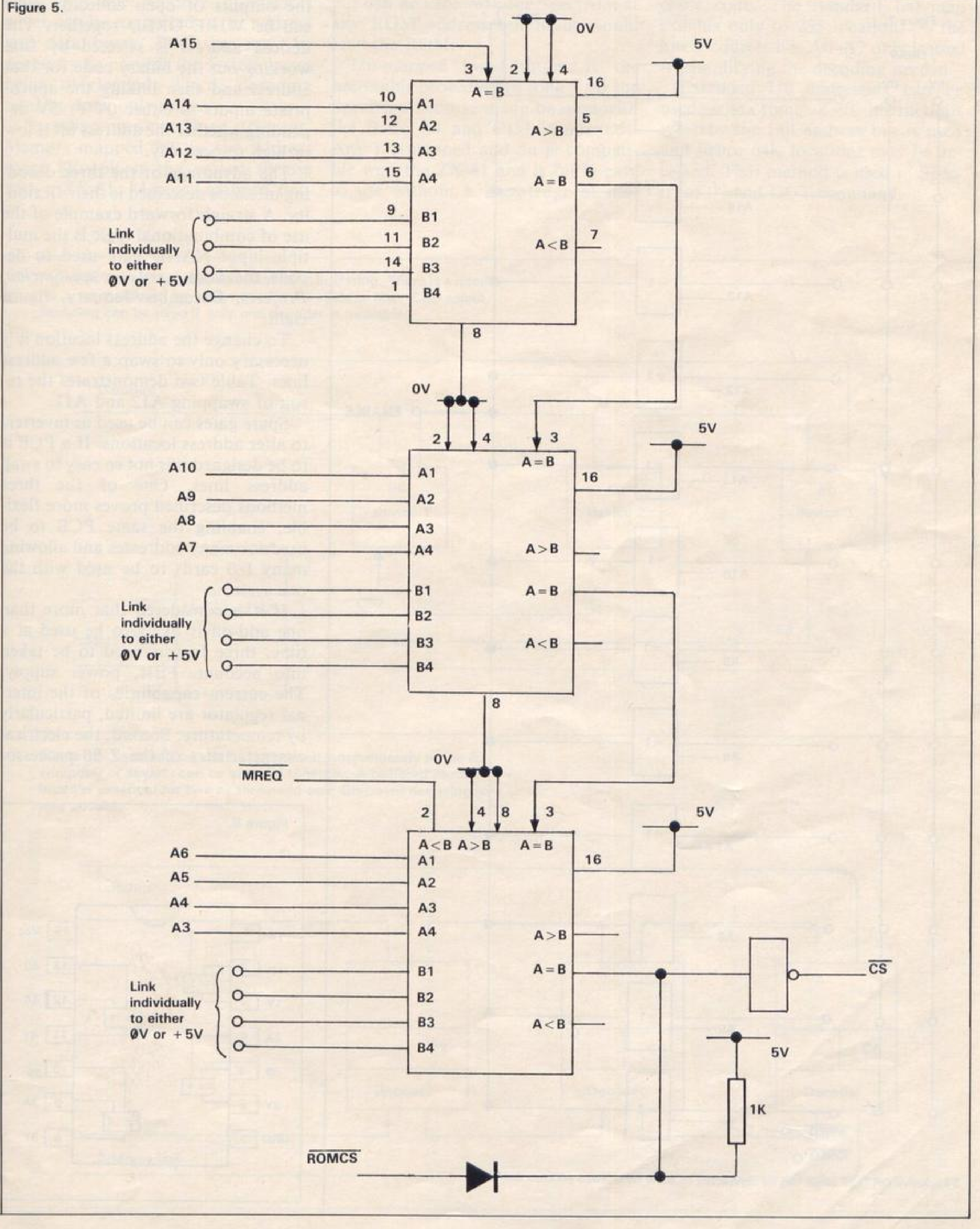
ENABLE G1	ENABLE G2*	SELECT C	SELECT B	SELECT A	Y0	Y1	Y2	Y3	Y4	Y5	Y6	Y7
X	H	X	X	X	H	H	H	H	H	H	H	H
L	X	X	X	X	H	H	H	H	H	H	H	H
H	L	L	L	L	L	H	H	H	H	H	H	H
H	L	L	L	H	H	L	H	H	H	H	H	H
H	L	L	H	L	H	H	L	H	H	H	H	H
H	L	L	H	H	H	H	H	L	H	H	H	H
H	L	H	L	L	H	H	H	H	L	H	H	H
H	L	H	L	H	H	H	H	H	H	L	H	H
H	L	H	H	L	H	H	H	H	H	H	L	H
H	L	H	H	H	H	H	H	H	H	H	H	L

*G2 = G2A + G2B
H = high level, L = low level, X = irrelevant



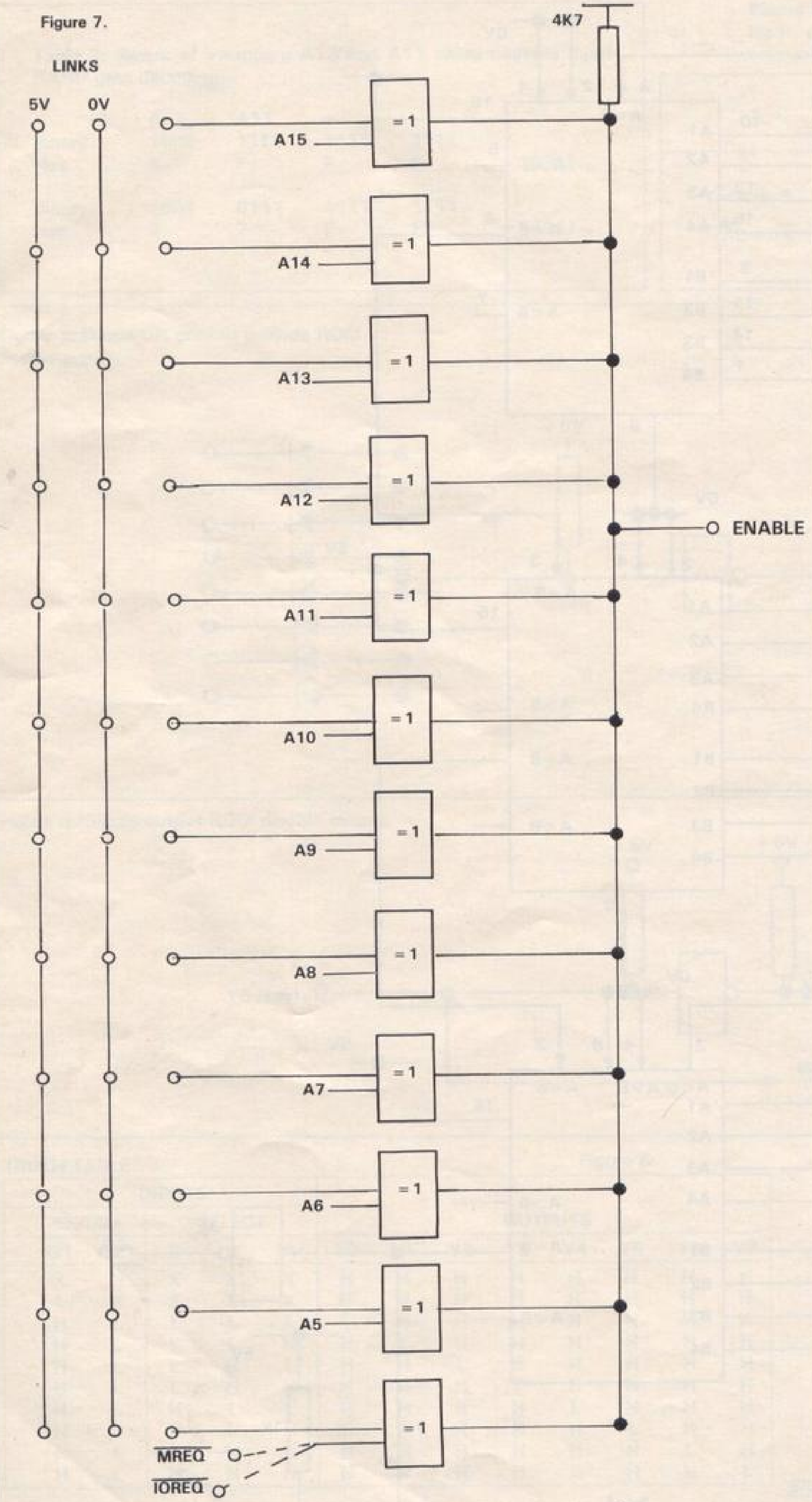
DECODER PART II

Figure 5.



DECODER PART II

Figure 7.



3 Exclusive OR '136 chips can be connected to allow hard-wired address decoding.

the outputs of open collector gates can be WIRE ORED together. The desired address is selected by first working-out the binary code for that address and then linking the appropriate inputs to either 0V or 5V depending whether the address bit is low or high respectively.

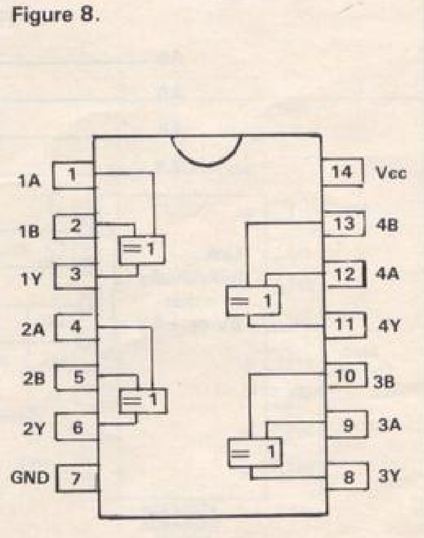
The advantage of the three decoding methods described is their flexibility. A straightforward example of the use of combinational logic is the multiple input NAND gate used to decode the latch card — see *Sinclair Projects,* December/January, figure eight.

To change the address location it is necessary only to swap a few address lines. Table two demonstrates the result of swapping A12 and A11.

Spare gates can be used as inverters to alter address locations. If a PCB is to be designed it is not so easy to swap address lines. One of the three methods described proves more flexible, enabling the same PCB to be used for many addresses and allowing many I/0 cards to be used with the one system.

If it is considered that more than one add-on is likely to be used at a time, three factors need to be taken into account. First, power supply. The current capabilities of the internal regulator are limited, particularly by temperature. Second, the electrical characteristics of the Z-80 processor

Figure 8.



DECODER PART II

chip limit the number of devices which can be connected to the address and data buses. Buffering may be necessary to prevent the system buses being overloaded. Third, decoding need be done only once.

Decoding need not be so stringent. Memory-mapped I/0 in the address space 8K–16K is the easiest to use with a ZX-81. Memory-mapped output can be used with the Spectrum at any ROM address but input would read the ROM.

I/0-mapped input/output is the preferable procedure to follow for the Spectrum because it can be used with the Basic IN and OUT commands. Any I/0-mapped add-on is compatible with the ZX-81 and is fairly easy to use without a knowledge of machine code. The standard I/0 map extends only to 255 locations — the lower address bus A0–A7 only is used — simplifying the decoding needed.

Extended I/0 addressing can be used with some Z-80 instructions whereby the full address bus is used and hence 64K locations may be accessed. That method is used in Spectrum IN and OUT command.

Figure 9. The address bus does not need buffering. There is a need for a motherboard to retain access to system bus. Chip-select decoding can be used if only one decoder is available.

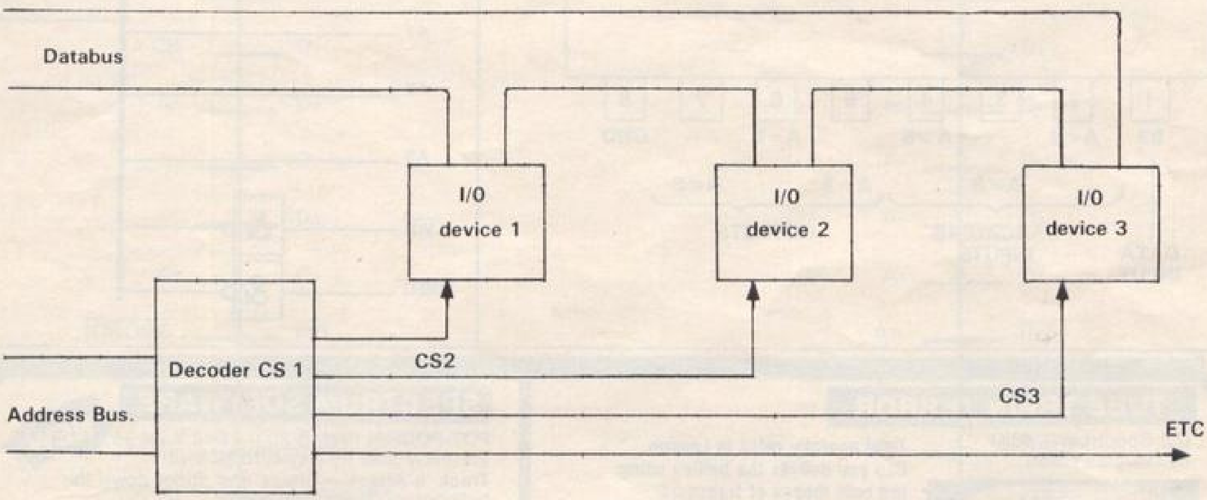
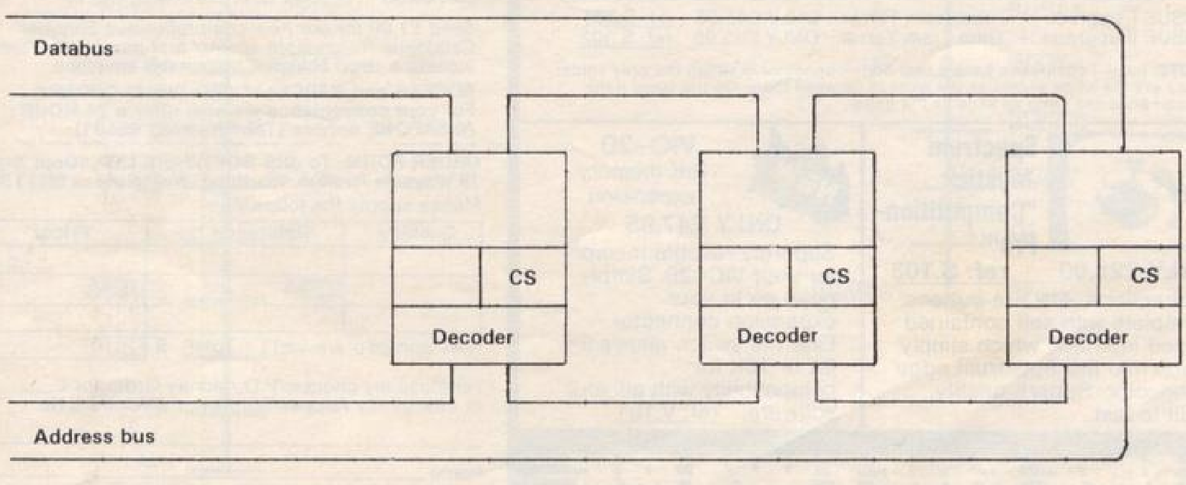
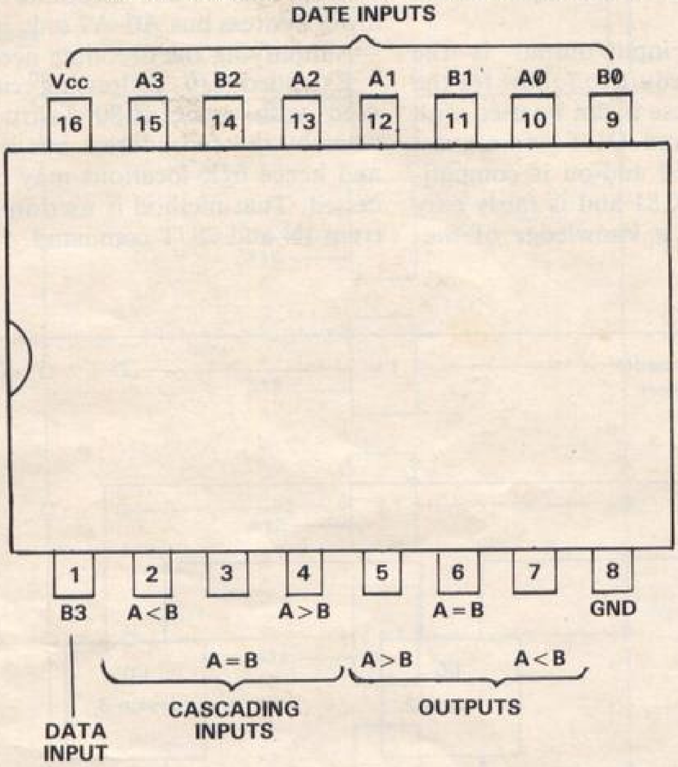


Figure 10. Each add-on can be connected independently to the ZX computer or several can be stacked together. A buffered motherboard is essential for two or three add ons. On-board decoding is also possible.

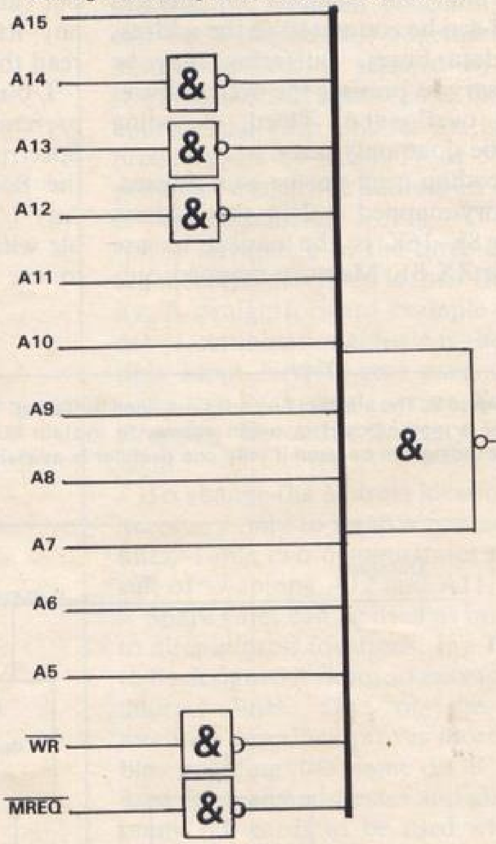


DECODER PART II

Pinout for S5485/N7485 4-bit magnitude comparator.



NAND gate decoding off address 36863_{10} (= $8FFF_H$)



EDGE CONNECTOR

Edge Connector signal allocation

SPECTRUM

BOTTOM	TOP
A_{14}	A_{15}
A_{12}	A_{13}
5v	D_7
9v	
Slot	Slot
0v	D_0
0v	D_1
CK	D_2
A_0	D_6
A_1	D_5
A_2	D_3
A_3	D_4
$\overline{IORQGE}$	$\overline{INT}$
0v	$\overline{NMI}$
Video	$\overline{HALT}$
Y	$\overline{MEMREQ}$
V	$\overline{IOREQ}$
U	$\overline{RD}$
$\overline{BUSRQ}$	$\overline{WR}$
$\overline{RESET}$	–5v
A_7	WAIT
A_6	+12v
A_5	–12v
A_4	$\overline{MI}$
$\overline{ROMCS}$	$\overline{RFSH}$
$\overline{BUSAK}$	A_8
A_9	A_{10}
A_{11}	

ZX-81

BOTTOM	TOP
5v	D_7
9v	$\overline{RAMCS}$
Slot	Slot
0v	D_0
0v	D_1
Ø	D_2
A_0	D_6
A_1	D_5
A_2	D_3
A_3	D_4
A_{15}	$\overline{INT}$
A_{14}	$\overline{NMI}$
A_{13}	$\overline{HALT}$
A_{12}	$\overline{MREQ}$
A_{11}	$\overline{IORQ}$
A_{10}	$\overline{RD}$
A_9	$\overline{WR}$
A_8	$\overline{BUSAK}$
A_7	WAIT
A_6	$\overline{BUSRQ}$
A_5	$\overline{RESET}$
A_4	$\overline{MI}$
$\overline{ROMCS}$	$\overline{RFSH}$

Watchdog system guards against heating breakdowns

In the second part of our series on controlling your central heating with the ZX-81, John Mellor describes how to add a necessary fail/safe device

WHEN A microprocessor is used to control central heating or to monitor the weather, it needs to be left running for a considerable time. No matter now much care is exercised, hardware and software faults may arise which will cause a failure in the system. If that happens it is important that no damage is done to the system and that a warning of the failure is signalled as soon as possible.

The first is achieved by making the system fail-safe. A fail-safe system is one in which the position of the valves, relays, actuators, with no power applied—or no signal applied—is a safe one. Certain actuators may need to be locked into their last position in the event of a failure. Motorised valves remain in their last position, solenoid valves will have a spring to open or close them. Careful design considering all possible eventualities is the only way to produce a fail-safe system.

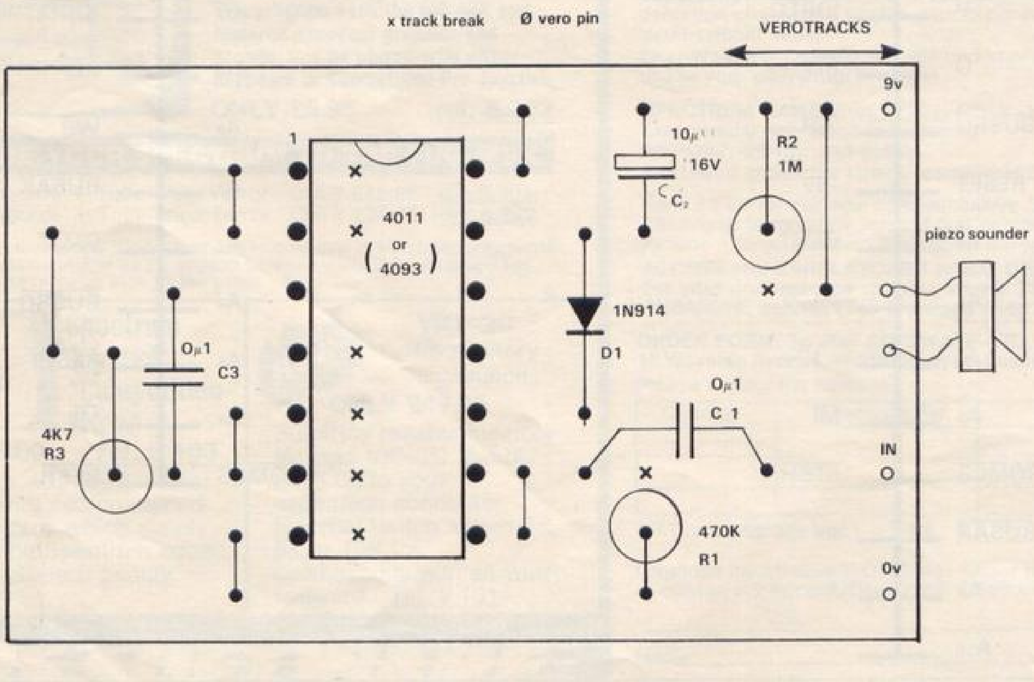
Loss of power or loss of signal from the microprocessor may not be the most catastrophic failure which can occur. An incorrect signal may cause more damage. Latched outputs will remain in their last controlled state after a system or program crash. If one of those outputs was supplying heat to a boiler, then unless some independent limiting device is fitted it is possible that the water may boil away and serious damage be done.

Where possible, outputs should require a pulsed control signal; a continuous high or a continuous low signal will be an indication of failure. The fail-safe condition should be that with zero output from the computer, i.e., the re-set condition.

The monitoring of the system is performed on industrial controllers by a watchdog circuit. It is a device which will sound an alarm in the event of a power failure or if it is not re-set at regular intervals, say once per second.

The Watchdog is connected to a single bit of one of the output ports. A software routine at a suitable place in the program generates a pulse on that output; the pulse re-sets the monostable and prevents the alarm sounding. The alarm is battery-powered so that it is independent of

Figure 2.

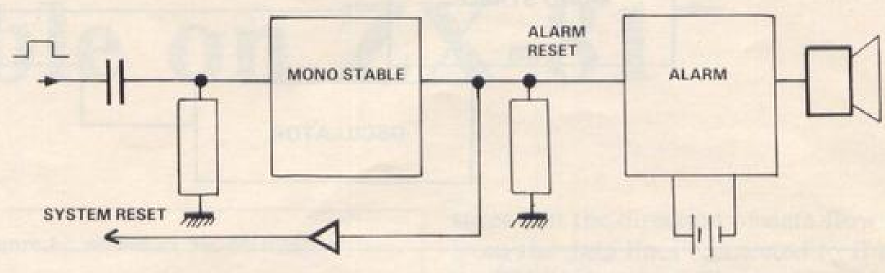


power supplies. The battery could be re-chargeable and a 'low battery' alarm may be included.

Two circuits are given, both using a single CMOS logic IC.

In figure three C_1 and R_1 ensure that the output of the first gate goes low only momentarily. When a positive-going pulse is received at the input to C_1 a positive pulse appears at the input to gate 1 which inverts the pulse. The manufacturer's data states that the input voltage must not exceed VDD or fall below VSS by more than 0.5V.

Figure 1.



The negative-going pulse will overshoot that limit by a large amount but, probably because of its short duration, I have not yet observed any ill-effects. A diode may be used to suppress the negative pulse, if required.

Capacitor C_2 is charged by the negative pulse from gate one. Diode D_1 prevents the capacitor being discharged again as the output of gate 1 goes high. C_2 discharges slowly through R_2 providing a high on one input of gate 4 unless regular pulses are received to keep it charged.

Gates 2 and 3 form an oscillator whose period is determined by C_3 and R_3. The pulse train appearing at pin 12 of gate 2 will appear only at the output pin 11 when pin 13 is high. This is a NAND being used to enable or disable the passage of a pulse train. A piezoceramic transducer is used as the audible warning device.

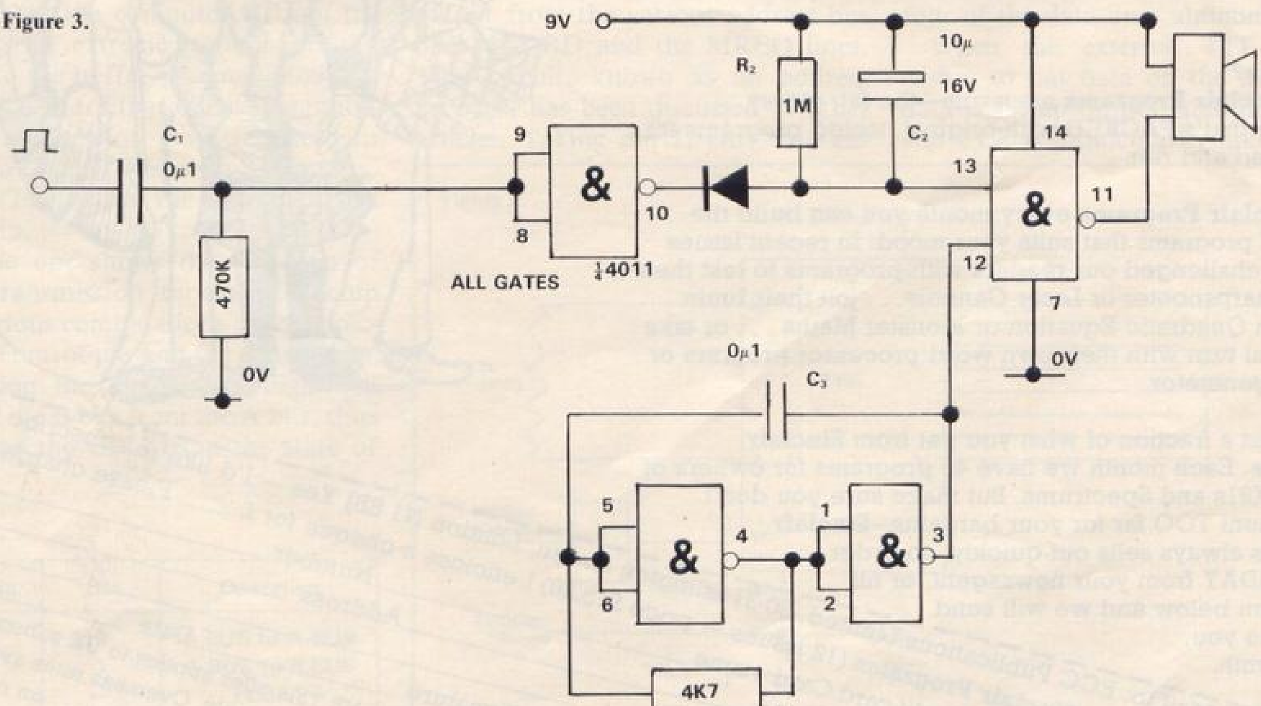
The prototype circuit works well from 5V to 15V. Gate 2 operates in its linear region, between high and low, so that it is not fully off or fully on all the time. As the frequency of the input pulse is increased it will turn off more and the tone will become quieter. The components shown result in an almost inaudible tone with an input pulse frequency of 1Hz.

When a 4094 was substituted for the 4011, the cut-off of the tone was very sharp but some breakthrough of the sound was heard on the transducer. The second circuit shown in figure five was found to be more effective with this IC.

The Watchdog can be made to generate a re-set pulse which may re-start some systems, and it can be latching. This one is not. A Sinclair has not been known to crash and then recover.

So when you set up your control or monitoring system and switch off or unplug the TV set there is no need to wonder whether the computer is still working or not. If there is no alarm, it is working.

Figure 3.



CENTRAL HEATING II

Figure 4.

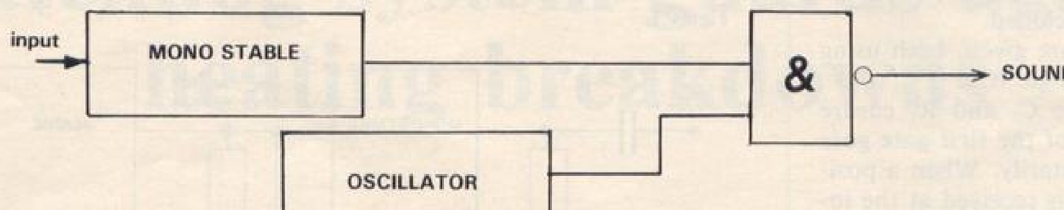
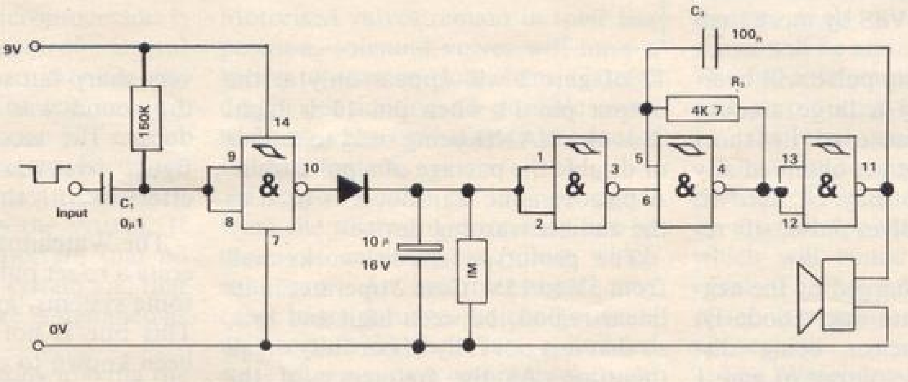


Figure 5.



FREQUENCY GAUGE

Frequency comparison possible on ZX-81

It is possible to attach a number of devices to Sinclair machines. Alan Pritchard considers ways of measuring inputs.

ONCE YOU have decoded I/O on Sinclair computers it becomes possible to attach a range of devices to the system. We deal with a number of interface chips and the outline of a future project to use the ZX-81 as a frequency meter.

The first device considered is the 74LS245, a three-state buffer chip. When it is enabled, i.e., it is not in its float state, the outputs of the device follow the inputs to the device. Any change in the input state is immediately reflected at the output.

Apart from the usefulness of the three-state buffer, it is also extremely valuable in preventing accidental damage to the computer. If you try placing an extreme voltage on the input to the buffer you may blow the buffer chip; try that on the computer data bus and you may well need to write to Sinclair Research for repairs. Figure one shows the pinout of the 245 chip.

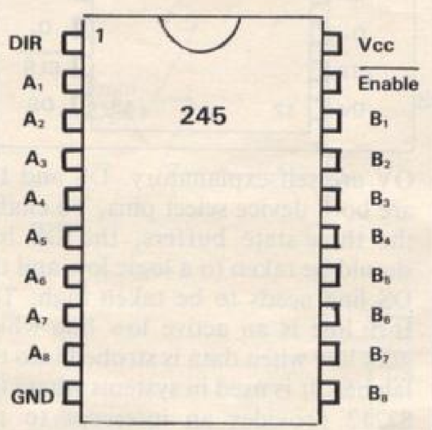
Table one shows the direction of data transmission through the chip for various combinations of the directional control pin and the enable pin.

Taking the enable pin high will isolate the B bus from the A bus, thus isolating the CPU from the state of the B bus, assuming that the A bus is connected to the data bus of the ZX-81, as shown in figure two. The line on the diagram emerging from the decoded address bus is provided from a circuit which provides a 1 output from the various address bus lines, the RD and the MREQ lines. That circuit, known as an address decoder, has been discussed in other articles. Taking pin 1, Dir, to 0 ensures that the direction of data flow is from the data lines connected to B to the ZX-81 data bus. The enable line is connected to cause the lines to float whenever the chip is not being addressed.

Table 1.

Enable	Dir	Operation
0	0	B BUS to A BUS
0	1	A BUS to B BUS
1	—	FLOAT

Figure 1. pin-out of the 74LS245

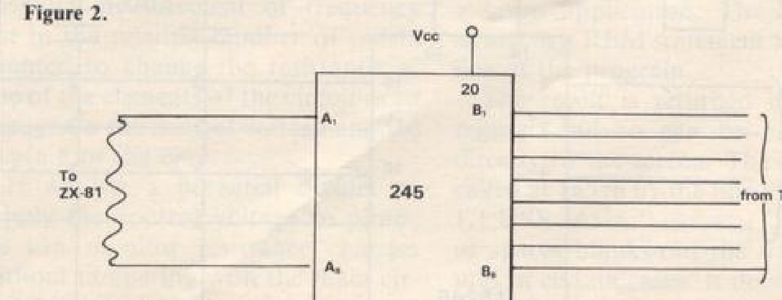


Using this simple circuit, it is possible to read TTL levels, via the buffer, from a program using the Basic PEEK instruction or the machine code LOAD instruction. The address obviously would depend on the design of the address decoder employed. It is often desirable to latch the input states which occurred at a certain moment, thus preserving the state of the lines until the computer looks at them.

To do that, we could use a conventional LSTTL latch, such as a 74LS75 quad latch. To latch the whole data bus, two of those chips would be required. Figure three shows how to use the chip to catch fast pulses. Only four of the data lines are latched.

When the external TTL circuit wishes to put data on the latch, the data is set up on the latch data lines and CLK is momentarily taken high,

Figure 2.



thus latching the input levels on to the Q lines of the LS75 chip. Those levels will stay until another clock pulse is applied to CLK.

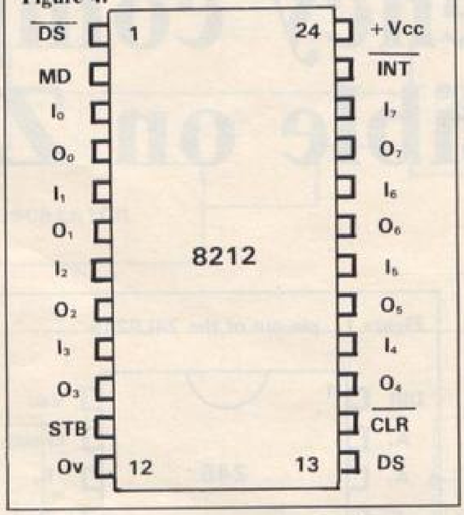
The levels on the Q lines can then be read at any time by the computer. The CLK can, if desired, be supplied by the ZX-81 address decoding circuit. The latter option means that the computer would get whatever data was on the input lines to the latch at the time the circuit was addressed. The two capacitors de-couple the TTL chips to prevent false switching occurring.

There is an easier way to achieve the same result. The 8212 chip, which was designed initially for use with the 8080 processor as a general-purpose in/out latch, combines the function of eight-bit latch and three-state buffer on the single chip. The difference between that chip and the 245 device is that the 8212 is only unidirectional; there is no pin on the 8212 which enables the user to switch the direction of data flow through the chip.

The 8212 affords the user a simple method of producing a buffered and latched eight-bit data bus for a microprocessor system. The pin-out of this useful device is shown in figure four.

First, an explanation of the labelling in the pin-out diagram. Vcc and

Figure 4.



OV are self-explanatory. $\overline{DS}$ and DS are both device select pins. To enable the three-state buffers, the $\overline{DS}$ line should be taken to a logic low and the DS line needs to be taken high. The $\overline{INT}$ line is an active low line which goes low when data is strobed into the latches. It is used in systems where the 82212 provides an interrupt to the CPU to inform the CPU that some action needs to be taken immediately to deal with the data on the 8212. It is not used in this project.

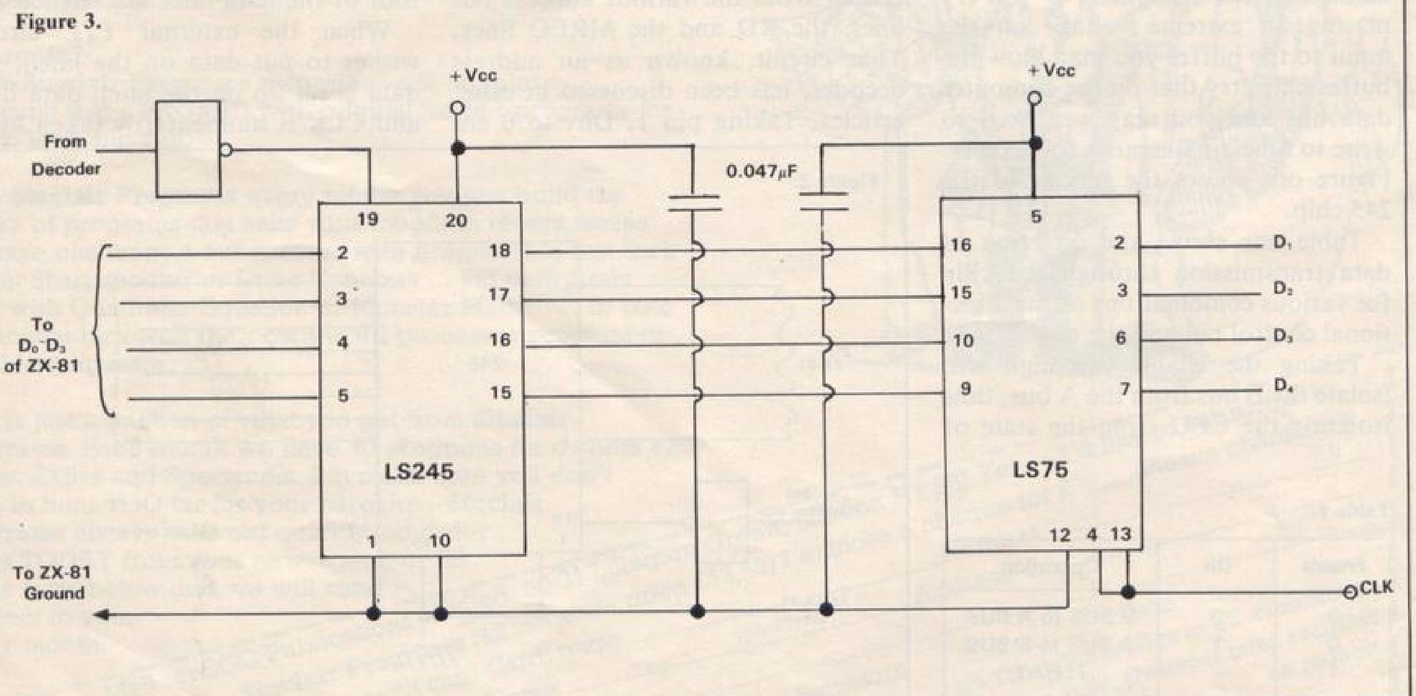
The $\overline{CLR}$ line, when taken low, clears the latches of any data. I0 to I7 are the data input lines to the 8212 and are connected internally to the inputs of the latches. O0 to O7 are the data output lines and are connected internally to the outputs of the three-state buffers contained in the 8212. If an 8212 is to be used as an output device, connect lines I0 to I7 of the chip to the D0 to D7 lines of the ZX-81. If the 8212 is to be used as an input device, lines O0 to O7 are connected to the ZX-81 data bus. The remaining lines of the 8212, MD and STB, are a little more involved.

The state of the MD line dictates whether data on I0 to I7 is strobed into the latches by the strobe line, STB, or by the device select logic. Consider the situation where MD is held high. The device select logic will clock the latches, thus placing any data on the input lines when the device was selected on to the output lines, O0 to O7.

There is a simple way of providing an output circuit for the ZX-81 using that device—figure five. The STB, $\overline{CLR}$ and MD lines are tied to Vcc. Whatever data is on the data bus of the ZX-81 when the device is selected will be put on to the latch. That can be done with the Basic POKE instruction or with the machine code LOAD instruction.

In that mode of operation, the

Figure 3.



FREQUENCY GAUGE

three-state buffers are permanently enabled. Thus the mode is not really of any use for input to the computer, as it would lead to a state of affairs similar to that with which we started—the lack of three-state buffering on the data bus, as an enabled three-state gate acts in a similar way to a TTL buffer, reproducing at its output the logic state at its input.

What is required for input to the micro is a state in which the three-state buffers are in the float state until the device is selected by the address decoding circuits of the computer. That can be done by tieing the MD line to O. Taking STB high puts data on to the latches but the data buffers are disabled until the device is selected by $\overline{DS}$ and DS. Data input can be simplified by tieing the strobe line to Vcc. Thus each change in input data is reflected in the state of the latches and the state of the input lines at the moment of device select appears on the data bus of the micro. The circuit for that mode is shown in figure six.

One of the applications is simple digital control circuits, in which the computer turns-on other devices under program control depending on the state of input lines to the system. Most signals from outside, however, are not digital—they are analogue—and what is really needed to measure the signals is one of the analogue-to-digital converter chips, the most common of which are the ZN427 and ZN427E.

It is possible to use the common 555 timer chip in the astable mode to estimate analogue quantities such as voltage and resistance.

Figure seven shows the circuit for the astable mode of operation of the device. The output is a square wave of TTL levels, the frequency of which depends on the two resistors and the capacitor in the circuit and also the potential difference on pin 5 of the chip.

Frequency measurement of the signal given could be accomplished by simple software by counting the level transitions in a given period. In one second, for example, the number of transitions from 0 to 1 and 1 to 0 would give a value twice the frequency of the square wave. In the first instance, we are not interested in the absolute measurement of frequency but in the relating number of pulses counted to change the resistance of one of the elements of the circuit or to changes in the control voltage applied to pin 5 of the chip.

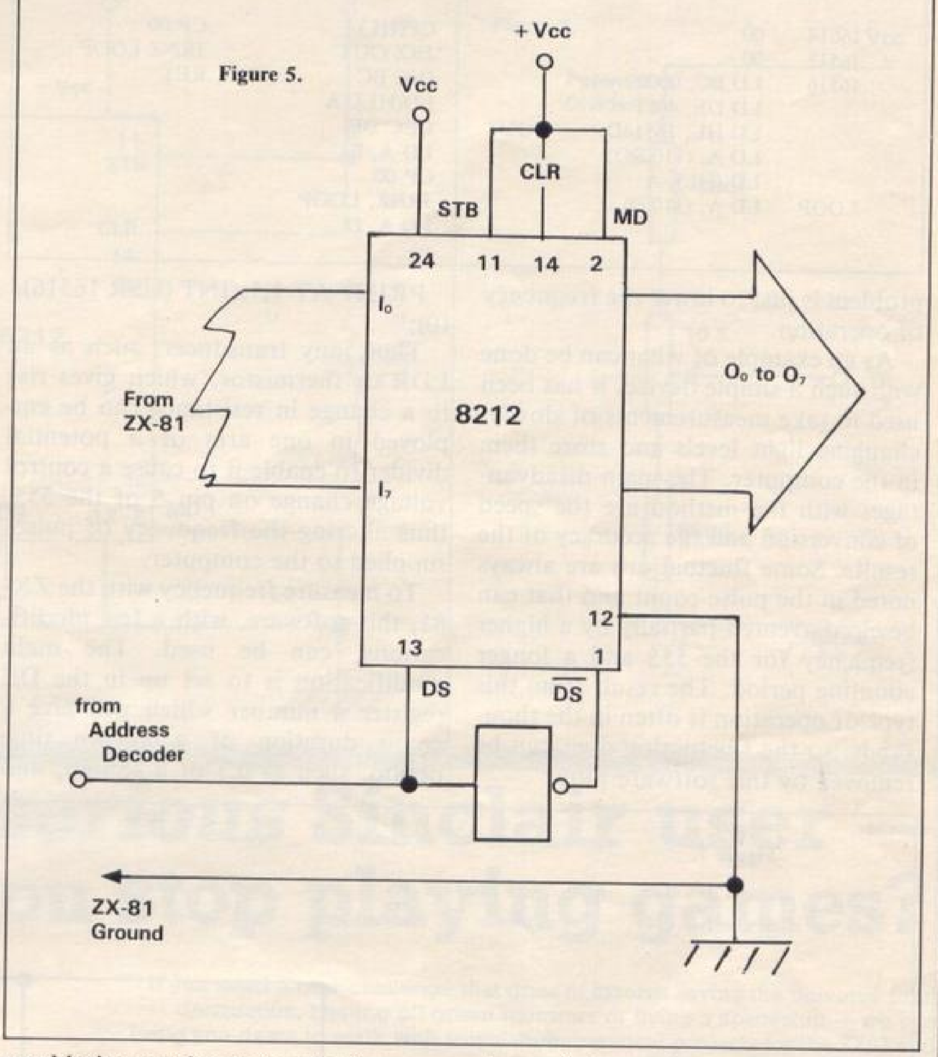
If we use a potential divider to supply the control voltage to pin 5, we can monitor resistance changes without tampering with the main circuit—figure eight.

The machine code routine for counting the transitions is shown in program one. The 11000D is the address of the 8-bit latch used in this application. The BC register is used to keep count of the pulses and the DE register is used to time the duration of the pulse-counting interval. The contents of the DE register can be varied to obtain the best results for a given application. The code was stored in a REM statement as the first line of the program.

The result is returned in the BC register and so can be printed-out directly to the screen. The routine is called at 16516 by the line PRINT AT 1,1;USR 16516;"   ". The line of spaces blanks-out the trailing figures in certain cases. It does not matter in this program which of the eight input lines is connected to pin 3 of the 555 circuit, as the software just looks for transitions.

If the frequency of the 555 causes transitions faster than the machine code can pick up, very peculiar results will be obtained. The answer to the

Figure 5.



FREQUENCY GAUGE

Program 1.

```
16614    00                      CP(HL)            CP 00
16515    00                      JRZ OUT           JRNZ LOOP
16516    LD BC, 0000             INC BC            RET
         LD DE, 40FF             LD(HL), A
         LD HL, 16514D      OUT  DEC DE
         LD A, (11000D)          LD A, E
         LD (HL), A              CP 00
LOOP     LD A, (11000)           JRNZ, LOOP
                                 LD A, D
```

problem is just to lower the frequency of operation.

As an example of what can be done with such a simple device, it has been used to take measurements of slowly-changing light levels and store them in the computer. The main disadvantages with the method are the speed of conversion and the accuracy of the results. Some fluctuations are always noted in the pulse count and that can be circumvented partially by a higher frequency for the 555 and a longer counting period. The result from this type of operation is often in the thousands, so the fluctuating digit can be removed by this software ploy:

PRINT AT 1,1;(INT (USR 16516)/10);"   "

Thus, any transducer, such as an LDR or thermistor, which gives rise to a change in resistance can be employed in one arm of a potential divider to enable it to cause a control voltage change on pin 5 of the 555, thus altering the frequency of pulses supplied to the computer.

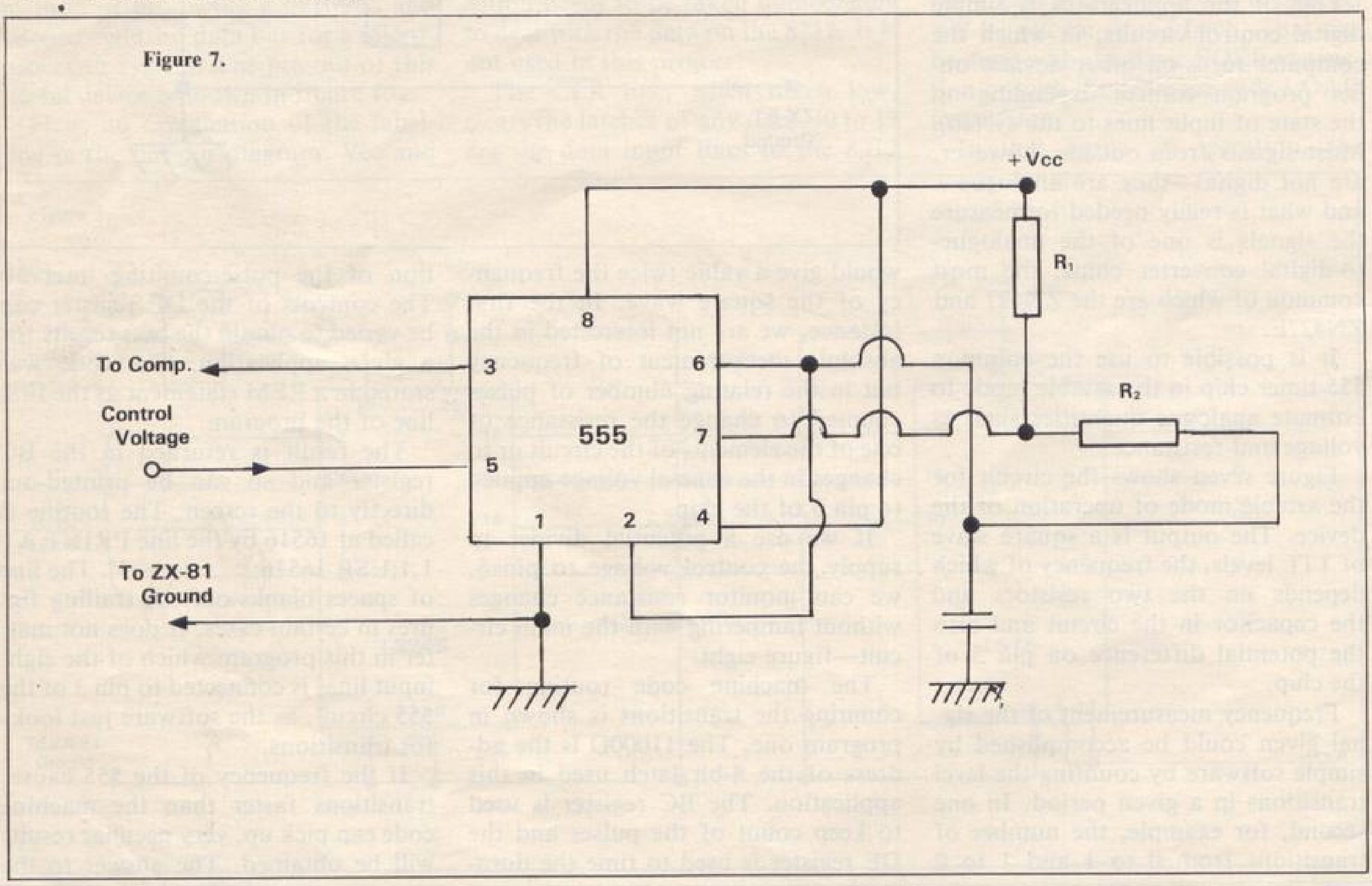
To measure frequency with the ZX-81, this software, with a few modifications, can be used. The main modification is to set up in the DE register a number which will give a count duration of a known time period, such as 0.1 of a second, and then count the pulses which come in in that time. If we divide the pulse count by two and then, in this instance, multiply by 10, we have the number of complete cycles in one second, which is the frequency. To set up that value, build a 555 circuit of fixed and known frequency with components selected so as to give a steady frequency.

Equation one shows the relationship of F to component values and so it is possible to determine the frequency for a given circuit. It is then a matter of trial and error in getting the count value for the DE register. To measure the frequency from other circuitry, the signal would have to be converted into a square wave by a device known as a Schmitt trigger. They are commonly available in LSTTL as the LS13 device.

Equation 1

$$F = \frac{1.4}{C\,(R_1 + 2^{*} R_2)}$$

Figure 7.



FREQUENCY GAUGE

Figure 6.

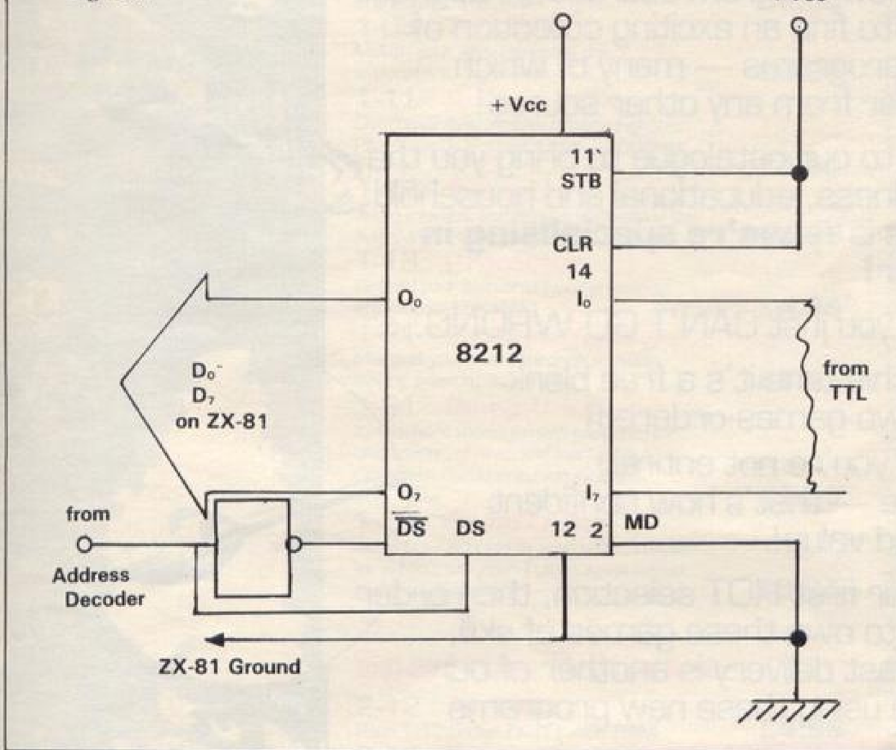
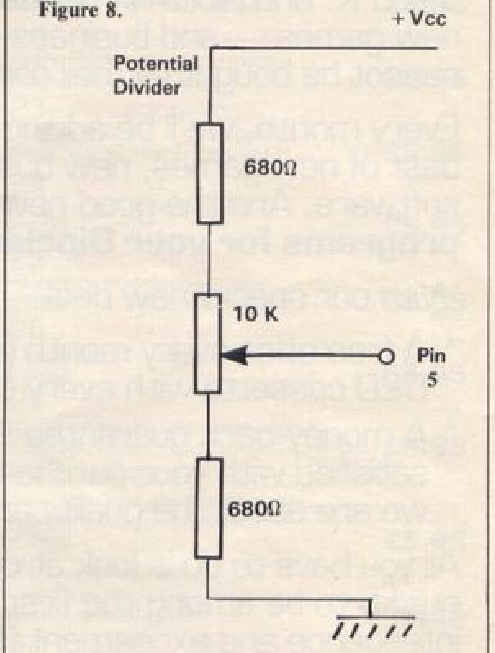


Figure 8.



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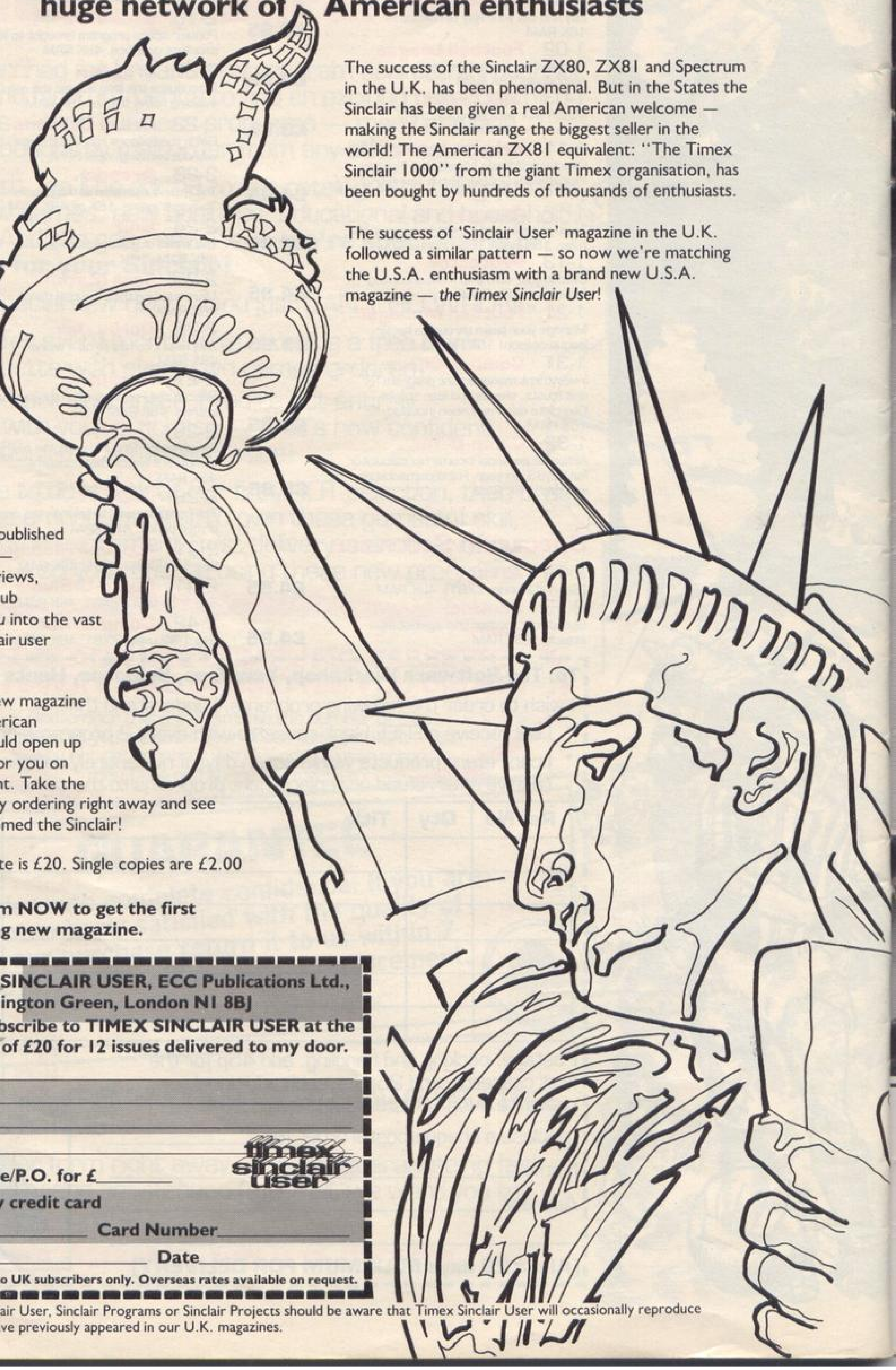

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