

Top Projects

1988



A collage of magazine covers from ETI Electronics Today International, featuring various electronics projects and advertisements. The covers include:

- Top Cover:** "Top Projects 1988" with a sparkler and a screwdriver.
- Second Row:**
 - Left: "BAR CODE LOCK" with a "WIN £2500" sticker and a handwritten number "6727229".
 - Middle: "QUARTER LOADS" and "RANDOM NUMBERS".
 - Right: "STATE OF THE CHAIR" and "PI-CIRCUIT TV world beater project".
- Third Row:**
 - Left: "Be it Known" advertisement for careers and education.
 - Middle: "THE MORTON DIFFERENCE" and "BURGLAR-ALARM SYSTEM".
 - Right: "SPEEDY Doppler Speed Gun Project" and "FREE" offer for a burglar alarm.

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The year's top projects from Britain's top electronics monthly



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The leading mag for the electronics enthusiast – out on the first Friday every month

Top Projects

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EDITOR

Geoff Bains

ASSISTANT EDITOR

Jez Ford

CONTRIBUTORS

Keith Brindley
Paul Chappell
Ian Coughlan
Paul Cuthbertson
John Dix
Graeme Durant
Nick Flowers
Richard Grodzik
Chung Yiu Ko
Ziad Mouneimne
Robert Penfold
Geoff Phillips
Greg Thompson
Leycester Whewell
Paul Wilson

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BICYCLE SPEEDOMETER

Leycester Whewell not only knows where he's going but how fast he's getting there too

This article in fact describes my Mark II bicycle speedometer. Since Mark I was built (in 1982) new semiconductor chips have enabled projects such as this to be built from fewer and more compact components and yet provide a greater number of features than originally possible.

As well as being suitable for a bicycle, this speedometer could also be adapted for other tasks of a similar nature.

The main aim of the design is to produce a unit low on power, simple to maintain and operate, reliable and capable of giving as much useful infor-

The four digit LCD on the Mark I was a limitation when it came to displaying elapsed time. To fit in a decade of hours, the seconds count had to be reduced to tenths of a minute. After numerous hours riding, a mental conversion back to seconds had to be done before the reading became meaningful.

The advent of triplexed LCDs and their respective driver chips has enabled more digits to be fitted into a display without an absurd number of connections. An eight digit LCD has been incorporated into this speedo with an ICM7231BFIPL driver.

Elapsed time can now be shown in seconds, minutes and four decades of hours. Distances need no longer wrap around to zero after 999.9 miles. The other main advantage of the triplexed LCD used is the annunciator arrow — there is one beneath each digit and these are used to indicate the operation mode.

A useful feature of most single chip or related low chip count systems is the standby mode. The 146805 has two, called WAIT and STOP. In the WAIT state the crystal oscillator and timer operate but when the timer counts down to zero or there is an external interrupt then normal processing is restarted.

The speedometer enters the WAIT state between regular timing intervals and the external interrupt caused by one revolution of the wheel. During this period the current consumed is about 1.5mA compared to 7.8mA during normal processing.

The relative proportions of time spent processing and WAITing determine the overall power consumed by the speedometer. A fixed proportion of time is spent servicing the time interrupts but the amount spent on wheel interrupts is directly proportional to speed. So whilst stationary about a 2mA is consumed and this rises to 2.5-3mA at 20mph.

The STOP state consumes less current than the WAIT state, because the crystal oscillator and timer also stop. If after a period of about a minute there is no interrupt due to the rotation of the wheel then the speedometer will clear the display and enter the STOP mode. To the user this gives the impression of it having turned itself off.

An interrupt from the wheel ends the STOP state and the speedometer updates the display and continues as before. This obviates the need for an on/off switch and allows data to be preserved from one period of use to another. About 0.5mA is consumed during the STOP state, so a set of four NiCds with a capacity of 450mAh will last 28 days if the speedometer is used for two hours a day. Changing the batteries every two to three weeks will allow a safe margin for leakage and variations in cell capacity due to ageing.

To preserve data in the processor when changing batteries, a lithium data retention battery and a diode prevent the supply voltage from dropping below about 2.5V. The batteries should only be changed when the speedometer is in the STOP state, this prevents excessive use of the lithium battery and (worse) running the processor from a

Mode	Display	Function
Set up Mode 0	-1-	X=0 for Imperial, 1 for metric units
Set up Mode 1	-2- XX. XX	Wheel size, from 18.00in to 28.00in
Mode 0	XXXXXX. XX	Total Distance (miles/km)
Mode 1	XXXXXX. XX	Trip Distance (miles/km)
Mode 2	XXXX.XX. XX	Total Time (HHH.MM.SS)
Mode 3	XXXX.XX. XX	Trip Time (HHH.MM.SS)
Mode 4	XXX. X	Current Speed (mph)/kmh)
Mode 5	XXX. XX	Top Speed (mph/kmh)
Mode 6	XXX. XX	Average Speed (mph/kmh)
Mode 7	XXX. 0	Time Trial Distance (miles/km)

Table 1 Display modes



mation as possible. I also wanted the Mark II version to behave more like a mechanical odometer in that it would not have to be turned on or off every time it was used and that the information would be preserved indefinitely without worrying too much about battery life.

Finally, since only a few units were to be built, the components had to be cheap and easy to use — no mass production here to bring down costs.

Choosing Chips

Several families of CMOS microprocessors have become readily available since building the Mark I (which used the 1802). These include the 80C35 and 80C85 series, the HD6303 and HD6305 series and the 146805 series.

Apart from the HD6303 which has an awkward 0.07in pin pitch, each series has a suitable member for making a speedometer. The 146805 was chosen since I already had an assembler for it and knew several sources from which it was readily available.

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supply voltage that is too low for the crystal frequency used. If this happens and the processor crashes then all data contained within it will be lost.

The Hall effect switch used to detect rotation of the wheel in Mark I worked perfectly in all conditions. However, as it consumed a relatively massive 3mA, an alternative had to be found which would not drain a set of batteries in a few days. The only form of detector that does not require a steady current source involved direct contact switching. A reed relay mounted so its axis was parallel to that of a bar magnet mounted on the wheel and perpendicular to the adjacent spokes was found to be suitable.

Debouncing of the contacts is performed in software, the current consumption is reduced to grounding a pull-up resistor when closed and only two wires are needed from the speedometer.

Initial operation of the relay proved to be problematic, each wheel revolution caused the relay to close three times in quick succession. I found that the relay was passing too close to the magnet and induction through the relay contacts was responsible. Increasing the minimum separation between them to over 5mm for that particular magnet cured the problem.

Operating Modes

Ten modes of operation are available. Eight are for normal use with two special ones for parameter setting. Special mode 1 is entered after the power-on reset which occurs when the batteries are inserted for the first time only. This mode is used to set the units used — imperial units are represented by a 0 and metric units by a 1. Changing from one to the other is done by pressing the reset switch. A third option, number 2, has been reserved for metric units with speed in metres/second although the additional program to do this is not written.

Pressing the mode switch selects special mode 2 which selects the wheel size to be used. Eight of the most common wheel sizes are displayed in turn by pressing the reset switch and range from 18in to 28in with 700mm being displayed as 27.56in. Pressing the mode switch again then selects the first of the normal modes.

Each of the normal modes is associated with one of the annunciator arrows under each digit of the display. When the modes are changed, as listed in Table 1, the arrow moves one digit to its right and back to the digit on the far left when the Total Distance mode is re-entered. If both switches are pressed together for over a second then the special modes are re-entered for a change in units or wheel size.

HOW IT WORKS

There is not a lot to be said about this circuit that isn't already said in the main text. The full circuit diagram of the speedometer is shown in Fig. 1.

The microprocessor (IC1) contains its own clock oscillator, requiring only the external components, X1, R6, C3, 4. The two 8-bit ports of the chip's built-in PIA are used to directly interface the LCD driver chip (IC2), the two control keys (SW1, 2) and the reed relay sensor. The latter also acts on the processor interrupt input.

The EPROM (IC3) containing the speedometer program is the only external device occupying the memory space of the processor and is directly mapped using IC5c and IC4.

Power is provided by either the NiCd batteries B1 with protection diode D1 or through the standby data-retention cell B2. Power on reset is provided by R1, C1.

As their names suggest, the Total Distance and Time modes keep a record of the total usage of the speedometer. They cannot be cleared using the reset switch. Neither mode will wrap around to zero in a hurry — it takes a million miles/km or 10,000 hours to do so!

The Current Speed mode does just that, displaying with a resolution of 0.1mph/kmh and the Top Speed mode displays with a resolution of 0.01 mph/kmh. Measuring to 0.01 mph/kmh is meaningless as far as absolute readings are concerned because of the error in the diameter of the wheel but it is useful when a comparison is made to a previous effort. Top but not Current Speed may be reset.

The remaining four modes are linked by the need for a common measurement origin. Trip Distance and Time display data in the same format as their Total Distance/Time counterparts and Average Speed is simply their ratio. Average Speed uses a time base of 3.6sec (0.001hr), distance in units of 0.01 miles/km and produces a result in 0.01mph/kmh. Its accuracy increases with both distance and time, so after about an hour

TOP PROJECT

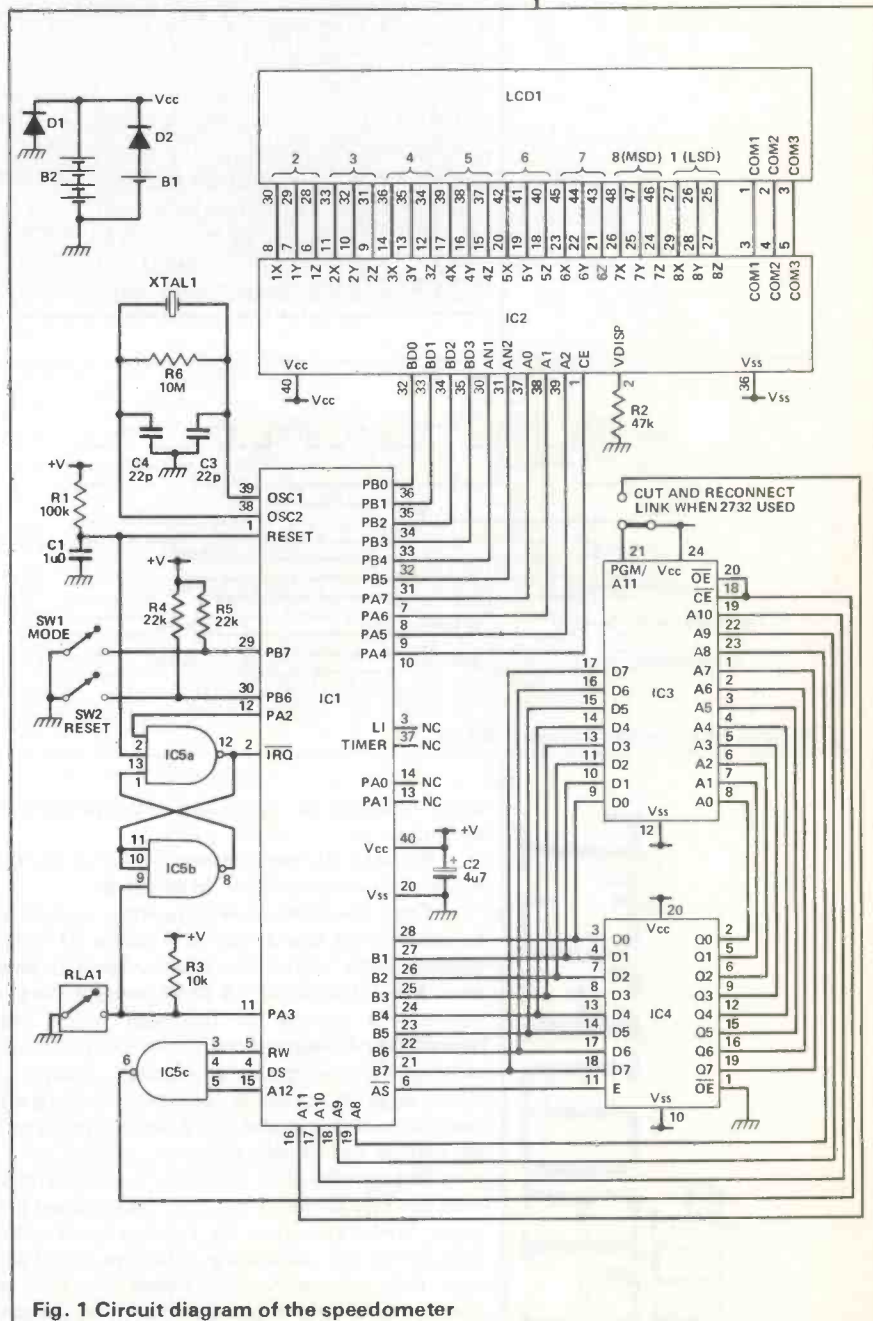


Fig. 1 Circuit diagram of the speedometer

THE 146805E2

The 146805E2 is a CMOS microprocessor based around a cut down version of the 6800. It contains one 8-bit accumulator (A), an 8-bit index register (X), a 5-bit condition code register, a 13-bit program counter (giving an 8K addressing range) and a 13-bit stack pointer.

The upper seven bits of the stack pointer are fixed so that the stack uses the top 64 of the 112 bytes of internal RAM (which runs from &0010 to &007F). All remaining locations in the memory map are available for use by external hardware with the interrupt vectors placed at the very top.

Two 8-bit I/O ports and their corresponding data direction registers are also in the zero page memory map along with the timer and its control register. The input to the timer may be from the processor clock or from the TIMER pin (or both ANDed) and a software selectable prescaler can be used to divide the input by powers of 2-128. The output from the prescaler goes into an 8-bit timer counter which can generate an interrupt when it counts down from &01 to &00.

An on-board oscillator simplifies the clock circuitry and crystals up to 5MHz may be used when $V_{cc}=5V$. The maximum crystal frequency allowed falls linearly with supply voltage to 1MHz at $V_{cc}=3V$.

Five clock periods are used per bus cycle, the relative timings for which are given in Fig. 2. To save pins, address lines 0-7 are multiplexed with the data bus. The falling edge of the address strobe (AS) latches the address in the earlier part of the cycle leaving the latter part of the cycle for data.

Data may be placed on the bus when the Data Strobe (DS) is high and is latched by the receiving device on its falling edge.

Software

The Speedometer program is driven by two sources of interrupt, one from the internal timer which times out at 80Hz and the other from the wheel relay at one per revolution. The timer interrupts are used to update the time modes and scan the mode and reset switches. By making full use of the 8-bit counter the period of the wheel rotation can be measured to a resolution of 1/20480sec.

This leaves the diameter of the wheel as the sole source of any significant error. Each wheel revolution triggers a background program to update the distance and calculate the speed — average speed is only calculated when needed for display.

The main problem with having two independent interrupt sources is the potential for conflict when both occur together. This is more serious for the wheel interrupt since delays in reading the time at which it occurs will result in the wrong speed being calculated. To ensure wheel interrupts are not delayed, the timer interrupt routine clears its source immediately and enables interrupts before continuing with advancing the time.

In return, the wheel interrupt must be very short so there is no possibility of another timeout before the previous one has been properly processed. Therefore the wheel interrupt simply reads the current time (and checks if a timeout is imminent to check for overflows), sets a flag and terminates.

A background program continuously tests this flag and when set it updates the distance counters, calculates the speed (and average speed if need be) and checks for top speed. When that is done the flag is cleared ready for the next wheel interrupt. The time taken to do all that is comparable to the time interrupt period and therefore cannot be included within the wheel interrupt routine.

Each time a wheel interrupt routine has been processed by the background program, the display is updated. One consequence of this is that in the average speed mode, the reading will not gradually decrease while the bike is stationary simply because no wheel revolutions are occurring to trigger a new calculation and display update. If a wheel interrupt has not occurred for one minute then the display is blanked and the STOP mode entered.

When the background program is not being executed the power-saving WAIT state is entered. Processing halts although the crystal still oscillates and instruction execution commences on receipt of the next wheel or timer interrupt.

The setup modes determine several parameters for the main program. The wheel size determines the amount which is added to the sub 0.01mile/km distance counters each time the wheel revolves. Each time that 0.01mile/km is passed, an amount corresponding to 0.01mile/km is deducted from the counter and the trip and total distance registers are incremented. Both are kept in BCD format which makes it simple to send to the display — and saves a lengthy series of calculations every time the display is updated.

A binary count of the trip distance is updated in parallel to the BCD count. This is used for calculating the average speed in a form ready for division by the trip time.

The total and trip time registers are also updated in BCD format for the same reasons as

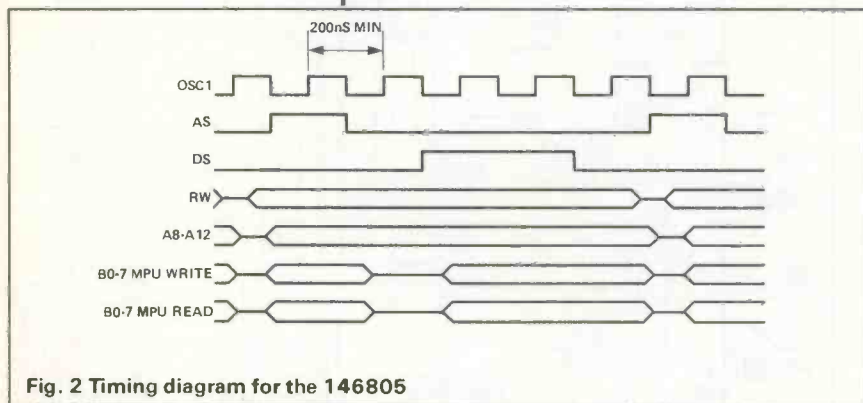


Fig. 2 Timing diagram for the 146805

some meaning can be attached to the 0.01mph/kmh digit.

Pressing the reset switch in any of the three modes will clear the data in all three.

The Time Trial mode is the most complicated to use and yet one of the most useful. This mode displays a trial distance in whole miles/km ranging from 1 to 100 inclusive. A short press of the mode switch will change to the next mode but if depressed for over a second then the trial distance will count round until it is released. Then on the falling edge of a press of the reset switch, the trip functions are all cleared and a decimal point on the far right of the display is set.

The speedometer will then function as normal until the Trip Distance reaches the value set in the Time Trial mode. The far right decimal point is then turned off and the trip functions are inhibited until they are reset. This allows the time and average speed at the trial distance to be preserved until a suitable time is found for them to be read.

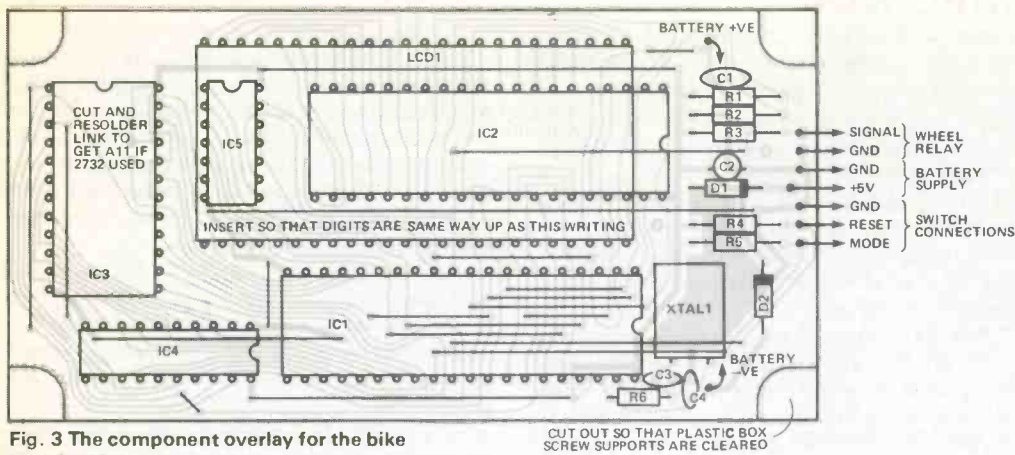


Fig. 3 The component overlay for the bike speedometer

the distance registers. A binary count of the trip time is also kept ready for calculating average speed. To save on processing time (and hence power) the average speed is only calculated in the mode in which it is displayed. Each time the display is updated the distance is multiplied by 1000 before a 32-bit division by the trip time takes place. This produces the result in the correct units for display. All that is left now is a series of divisions by 10 to convert the binary result into BCD.

When selecting between imperial and metric units, all that is done is to select a different table for the wheel sizes. Each entry in the metric list is 1.609344 times as big as its imperial counterpart so the distances come out in km rather than miles. No other changes are necessary since the time base used to calculate speed is the same in both cases.

One feature of the speedometer is that when a change of units is made, the total and trip distances are corrected accordingly. This involves converting the BCD counts to binary, scaling up or down by a factor of 1.609344 and then converting back from binary to BCD. Going to and from another set of units usually results in a loss of 0.01mile/km due to rounding off in the division routine.

Construction

A single sided PCB (see Fig. 3) has been produced for the speedometer which fits into a 120x65x40mm plastic box. Boxes of exactly the

BUYLINES

A few of the components required for this project are difficult to come by. The processor (IC1) can be obtained from Jermyn Distribution (Tel: (0732) 450144) as can the LCD driver (IC2). The LCD itself can be purchased from Verospeed (Tel: (0703) 644555) or from Farnell Electronics (Tel: (0532) 636311) as part number 175-595. Farnell is usually unwilling to trade with the public but all Farnell components may also be obtained from Trilogic (Tel: (0274) 684289).

The author can supply programmed EPROMs for this project for £6 (if EPROM supplied — note this project uses a low power 2716) or £14 inclusive of the EPROM. The EPROM source code is available copied onto a BBC micro disk (40 or 80 track disk supplied) for £7.50 or with the 6805 cross assembler for £15. The author will also make up boards from the ETI PCB Service without the case or EPROM for £41.

Please address software board make-up enquiries and orders to Leycester Whewell, 1 Park Terrace, Berrington Road, Tenbury Wells, WR15 8EJ.

PARTS LIST

RESISTORS (all 1/4W 5% unless specified)

R1	100k
R2	47k (1%)
R3	10k
R4, 5	22k
R6	10M

CAPACITORS

C1	100n ceramic
C2	4µ7 tantalum
C3, 4	22p ceramic

SEMICONDUCTORS

IC1	MC146805E2 or CDP6805E2T
IC2	ICM7231BFIPL
IC3	ETC2716Q
IC4	74HC373
IC5	74HC10
D1	1N4001
D2	1N4148
LCD1	8-digit triplexed LCD

MISCELLANEOUS

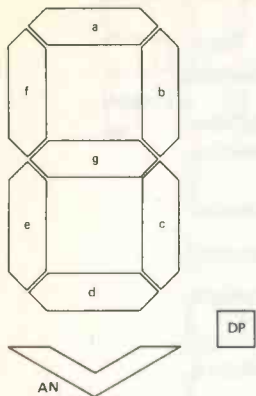
B1	4X1.2V NiCd batteries and holder
B2	3.6V AA lithium cell
SW1, 2	SPST push switch
RLA1	Reed relay
X1	3.2768MHz crystal
PCB	Bar magnet. 2X24-way socket strips for LCD (if required). Connecting cable. Case. Clear sticky plastic.

same size are also made in diecast aluminium and both have four 3mm screws to attach the lid to the rest of it.

The four corners of the PCB must be radiused so clearance is provided for the columns into which the lid screws fit. The PCB is marked for this.

The first thing to do is to solder the wire links into position on the PCB. There are nearly 20 of these and some run underneath the ICs. Insulating wire should be used (wire wrap is best) since a number of links are close together. The next stage depends on your use of IC sockets.

If the EPROM is the only device destined for an IC socket then the other ICs can be soldered straight in — paying particular attention to their orientation. The remaining passive components can also be soldered straight in — extra support should be given to the liquid crystal display with double sided sticky foam.



CONNECTIONS TO EACH DIGIT

	COM1	COM2	COM3
X	f	e	AN
Y	a	g	d
Z	b	c	DP

Fig. 6 Connections and multiplexing of the triplexed LCD

TRIPLEXING

An important consideration for the design of any display with a large number of independent elements is the arrangement of connections to the driver circuitry.

With large displays this is a large problem since the number of connections which have to be made means it is difficult to keep pins to a DIL format.

The simplest way to cut the number of connecting pins (and as a consequence, the complexity of the drive circuit) is to multiplex the display. This means that each character of the display is only active for a short period of time (of the order of several ms) before giving way to the next one.

The cycle for the whole display must be repeated at least 30 times per second so the human eye responds to a time-averaged light level from each character. It cannot normally detect that each digit is on for a fraction of a second.

Multiplexing LEDs is very straightforward. Each character of the display has either all the anodes (or cathodes) of the component LEDs joined together and these are fed to separate drive outputs. Each cathode (or anode) of a LED in a character is wired to the corresponding one in each of the other characters. These also go to a set of drive circuits.

So, for a 4-digit display of seven segments each, there would be four connections for the digit common wires and seven connections for the segment wires — a total of 11 wires to drive 28 display elements.

For each character in turn, current is allowed to flow through its common terminal only while current is allowed to pass through those segments of that character which are on. The remaining digits are all blank until it is their turn in the cycle.

Multiplexing does have limitations. For an n-character display, each can only be active for 1/n of the time for each cycle, so n is usually under 10. Otherwise there is a problem with overall brightness.

The same principle of multiplexing applies to liquid crystal displays as well. However, it is far more complex because an ordinary LCD is driven with alternating current — a feature which is necessary to prevent electrolysis of the display fluid.

A square wave signal (about 30-200Hz and 3-4V peak-to-peak) is applied to the backplane of the display. The amount of contrast produced by each element depends upon the difference in voltage levels compared with the backplane. An element which is off has the same voltage levels applied to it as the backplane so the difference is always zero. An element that is on has the opposite voltage to the backplane applied to it which keeps a constant difference between them.

Since each element must always be kept at the same or opposing voltage to the backplane, a new approach must be found for multiplexing. As indicated earlier, the contrast depends upon the difference in voltage levels between the segment and the backplane. Since the whole system is running on alternating current it is possible to calculate a root mean square (RMS) voltage difference between the two beyond which an element will appear to be on and below which it will appear to be off.

An RMS voltage of under 1.1V produces a low contrast so that the element appears to be off. Above 2.1V the contrast is such that the element is on. These thresholds decrease as temperature increases at a rate of about 7mV per °C.

The greater the ratio of RMS voltages for 'on' to 'off' elements the better because this also increases the display viewing angle.

In the display used in the speedometer there are three backplanes running parallel to another along the length of the display. Each digit has three connections to it called segment lines (they run across the display) which make a matrix of nine points with the backplanes.

A display element is placed at each crossing point (see Fig. 6) so there is sufficient capacity for the seven segment digit, a decimal point and an annunciator arrow.

A waveform must be applied to each of the backplanes and to the segment lines so a sufficient RMS voltage can be created at any point in the matrix (and so turn on that element) while at the same time, the RMS voltage across the elements that are off is kept below 1.1V.

Care must be taken in soldering in the LCD. I have come across two types which are suitable for this display. One type has the pins bonded directly to the glass substrate and I strongly recommend that a socket is used for these as too much heat from can easily damage the tin/indium strip which connects the pins to the rest of the display.

The second type has a special contact strip for each side of the display. When assembled the whole can be soldered in directly to the board

without much problem of heat damage. There will probably be 26 pins per strip for the display but only the middle 24 are needed, so the outer ones can be cut off.

If you use IC sockets throughout then check for clearance between the display driver chip and the display above it before soldering. The procedure for the rest of the assembly is as above.

The final component to be soldered is the data retention cell which is mounted on the underside.

```

0000 16 D9 19 63 18 ED 1E 77 21 01 22 46 22 FB 23 BB
0010 24 C5 28 DB 2C F1 31 07 35 1D 37 28 38 4C 39 33
0020 9B 9C A6 F4 B7 04 A6 F0 B7 00 A6 3F B7 05 3F 01
0030 A6 05 B7 09 A6 FF B7 08 CD 18 64 CD 1D 45 1F 09
0040 1D 09 BF 0F 1B 05 CD 1E 4B 1F 1B CD 1D 45 3D 16
0050 2A F0 04 00 04 3F 16 20 E9 3F 63 CD 1D E8 BE CD
0060 1D 45 20 DA 4F AE 54 E7 10 5A 2A FB 1E 34 A6 10
0070 B7 16 A6 05 B7 35 A6 2B B7 3B B7 39 A6 90 B7 3D
0080 10 62 B1 3F 1C 3F 1D 3F 1E 3F 1F AE 20 3B 23 39
0090 22 39 21 39 20 39 1F 39 1E 39 1D 39 1C B6 1C B1
00A0 24 25 32 26 16 B6 1D B1 25 25 2A 26 0E B6 1E B1
00B0 26 25 22 26 06 B6 1F B1 27 25 1A B6 1F B0 27 B7
00C0 1F B6 1E B2 26 B7 1E B6 1D B2 25 B7 1D B6 1C B2
00D0 24 B7 1C 3C 23 5A 26 B5 81 3F 1F 3F 1E AE 10 3B
00E0 23 39 22 39 1F 39 1E B6 1E B1 26 25 16 26 06 B6
00F0 1F B1 27 25 0E B6 1F B0 27 B7 1F B6 1E B2 26 B7
0100 1E 3C 23 5A 26 D9 B1 E6 00 B7 23 3F 1F AE 0B 38
0110 23 39 1F B6 1F B1 27 25 0B B6 1F B0 27 B7 1F 3C
0120 23 5A 26 EB B1 8F 2B AE 03 E6 20 E7 24 6F 20 5A
0130 2A F7 3F 29 3F 1F 3F 1E 20 52 34 1C 24 1E B6 22
0140 B8 27 B7 22 B6 21 B9 26 B7 21 B6 20 B9 25 B7 20
0150 B6 1F B9 24 B7 1F B6 1E B9 29 B7 1E 34 1D 24 22
0160 B6 23 B8 27 B7 23 B6 22 B9 26 B7 22 B6 21 B9 25
0170 B7 21 B6 20 B9 24 B7 20 B6 1F B9 29 B7 1F 24 26
0180 3C 1E 38 27 39 26 39 25 39 24 39 29 3D 1C 26 AA
0190 3D 1D 26 CB BE 2B 81 4F B7 20 B7 21 B7 22 B7 23
01A0 A6 03 B7 2A 3F 1C A6 0A B7 1D CD 19 25 F6 44 44
01B0 44 44 BB 23 B7 23 24 0A 3C 22 26 06 3C 21 26 23
01C0 3C 20 3F 1C A6 0A B7 1D CD 19 25 F6 44 0F BB 23
01D0 B7 23 24 0A 3C 22 26 06 3C 21 26 02 3C 20 3C 3A
01E0 2A 2A C1 9F A0 04 97 B1 9F AB 04 B7 2A A6 03 B7
01F0 2B 3F 24 3F 25 3F 26 A6 0A B7 27 CD 1B B3 B6 1F
0200 3A 2A BE 2A F7 CD 1B B3 B6 1F 4B 4B 4B 4B BE 2A
0210 FB F7 3A 2B 2A E5 81 15 00 1E 1B B6 0B 27 06 A1
0220 01 27 FB 26 03 9A 9D 9B 40 97 B0 17 B7 19 B6 1B
0230 A2 00 B7 1A BF 17 3F 1B 80 1F 09 07 00 05 0E 1B
0240 02 14 00 B6 1B A1 F0 24 0C 3C 1B 0A EF 26 06 B7
0250 10 B7 11 B7 12 B6 1B AB 01 B7 1B 01 1B 0F 9A CD
0260 1A A7 B6 3A 2B 07 AD 06 AD 12 CD 1A BB 80 3A 3B
0270 26 09 A6 2B B7 3B AE 52 CD 1C 09 B1 0C 63 0D 3A
0280 39 26 09 A6 2B B7 39 AE 5B CD 1C 09 B1 3A 3D 26
0290 14 A6 90 B7 3D 3A 16 0C 63 0B 9B 3C 26 04 3C
02A0 3B 26 02 3C 3A 9A 81 AD 24 CD 1B 7D 0E 13 03 3F
02B0 15 81 0F 14 FA B6 15 2B FB 4C B7 15 A1 15 26 F1
02C0 B6 3A 2B ED A6 FF B7 34 B6 36 B7 37 81 0E 01 24
02D0 B6 13 2B 0A 4C A1 04 25 02 A6 80 B7 13 B1 BE 3A
02E0 A3 07 26 F9 4C A1 AB 27 06 A1 B2 25 EE AE AB B7
02F0 13 CC 1B 5E 0E 13 03 3F 13 B1 BE 3A A3 07 26 06
0300 B6 13 A1 AB 24 F1 3F 13 3C 34 26 05 A6 80 B7 34
0310 B1 B6 3A 2A 0B A1 B1 26 03 CC 1C AE 3F 34 20 07
0320 A1 0B 25 02 3F 34 B1 4F 3D 36 27 02 A6 0B BB 35
0330 4B 97 D6 1B 00 B7 A1 B7 1C D6 1B 01 B7 42 B7 1D
0340 3F 20 A6 00 B7 21 A6 04 B7 42 B6 26 A6 65 B7 23 CD 19
0350 25 B6 21 B7 43 B6 22 B7 44 B6 23 B7 45 B1 0E 63
0360 1B B6 62 AB 01 B7 62 AB 06 2B B7 62 AB 60 24
0370 0B B7 62 3C 61 B1 3D 61 27 02 3F 61 81 0C 01 0E
0380 B6 14 2B 09 4C A1 04 25 02 A6 80 B7 14 B1 0E 14
0390 03 3F 14 B1 3F 14 0E 13 F4 B6 3A 2B 14 27 EE A1
03A0 02 27 EA A1 04 27 E6 A1 07 27 20 A1 01 05 27 52 26
03B0 22 A1 80 26 0B 3C B6 B6 A0 03 25 02 3F 36 B1
03C0 3C 35 B6 35 A1 0B 25 02 3F 35 B1 0F 63 03 3F 63
03D0 B1 1E 63 4F B7 5E B7 5F B7 60 B7 3E B7 3F B7 40

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Listing 1 The hex dump of the used parts of the EPROM

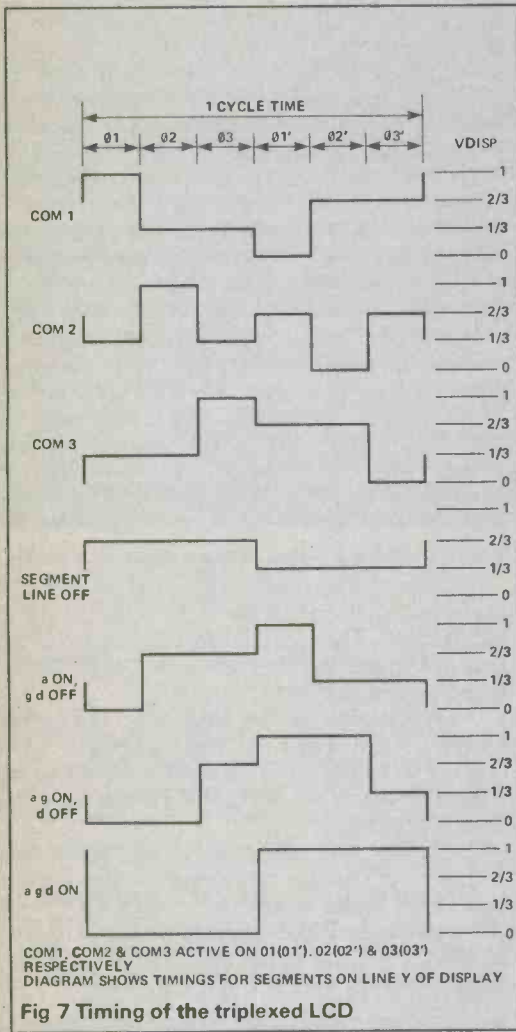


Fig 7 Timing of the triplexed LCD

Figure 7 shows the voltage waveforms that are applied to the three backplanes as well as some examples of segments that are off and on. Within the display driver chip there are three 75k resistors in series which are used to generate the intermediate voltage levels $\frac{1}{3}V_{DISP}$ and $\frac{2}{3}V_{DISP}$. One end of the resistor chain is attached to the +5V supply of the chip and the other is connected to another pin so the voltage across the display can be controlled.

Since this project is powered by NiCd batteries which have good voltage/discharge characteristics, a constant voltage can be applied across the display just by tying the open end of the chain to ground with a 1% resistor (F2).

The mean voltage applied to the backplanes is $V/2$. For the parts of the cycle in which a particular backplane is not being used its voltage is kept at either $V/3$ or $2/3$ — a difference of $V/6$. When it is in use, either V or $0V$ is applied which is a difference of $V/2$.

For a given backplane, if the segment on a particular segment line is off then the voltage applied to it is between $V/2$ and that of its backplane. This keeps the RMS voltage between the two as low as possible for that segment and yet not too high for the other segments in that line for them to be turned on when they shouldn't.

When a particular segment is on, the voltage applied to it is the complement of that on its backplane. This causes the RMS difference between them to go above the 'on' threshold and yet that of the other segments is still kept below the 'off' threshold.

The main drawback of multiplexing LCDs is that the RMS voltage across off segments is not zero (unlike non-multiplexed displays). This causes some polarisation of the fluid which reduces the display angle by perhaps 20° .

It is for this reason that it is difficult to read a computer LCD screen (greatly multiplexed) at more than 30° to the normal but not a simple LCD watch which does not have a multiplexed display. These problems have very little effect on the speedometer since the rider is viewing it from a nearly constant position.

This should not be connected until the batteries have been installed. This simplifies checking the power on reset and avoids draining the cell with the processor running. Foam strips with adhesive on both sides should be used to fix the cell to the board as well as insulate it from the tracks.

Before soldering, a piece of wire should be used to tie the cell to the underside of the board using the two remaining unused holes. Experience has shown that the contact leads on the cell are not

strong enough by themselves to support it indefinitely against the vibrations of the road.

Alternatively, two wires could be used to join the cell to the board so that it is free to rest on the base of the case.

Once the PCB is completed, the EPROM (see Listing 1) can be inserted and some testing carried out by temporarily connecting the batteries, switches and reed relay. Correct operation can be verified by running through the operating modes of

03E0	B7 56 B7 57 B7 58 B7 59 B7 3A B7 3B B7 3C B7 4E	05F0	FB B6 00 AA F0 B7 00 B6 33 OF 63 02 AA 20 B7 01
03F0	B7 4F B7 50 B7 51 A6 90 B7 3D A6 2B B7 39 1D 63	0600	19 00 18 00 1F 00 B6 2C B7 01 19 00 18 00 1D 00
0400	B1 4F B7 5C B7 5B B7 5A B1 E6 03 AB 01 E7 03 AB	0610	B6 2E B7 01 19 00 18 00 1E 00 B6 2D B7 01 19 00
0410	06 2B 3A E7 03 AB A0 24 34 E7 03 E6 02 AB 01 E7	0620	18 00 18 00 B6 31 B7 01 19 00 18 00 1C 00 B6 2F
0420	02 AB 06 2B 28 E7 02 AB A0 24 22 E7 02 E6 01 AB	0630	B7 01 19 00 18 00 1F 00 B6 30 B7 01 19 00 18 00
0430	01 E7 01 AB 06 2B 16 E7 01 AB 60 24 10 E7 01 F6	0640	1D 00 B6 32 B7 01 19 00 18 00 B1 3D 34 28 13 CD
0440	AB 01 F7 AB 06 2B 06 F7 AB 60 24 01 F7 B1 B6 36	0650	1E 63 CD 1E B5 CD 1E D8 CD 1E EB CD 1F 39 A6 10
0450	B1 37 27 F9 4D 27 4B AE 4A AD 2B AE 4A CD 19 EB	0660	B7 16 B1 B6 19 B7 27 B6 1A B7 26 3F 1E B6 43 B7
0460	AE 4E AD 22 AE AE CD 19 EB 3F 20 B6 3E B7 21 B6	0670	1F B6 44 B7 22 B6 45 B7 23 CD 18 DD B6 22 A1 FF
0470	3F B7 22 B6 40 B7 23 AD 10 B6 23 B7 40 B6 22 B7	0680	27 32 3F 26 A6 0A B7 27 CD 18 D9 B6 1F B7 12 CD
0480	3F B6 21 B7 3E B1 CD 19 97 A6 C9 B7 1C A6 2B B7	0690	18 D9 B6 1F 48 48 48 48 BB 12 B7 12 CD 18 D9 B6
0490	1D CD 19 25 A6 7D B7 26 4F B7 27 B7 25 B7 24 CC	06A0	1F B7 11 CD 19 0B B6 1F 48 48 48 48 BB 11 B7 11
04A0	18 BB AE 4A AD 2B AE 4A CD 19 EB AE 4E AD 22 AE	06B0	B6 23 B7 10 B1 B6 10 B1 5A 25 1C 26 0E B6 11 B1
04B0	4E CD 19 EB 3F 20 B6 3E B7 21 B6 3F B7 22 B6 40	06C0	5B 25 14 26 06 B6 12 B1 5C 25 0C B6 10 B7 5A B6
04C0	B7 23 AD 10 B6 23 B7 40 B6 22 B7 3F B6 21 B7 3E	06D0	11 B7 5B B6 12 B7 5C B1 B6 47 BB 42 B7 47 B6 46
04D0	B1 CD 19 97 A6 7D B7 1C 3F 1D CD 19 25 3F 24 3F	06E0	B9 41 B7 46 24 04 AE 4A 20 35 B1 0C 63 30 B6 49
04E0	25 A6 C9 B7 26 A6 2B B7 27 CD 18 BB 18 00 20 00	06F0	BB 42 B7 49 B6 48 B9 41 B7 48 24 22 3C 40 26 06
04F0	22 00 24 00 26 00 27 00 27 56 2B 00 AE 2C B6 36	0700	3C 3F 26 02 3C 3E AE 4E AD 15 OF 63 11 B6 4F B1
0500	E7 06 A6 OF E7 04 E7 05 E7 07 A6 01 20 29 BE 35	0710	61 25 0B B6 50 B1 62 25 05 A6 40 B7 63 B1 B1 BF
0510	5B D6 1C EC A4 OF A6 20 B7 31 D6 1C EC 44 44 44	0720	28 9F AB 04 97 5A F6 AB 01 F7 AB 06 28 0A F7 AB
0520	44 B7 30 D6 1C ED A4 OF B7 33 D6 1C ED 44 44 44	0730	60 24 05 F7 B3 28 26 ED B1 B6 34 A1 06 26 3D B7
0530	44 B7 32 AE 2C A6 02 E7 01 A6 OF E7 03 A6 0A F7	0740	3A BA 3B BA 3C 27 35 3F 20 B6 3E B7 21 B6 3F B7
0540	EC 1D CC 1D F1 BE 34 2A 06 A3 B1 2F 2C 26 AD 5B	0750	22 B6 40 B7 23 A6 03 B7 1C A6 EB B7 1D CD 19 25
0550	D7 1D 53 20 0E 20 12 20 1D 20 1F 20 29 20 31 20	0760	3F 1D 3F 1C 3F 24 9B B6 3A B7 25 B6 3B B7 26 B6
0560	37 20 39 AE 4A AD 47 20 04 AE 4E AD 41 B6 31 AA	0770	3C B7 27 9A CD 18 BB AE 5D CD 19 EB B1 80 00 00
0570	20 B7 31 CC 1D F1 AE 52 20 02 AE 56 AD 30 B6 2F	0780	00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
0580	AA 20 B7 2F 20 E7 AE OF B6 12 AA OF B7 12 20 02	0790	00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
0590	AE 5F 3C 2C AD 1B 20 D5 AE 5D 20 F6 3F 2C B6 61	07A0	00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
05A0	B7 2E B6 62 B7 30 A6 OF B7 32 AD 11 20 BF F4 B7	07B0	00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
05B0	2C E6 01 B7 2E E6 02 B7 30 E6 03 B7 32 AE 06 E6	07C0	00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
05C0	2C A4 OF E7 2D E6 2C 44 44 44 44 E7 2C 5A 5A 2A	07D0	00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
05D0	EE 5F E6 2C 26 09 A6 OF E7 2C 5C A3 05 25 F3 BE	07E0	00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
05E0	34 A6 10 EA 2C E7 2C B1 AE 07 A6 OF E7 2C 5A 2A	07F0	00 00 00 00 00 00 1A 39 1A 39 1A 17 1F 7D 1B 20

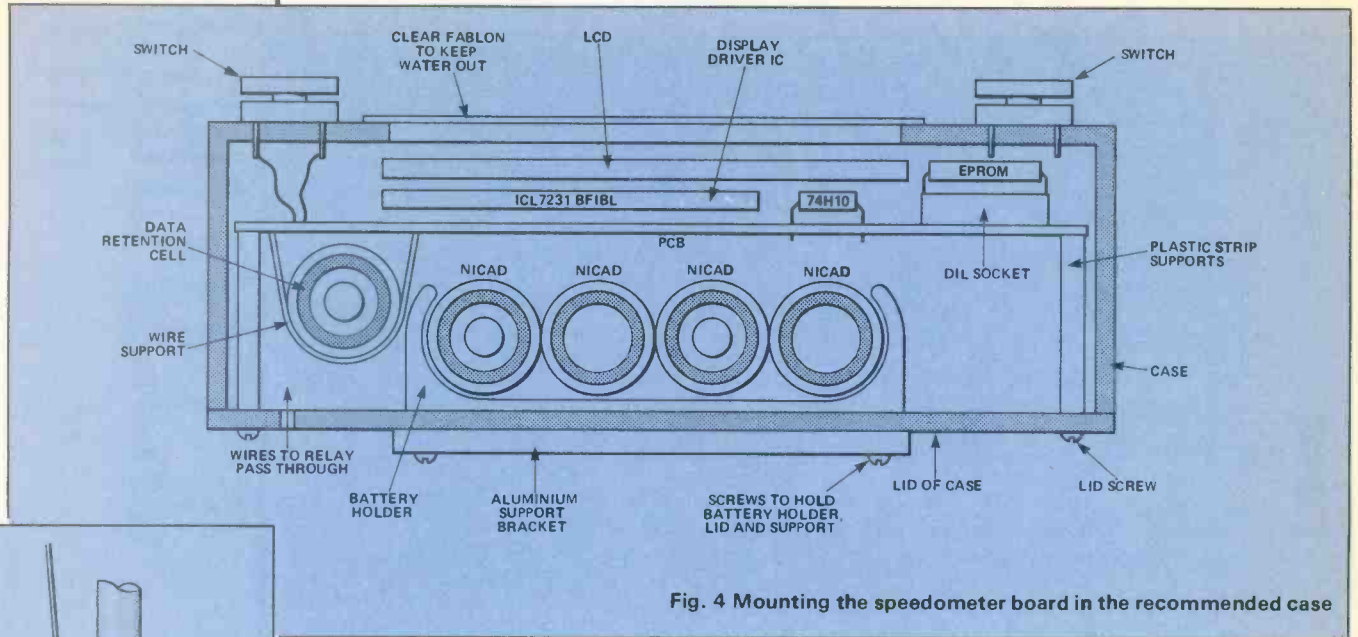


Fig. 4 Mounting the speedometer board in the recommended case

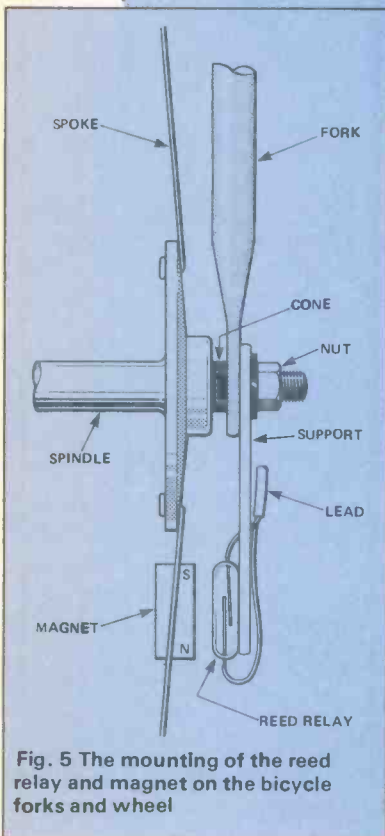


Fig. 5 The mounting of the reed relay and magnet on the bicycle forks and wheel

the speedometer, checking its function by opening and closing the relay with a magnet 'by hand.'

The plastic box normally includes some PCB supports which run in vertical grooves in the walls of the case. I have used these to hold the board at the correct height so the display can be seen through a hole cut in the case (Fig. 4). A little trimming of the board where the supports go may be needed in order to achieve a good fit.

To prevent rain getting into the case, it is used upside down so the lid is on the bottom with the display showing through what was the base. Clear self adhesive plastic film covers the display cutout to create a watertight seal.

The four AA NiCd cells are held in a 4x1 battery holder mounted at the base of the case, on the lid. The two screws holding the battery holder to the lid of the case are also used to attach it to the support bracket. I used a bent strip of aluminium to fix the speedometer box to the front brake assembly.

Low profile switches with short leads are the easiest to mount on the box. Two small holes were made in the case for each switch for the leads. Wires were soldered to the switches and passed through the case before gluing. No problems have ever been encountered in the rain with this arrangement of switches.

The reed relay lead passes through a small hole in the lid to where the relay is mounted at the bottom of the forks. If the clearance between the wire and the case is very small then no glue is needed to make a seal since surface tension will prevent water from seeping into the case.

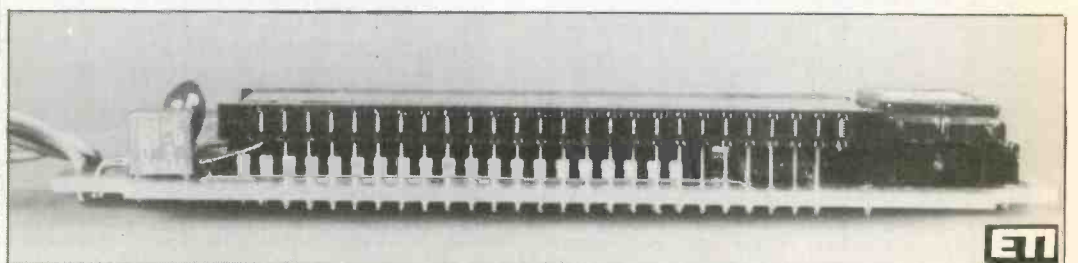
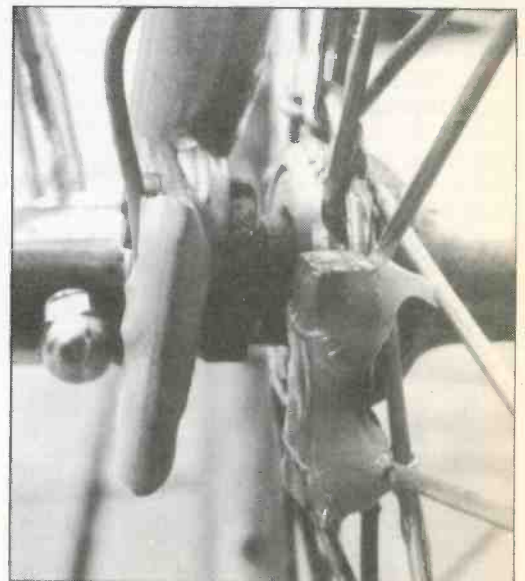
The relay can be mounted on a small aluminium bracket bolted to one of the front forks on the axle (Fig. 5). It is a good idea to encapsulate the mounted relay and any bare wiring to prevent tripping by rain. Silicone bath sealant or epoxy

glue is suitable for this or even paint at a pinch.

The magnet is positioned on a spoke so that it passes within about 10mm of the relay (but does not touch it). The exact distance will vary with the type of magnet and reed relay used and must be found by trial and error.

The magnet can be fixed either by gluing/tying it to the spoke, by making another small bracket or by fixing it to one of the clip-on spoke reflectors which are easily and cheaply available from bike shops.

Once the reed relay and magnet are mounted and wired in, the case can be bolted to the handlebars, front brake calipers or wherever it can be conveniently read and operated and you can then peddle off into the sunset confident in the knowledge of exactly how fast you are going.



TOP PROJECT

SPECTRUM EPROM EMULATOR

TOP PROJECT

It is a fact of life that when it comes to designing and debugging microprocessor based circuits, your old single beam valve oscilloscope and trusty Avo won't get you very far! Micro-processors are tricky beasts to get going at the best of times and specialised development and support tools are really aimed at the professional engineer in industry, where the elevated price tag is of secondary importance.

One extremely valuable piece of microprocessor development equipment is an in-circuit emulator. This usually takes the form of a big box of tricks and a 'pod' on the end of an umbilical cable, which plugs into your target circuit in place of the microprocessor chip. From then on, the emulator pretends to be the processor, and if desired the memory too, simulating all the functions in real-time.

The emulator provides facilities to start and stop the processor, examine and change register values, and perhaps most importantly, examine and change the memory contents. Such systems provide an amazingly powerful development tool, cost many thousands of pounds and no, we're not going to build one!

A few steps down in complexity from the in-circuit emulator but no less valuable, is the so-called EPROM emulator. Once again this provides a 'pod' at the end of a cable which plugs into the target board, this time in the place of the EPROM containing the operating software.

As far as the target board is concerned, the EPROM emulator is the EPROM — a block of read-only store. However, the emulator is in fact RAM and data can be put into it during code development, from some external source such as a home computer.

This means that changes to code can be made in seconds, without going through the hassle of erasing and programming EPROMs each time you discover a tiny bug in your software. It also means that short test routines can be quickly employed to test and debug new hardware, again saving time with EPROMs.

Such EPROM emulators have appeared in ETI before, so what is so special about this one? The major difference is in the method used to download the code into the emulator. Usually, having been compiled/assembled, the code is moved from the development computer into the emulator via a serial link. This requires a program to be running in the home computer to transmit the data, and some hardware in the emulator to receive the data and write it into the appropriate RAM locations. In this design all that is unnecessary.

A Full Spectrum

This emulator has been designed for use with our old friend the ZX Spectrum and simply plugs onto the expansion port at the back. The emulator RAM maps

itself into the Spectrum memory as an 8K location block starting at address 49152.

The idea is that the Spectrum sees the emulator RAM as its own memory so that downloading data is handled automatically. However, the Spectrum's memory map is full of its own RAM already.

In order to overcome this, the emulator RAM is configured as 'Write-Only' memory (WOM!?) as far as the Spectrum is concerned. This means that if the Spectrum writes to these locations, the data is put into both its own RAM and that of the emulator. If the Spectrum reads from these locations, it sees only its own RAM contents. Thus the emulator will not affect in any way the operation of the Spectrum, yet manages to receive download data at the same time.

In this way we simply use the Spectrum BASIC 'Poke' command to put suitable data into the emulator. However, even more amazing is the possibility of assembling code into this area of memory. The mere act of assembling source code on the Spectrum writes executable code into memory, and in this case into the emulator RAM at the same time.

With an ordinary serially loaded EPROM emulator, getting executable code into the emulator RAM is a lengthy process. First, it is necessary to load the assembler into the computer, then load the source

Graeme Durant's Spectrum bears more than a passing resemblance to a development system's EPROM



HOW IT WORKS

The block diagram for the system is shown in Fig. 1. The eprom emulator basically consists of a block of static RAM, its address and data lines being switchable between one of two external ports.

The port shown on the left is connected to the Spectrum address and data busses via the Spectrum's expansion slot. This port is write-only, and allows the EPROM data to be downloaded into the emulator from the Spectrum.

The port shown on the right goes to the target system via a cable and EPROM look-alike pod. This port is read-only, and emulates the effect of an EPROM.

The switching of the RAM between these two ports is handled by some simple control logic — basically by the state of the power supply to the target board as sensed by the EPROM-pod power pin. If the target board is turned off, the emulator is switched to its download mode. EPROM emulation starts as soon as power is sensed on the target board.

The emulator board itself is always powered from the Spectrum, via the 5V supply connection on the expansion slot.

The circuit diagram (Fig. 2) demonstrates operation in more detail. The heart of the emulator is IC4, an 8K x 8bit CMOS static RAM chip. The switching of data and address lines to IC4 is achieved by means of the tri-stateable 8-bit buffers IC1, 2, 3, 8, 9 and 10.

Looking first at the write-only port from the Spectrum, the incoming data and address signals arrive on the emulator board via edge connector SK1, and are buffered by IC1 and IC2, 3 respectively onto the data and address lines of IC4.

The 8K locations present in the emulator are mapped into the Spectrum's memory space by IC5b and c so that they start at 49152 (dec). IC6b detects a memory write access by the Spectrum to one of these locations.

The write strobe to IC4 is derived from the output of IC6b and can be disabled in emulation mode by IC5a.

Looking now at the read-only port to the target system, the outgoing data and the incoming address signals leave or enter the card via connector SK 2, and are buffered by IC8 and IC9, or 10 respectively from or onto the data and address lines of IC4.

This time there are only thirteen address bits coming from the pod, so these all go to the RAM without decoding — any decoding will already have taken place on the target board.

The most significant address bit from the target system (A12) has a high value pull-up resistor R5 connected to it. This is there to ensure that this line doesn't pick up noise whilst the board is emulating the smaller 4K EPROM (2732) with this address line floating unconnected. This does mean however that whilst emulating the 2732, data should be placed in the top half of the 8K RAM, starting at Spectrum address 53248 (dec).

It is worth noting too that the RAM address and data lines are not connected to the two external ports in the same order as defined by the manufacturer's data sheet. This dramatically simplifies the PCB

layout, and has no effect on operation providing that a data line from a port goes to a data line on the RAM, and an address line from a port goes to an address line on the RAM.

Each unique address combination will access a different RAM location capable of storing data; it does not matter where exactly this occurs on the chip! Naturally, the data and address lines on the two ports must match so that data put into a certain address from the Spectrum end will be found at the same location at the emulation port.

As mentioned previously, the operating mode of the card is determined by the state of the power supply on the target board. This is detectable on the pod by the voltage on the 'EPROM' power pin, and is handled by Q1 and its associated biasing resistors. When the target supply exceeds about 3.5V Q1 turns on (the transition voltage being set by R8 and R9). The state of Q1 is converted into TTL levels by schmitt inverter IC7a. An LED driven via IC7b indicates when the emulation mode is in operation.

The circuit diagram shows this voltage sensing taking place on pin 28 of the 2764 pod. A second connection, via diode D1, comes from pin 26. This is for 2732 emulation, when the EPROM supply pin does not coincide with that of the larger device, and pin 28 is unused (diode D1 is present to protect the target system from a possible fault condition, if in the case of 8K device emulation, pin 26 of the EPROM socket is not open circuit as the 2764 pinout assumes).

Imagine first that the target board power is off, and the emulator board is thus in the download mode. Q1 will be switched off, and so the output of IC7a will be low. The output of IC7c is always the complement of the output of IC7a, so will be high.

The low output of IC7a will directly enable buffers IC1, 2, 3 so that the Spectrum data and address signals will reach the emulator RAM. At the same time, the high output of IC7c will allow IC5a to pass write strobes from the Spectrum to the RAM, so that the download information can be written into IC4. The high output of IC7c also disables the address buffers (via IC6a,c) from the emulation port IC9, 10, and disables the data output drivers in IC4 and the data buffer to the emulation port IC8.

After the download is complete, the target system power can be applied. Q1 turns on, sending the output of IC7a high and the output of IC7c low. IC7a disables the three Spectrum port buffers IC1, 2, 3, thus effectively decoupling the emulator from all the Spectrum's influence.

Similarly, IC7c enables the emulation port address buffer so that IC4 receives the required EPROM address signals from the target board.

Any further write strobes from the Spectrum are stopped by the low signal on pin 1 of IC5a, so now the RAM is held in its read mode constantly. The logic is carefully arranged so that as long as the Spectrum is not trying to write data to the RAM at the time, changing mode from download to emulation or back can never cause an erroneous write pulse to be sent to the RAM, which might otherwise

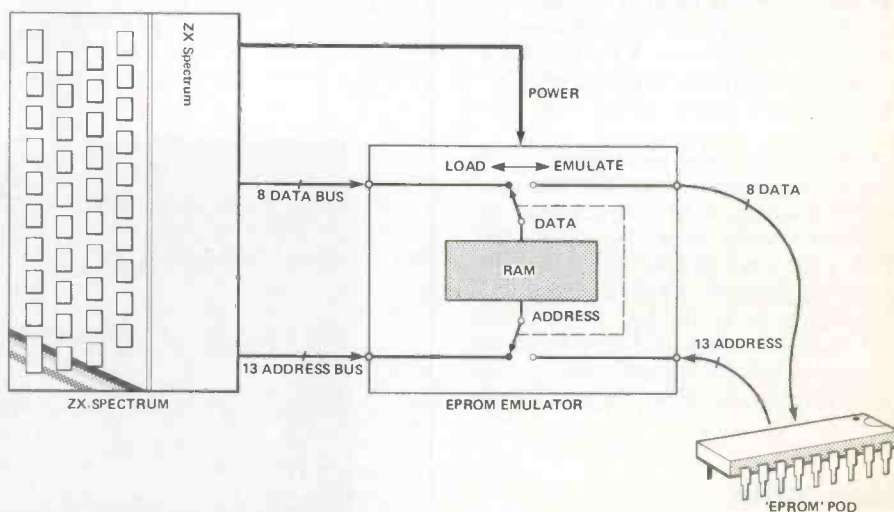


Fig. 1 Block diagram of the EPROM Emulator

TOP PROJECT

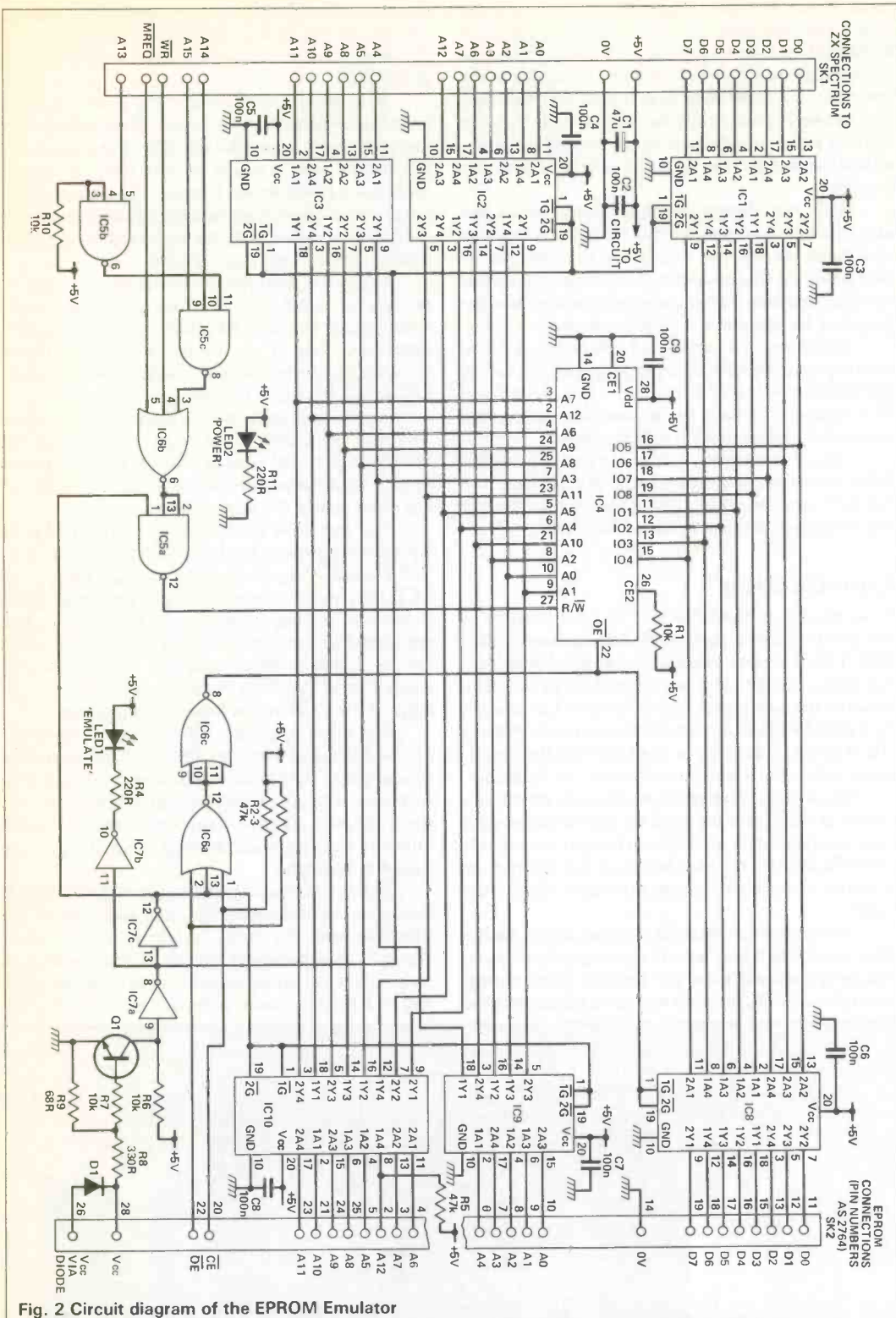


Fig. 2 Circuit diagram of the EPROM Emulator

corrupt its contents.

When the target board decided to access our 'EPROM', it pulls the \overline{CE} and \overline{OE} pins on the pod low after supplying a suitable address. This condition is detected by IC6a and c, and (assuming the emulation mode is in operation) the data output drivers (IC4) and emulation data bus buffer (IC8) will be enabled. The accessed data can then get from the RAM to the target board.

The timing specification for access is shown in the table on the right. The resistors R2 and R3 on the \overline{CE} and \overline{OE} lines of the pod reduce the sensitivity of these signals to noise pickup when the target system is unpowered.

Finally, decoupling capacitors are distributed liberally about the board to ensure that the supply to the emulator is noise free. A large value capacitor, C1, is also included near to the power connections

from the Spectrum. This helps to avoid supply dropouts if the Emulator is accidentally knocked, and also prevents problems due to the fact that the power supply is connected remotely.

	MINIMUM	MAXIMUM
Address access time	-	186ns
\overline{CE} to output valid	-	118ns
\overline{OE} to output valid	-	118ns
\overline{CE} to output High-Z	-	55ns
\overline{OE} to output High-Z	-	55ns
Output data hold time	20ns	-

These timings make the emulated device equivalent to a 250-300ns part

code. Once assembled, the object code must be saved, then the serial link download program must be loaded into the computer, after which the object code must be re-loaded in order to transmit it to the emulator. If a small change is required in the code, this whole process must be repeated. If you are working with floppy disks or worse still audio cassettes, all this loading and saving is painfully slow and very tiresome.

With the design described here, once the assembler has been loaded into the Spectrum, it can stay there, as can the source code. Code can be assembled into the emulator, the source code can be tweaked and then immediately re-assembled into the emulator for another try — all in seconds!

This design is capable of emulating the two industry standard EPROMs most commonly used by the hobbyist — the 2732 and the 2764 (4K×8 and 8K×8 respectively) and has an emulation access time equivalent to that of a 250-300ns device.

Thus it is perfectly suited for use with 4MHz Z80A based target systems (such as ETI Spectrum Co-processor CPU card), and indeed any application requiring such a medium speed EPROM.

Construction

Construction of the EPROM Emulator should not prove to be difficult, particularly if the recommended PCB (Fig. 3) is used. This is a double-sided board and requires a number of interconnections to be made between the two layers. (The board is not a through-hole plated PCB due to the excessive costs involved.) Use tinned copper wire pushed through the appropriate hole in the board and soldered in on both sides.

Many of the required through connections are made via the IC pins themselves, each time a copper track is connected to an IC pin on the component side of the PCB. In these cases (48 in all) the ICs must be soldered in on both the top and underside of the board.

This is straightforward if you plan to put the ICs directly into the board but can create problems if you decide to put the ICs into DIL sockets. Sockets must be employed which provide access for soldering to the

topside of the PCB. This really means DIL sockets of the 'turned-pin' variety, designed in such a way that the base of the pin is visible on the component side of the PCB.

To fit these sockets, solder into place as normal from the underside of the board. Then solder in on the component side of the board but not directly with a soldering iron (it would be very difficult to avoid melting the plastic socket frames). The pins should be heated in turn from the underside of the board whilst dabbing fine solder onto the topside of the pin, until solder flows to form a good joint.

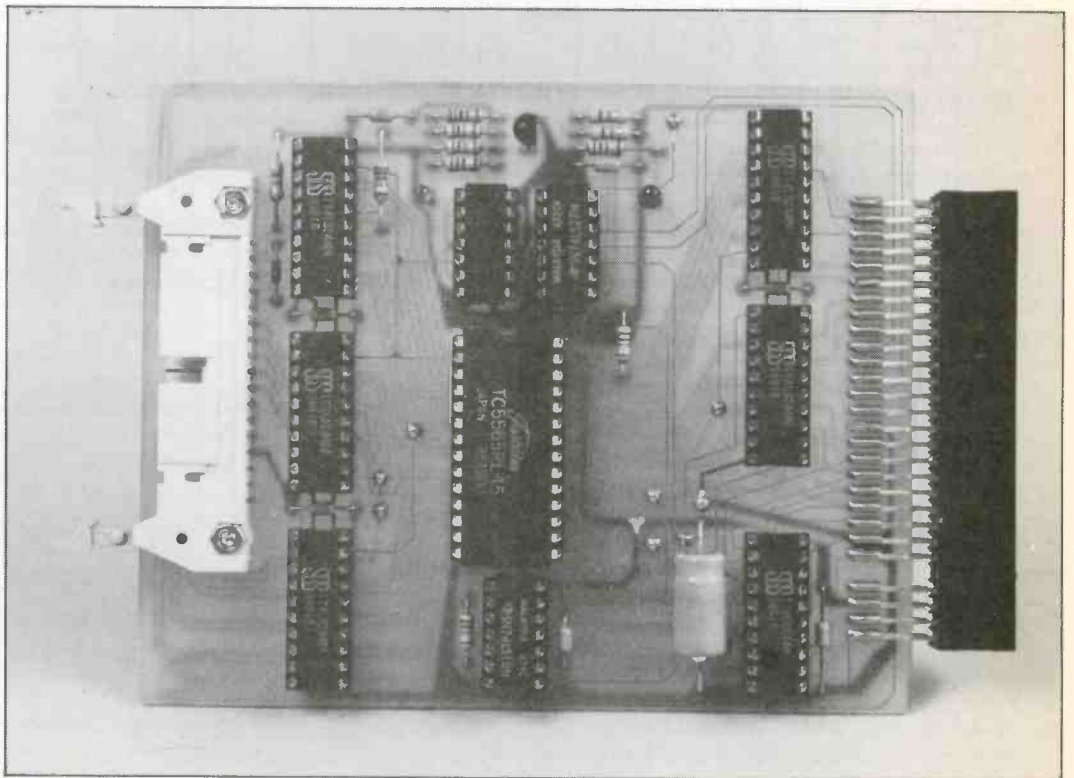
Once the through connections and the IC sockets (if used) are in place, the rest of the components can be inserted. No particular order is necessary, but it is always wise to put the semiconductors in last of all. Remember to put the LEDs, Q1, D1 and C1 in the right way round!

All that remains now is to fit the two connectors SK1 and SK2. SK1 is the edge connector for the Spectrum port and must be fitted so that one row of its pins are soldered to the topside of the PCB, and the other row to the underside.

The two rows of pins will probably need to be squashed together a bit, before fitting the connector to the board. The pins do not go through holes in the PCB, they lay flat against its surface and are soldered down by flowing solder onto the copper pad associated with each pin. Squashing the pins together can be achieved either using pliers or more easily, using a small vice. SK1 should then be slid onto the edge of the PCB and soldered into position.

The other connector SK2 sits at the other end of the PCB and provides the EPROM emulation connections. The pinout used is shown in Fig. 4. This connector should be simply inserted and soldered into place. For extra reliability, it is recommended that M2.5 nuts and bolts are used through the PCB to fix the socket in position.

This completes the construction of the PCB itself, but now we must look briefly at the cable assemblies which connect the target system to the emulator. Basically, these consist of a length of ribbon cable with an IDC header socket at one end to plug into SK2, and an IDC DIL header at the other end to plug into



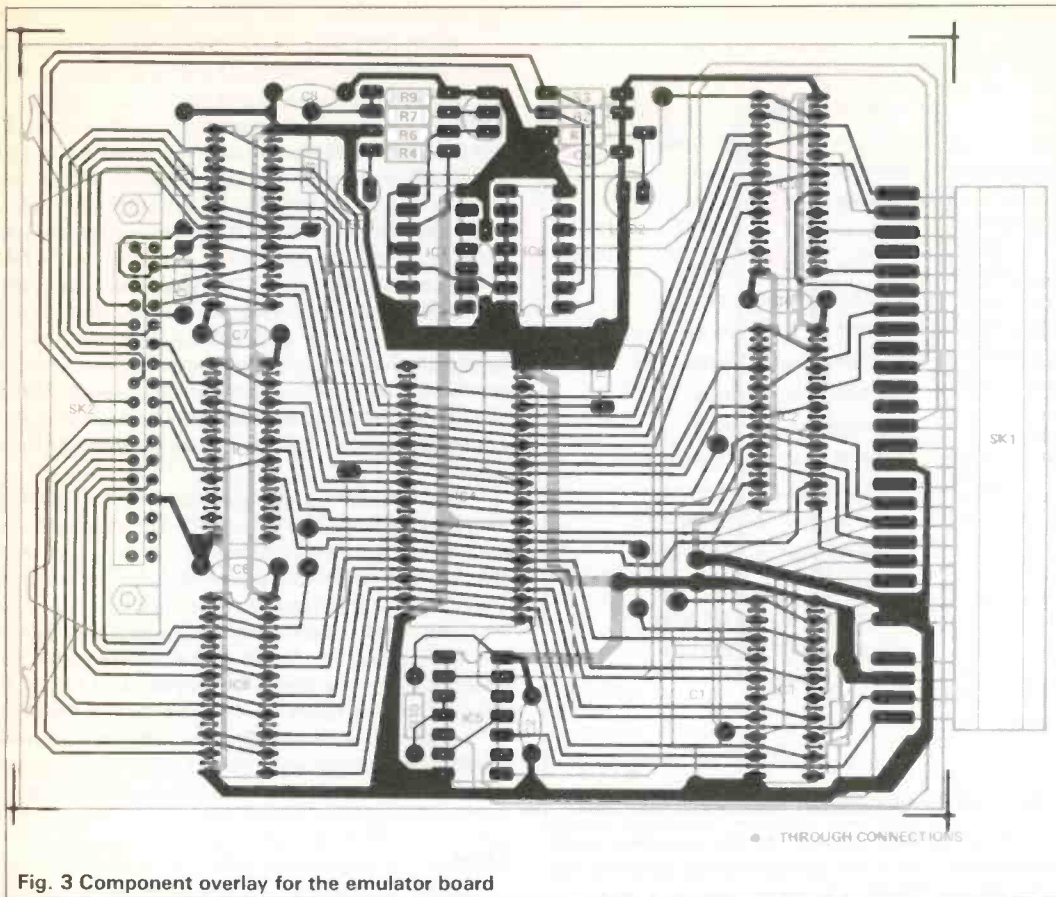


Fig. 3 Component overlay for the emulator board

the target system EPROM socket.

A different cable assembly is used depending on which size EPROM is being emulated, so you may need to make up two types.

Figure 5 shows the pinouts of the two types of EPROM we are seeking to emulate. The 2732 is in a 24-pin package, whilst the 2764 is in a 28-pin package. The pinouts are so designed that if you put the smaller device in the larger device's outline, matching up the ground pins, the rest of the signals correspond perfectly.

Obviously, the 2732 does not need as many signal connections as the 2764 but if the emulator provides all the connections for the larger device then the smaller device simply uses a subset of these signals. So, it is possible to make the required emulation connections to either device by only changing the size of DIL pod on the end of the cable assembly — no further signal switching is required.

Figure 5 also shows the construction of the two cable assemblies. Care must be taken to ensure that the DIL plug and the IDC header socket are fitted exactly as shown, particularly the latter which has a number of unused socket positions.

The length of ribbon cable used should not be much more than about 200mm, since the signals travelling up and down it are ordinary TTL levels, and are at quite high speeds. Any longer and the emulation could become unreliable. If it were necessary to have a much longer cable, then high-speed twisted pair line drivers would have to be used, but this is really beyond the scope of this simple project.

To actually fit the connectors to the cable, you should ideally use one of the special presses designed for IDC work. Not everybody has one of these(!) but with a little care it is quite possible to use a small vice to do the same job.

First the IDC connector should be loosely assembled so that it sandwiches the end of the ribbon cable. Then the two halves should be carefully

squashed together in the vice, to make a permanent connection to the cable. Before the permanent connection is made, you must be absolutely sure that the ribbon cable is correctly positioned in the connector, because it is not easy to go back after the connector has been assembled.

It is worth then plugging it into the emulator and testing the connections from the PCB to the DIL pod with a continuity tester to make sure that correct and reliable links have been formed. Once this has been done, we are ready to test the Emulator itself.

Testing

Before plugging the board into the back of your beloved Spectrum, it is wise to check that there are not potentially damaging short circuits between the emulator's power and ground lines, using a multimeter on the ohms range. If there are, make sure that the shorts are found and eliminated before moving on.

Then take the plunge and push the emulator onto the expansion port of your Spectrum. Apply the power. The power indicator, LED2, should light up and LED1 (the emulation LED) should be off.

BUYLINES

There are no special parts needed to build the emulator, and your usual supplier should stock most of the components required.

The miniature axial ceramic capacitors used in this project are available from Verospeed as order code 92-50952H. Verospeed can be contacted at Stansted Road, Boyatt Wood, Eastleigh, Hants SO5 4ZY. Tel: (0703) 644555.

Suitable DIL sockets for soldering on the topside of the PCB should be commonly available, but try the turned pin range from Maplin if uncertain. Maplin can also supply the Spectrum edge connector if required, order code FG23A.

The PCB is available from the ETI PCB service.

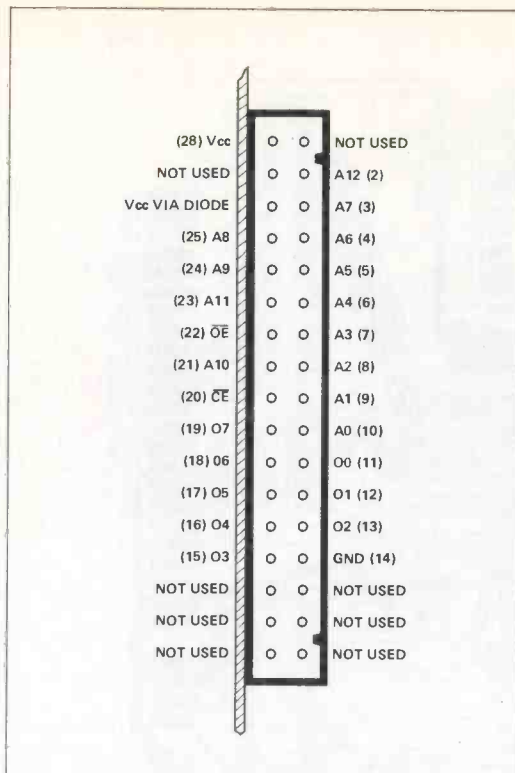


Fig. 4 IDC header plug pinout (viewed from pins)

If all is well, fit one of the emulator cable assemblies so that you can get at the 'EPROM' pin connections. Using a piece of wire or a croc clip, connect the Vcc pin on the EPROM pod (pin 28 for 2764, pin 24 for 2732) to +5V somewhere on the emulator card to simulate the power being applied to the target system. This should switch the emulator into emulation mode — LED1 should illuminate.

If the circuit has responded so far, the rest of the emulator can be tested (remove the test wire on the Vcc pin). Using Spectrum BASIC, poke a data value of 85 (dec) into the top location of the emulator (Spectrum address 57343). In binary, this data value has alternate one and zeros, and is thus great for

finding stuck bits.

Next, put the emulator into emulation mode by reconnecting the Vcc wire. The data just loaded into the RAM can be looked for at the pod by pulling the 'EPROM' CE and OE lines low using further wires. At this point it becomes convenient to plug the pod into a solderless breadboard or similar to make the necessary connections. If you do not have such a thing plug the pod into an IC socket and solder test wires to the pins.

Since unconnected TTL input lines float at the logical high level, leaving the emulation address inputs open circuit on the pod will address the highest location in the RAM; this is where we put our test data previously. So, using a voltmeter or a 'scope, it should be possible to look at the data bits coming out of the emulator pod one by one, checking that they are correct.

If all is well, try loading a value of 170 (dec) into the same location (this value in binary is the same as the last but with the ones and zeros swapped) and check for the correct bits on the pod data pins. If you are using a plug-in breadboard to test the emulator, it is quite easy to check a few more addresses besides the top location — simply pull down some of the address pins on the pod to 0V, having poked suitable test data into the RAM. This is certainly worth trying.

After all this static testing the real proof that the emulator is working must be to try it in a real target system, after loading real executable code into it.

Use

Using the emulator in a real target system is very simple, so long as a few basic rules are obeyed. With the target system unpowered, and the emulator connected to both the Spectrum and the target board, code should be assembled/compiled into the appropriate area of Spectrum RAM.

For 2732 emulation, the starting address in the Spectrum should be 53248 (dec). For 2764 emulation, the starting address in the Spectrum should be 49152 (dec).

One vital thing to remember is that these starting addresses are equivalent to address zero in the

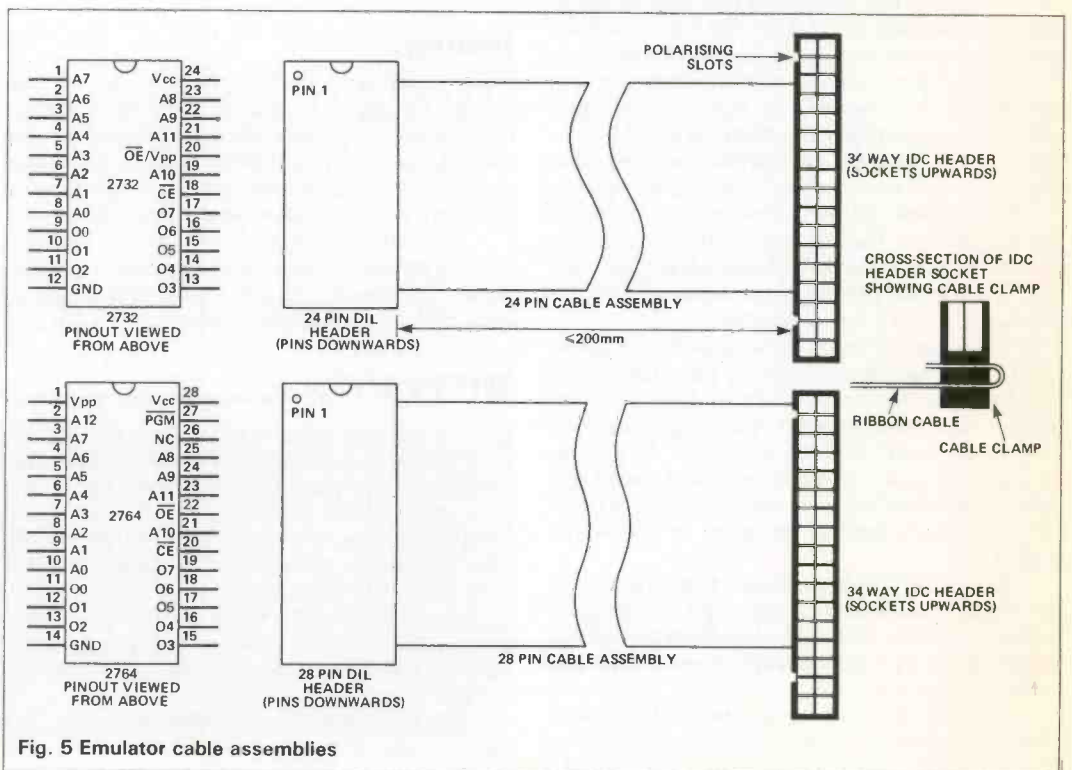


Fig. 5 Emulator cable assemblies



'EPROM' — the whole 'EPROM' contents are offset in the Spectrum memory by an amount equal to these starting addresses.

If your assembler allows you to assemble object code into a different area of memory to the runtime locations, then you are lucky. Simply write the source code from the target system's point of view starting at address zero, and then assemble it into the Spectrum memory starting at the addresses listed above.

PARTS LIST

RESISTORS (all 1/4 W 5%)

R1, 6, 7, 10	10k
R2, 3, 5	47k
R4, 11	220R
R8	330R
R9	68R

CAPACITORS

C1	47 μ 10V axial electrolytic
C2-9	100n miniature axial ceramic

SEMICONDUCTORS

IC1-3, 8-10	74LS244
IC4	6264 — 150ns 8k x 8 CMOS sRAM
IC5	74LS10
IC6	74LS27
IC7	74LS14
Q1, 2, 3	BC548
LED1	Green LED 3mm diam
LED2	Red LED 3mm diam
D1	1N4148

MISCELLANEOUS

SK1	Edge-connector for Spectrum (28 way double-sided)
SK2	34 way PC mounting right-angled IDC header plug

DIL sockets (see text). Cable assembly to EPROM pod (see text). PCB. Tinned copper wire for through connections. M2.5 nuts and bolts for SK2.

Unfortunately, the majority of software development tools for the Spectrum cannot handle such complicated concepts (!), being much less powerful than proper professional development software (though of course much cheaper!).

The only problem this does create concerns the assembler generated addresses in the executable code. Obviously, you must assemble the code into the Spectrum starting from the addresses listed above. As far as the target system is concerned, all the absolute addresses generated by the assembler in the resulting object code will have an inbuilt offset equal to that starting address. If you are able to make your code relocatable by using only relative addressing, then there is absolutely no problem. However, if you are forced to use absolute addresses in your program, then it will be necessary to correct them by hand, subtracting the Spectrum start address before download.

This whole problem could have been overcome during the hardware design, by mapping the emulator into the area of Spectrum memory starting at zero instead of where it is. Unfortunately, most assemblers for the Spectrum will not allow assembly into that part of the memory map, since that is where the Spectrum operating system EPROM sits. Despite the problem with offsets, the actual method used at least guarantees that the assembler will work!

Once the code has been assembled, the power can be applied to the target system and (assuming that the program is correct) it should spring to life. Further downloads can then be achieved by simply repeating the above process again.

One interesting possibility worth noting concerns EPROM programmers. Once the final working version of your software is available, having developed and tested it using your EPROM emulator, it is possible to use the emulator as the source of the data for an EPROM programmer. After downloading the code into the emulator, the pod can be plugged into the programmer, and the data read out, just as if you were copying a real EPROM. This provides an easy means for the transferral of code from the Spectrum to the programmer, without using messy serial links and the like.

Just one extra reason for building this simple but effective development tool!



THE QWL LOUDSPEAKER

*John Dix presents
an innovative
loudspeaker design
that enhances the
low frequency
response of small
units*

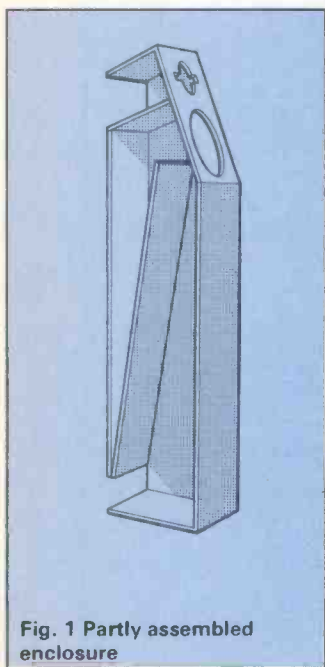


Fig. 1 Partly assembled enclosure

TOP
PROJECT

In these enlightened days of CD, DAT and all that is silent at the source, there is proportionately less in the music budget to be spent on the loudspeakers. The loudspeaker systems manufacturers have concentrated on smaller enclosure designs to achieve a cost reduction with the minimum possible sacrifice in performance.

Although it is more difficult to maintain the low frequency response with a small enclosure, reducing the dimensions has a number of advantages. A significant increase in structural stiffness reduces unwanted radiation from the cabinet walls. The narrow frontal area also improves the sound distribution.

Larger loudspeaker systems have to be complex because a mid-range unit is needed, with careful integration of responses to cover the whole frequency range. In a smaller unit, a single bass/mid-range unit provides seamless coverage beyond the critical mid-frequency range, easing crossover design and producing a radiation pattern conducive to a natural spread of sound and a usefully wide stereo sound stage.

However if a small enclosure results in an abrupt roll off of bass level below 100Hz, the bass lightness becomes readily apparent and there is therefore a limit to the economy feasible if a unit is to provide the reasonably long throw cone excursions necessary for adequately low frequency radiation.

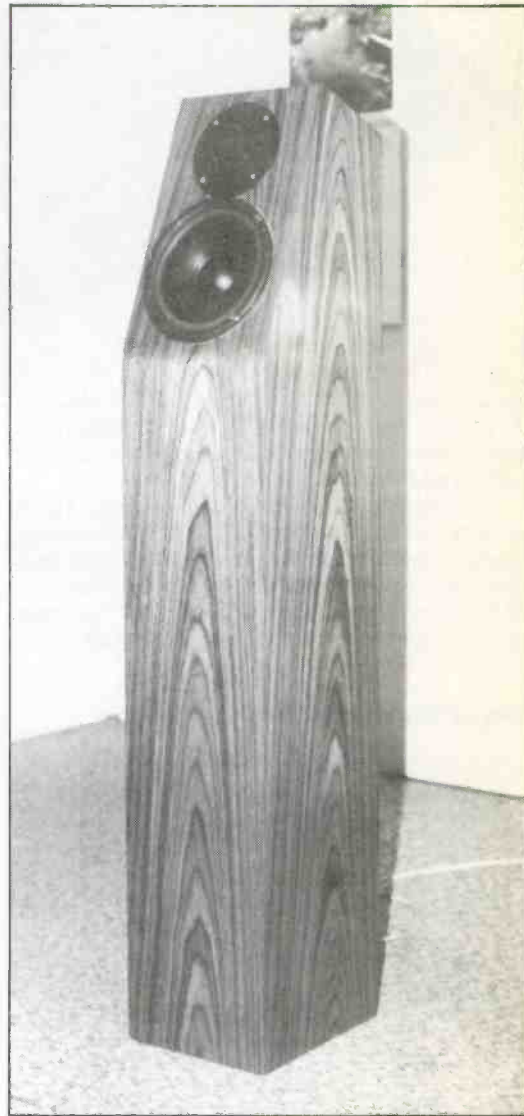
An obvious advantage of small speakers is their convenience — often they are placed on shelves in wall units and so on. However, close proximity to a wall can give rise to interfering standing wave patterns which deteriorate the stereo image. Having the speakers away from the wall, stably in space at a height such that the high frequencies are not absorbed by the sofa, gives an obvious improvement in depth and image precision.

Bearing all these points in mind it seems logical to consider whether the space within and under the speaker stands could not be used to enhance the low frequency response while maintaining a low cost, freestanding configuration.

Enclosure Design

A freestanding loudspeaker enclosure with similar dimensions to that of a small speaker on a stand, if of conventional design and construction, presents a difficult acoustic problem to the designer because of the long narrow parallel walls. These will tend to vibrate and resonate giving a resonant pipe-like colouration to the low frequency sound which is difficult to control and eliminate.

An alternative approach (satisfying from an acoustic engineering point of view) is to deliberately exploit the characteristics of a resonant pipe in such a way that the loudspeaker unit is correctly loaded and terminated at the low frequencies, whilst adequately suppressing



unwanted pipe resonant modes.

The low frequency efficiency of such an arrangement is somewhere between that of a horn and a bass reflex enclosure and therefore reduces the demands made on the low frequency excursions of the small diaphragm bass speaker unit.

The principle involved utilises the properties of a closed at one end quarter wavelength pipe as originally proposed by Voigt in his patent No 447749 and subsequently adapted and described by R West and R Baldock in their designs. The design produced by R West was intended for a corner position with the speaker unit firing into the corner to spread the high frequency sound by reflection from the walls, and R Baldock's designs were intended for either a semi-omnidirectional sound distribution or a wall reflected distribution.

Present day practice favours loudspeaker operation away from corners and walls, firing directly at the listeners.

The Quarter Wave Loading Enclosure

The construction of the design is depicted in Fig 1. The bass enclosure consists of a quarter wavelength rectangular section pipe with a linear taper, resonant at about 50Hz.

The bass loudspeaker unit is situated at approximately halfway along the acoustic axis in the best position to suppress higher order resonant modes. At resonance the acoustic pressure is high at the tapered end and still reasonably high at the loudspeaker unit. This ensures that effective acoustic loading is presented to the loudspeaker cone and small excursions of the cone at high pressure are manifested as much larger low pressure movements of air out of the port at the bottom of the enclosure.

Such a process, similar to horn loading, contributes to efficient bass frequency operation with low distortion up to a frequency of 200Hz, where direct radiation from the cone takes over. The enhanced bass response produced by this method of loading compared with that from the same unit in a 10 litre sealed enclosure is shown in Fig. 2, where the curves were obtained under identical measurement conditions.

This enclosure not only satisfies the requirements of being free-standing with the drive units at a convenient height but also provides an enhanced bass response, using the space that would otherwise have been taken up by a stand. Furthermore, only small cone excursions are required in the bass loaded region and this places the minimum of demands on linearity of the cone suspension and the magnetic field in the voice coil gap, allowing reasonably low priced drive units to be employed.

Continuing the quest for a low price design, it is tempting to consider a wide range twin cone unit for use in this enclosure. Fig. 3 shows the high frequency response of a 165mm diameter paper cone bass unit used in this position with considerable ripple in the response due to cone "break-up"



modes. Unfortunately, when a small tweeter cone is added to the main cone to widen the frequency range, any improvement in frequency response is accompanied by main cone "break-up" ripple as shown in Fig. 4.

A much smoother performer is the 165mm polypropylene cone bass unit with a frequency response as shown in Fig. 5 and this type is recommended for use in the quarter wave enclosure.

Because of the unsatisfactory response of twin cone units, space is provided in the top of the quarter wave enclosure, as shown in Fig. 1, to house a suitable tweeter.

Construction

The enclosure has been designed to make the construction as simple as possible and if the various pieces (see Fig. 6) are cut accurately square then there should be no difficulties in assembly.

Referring to Fig. 7 it can be seen that there are

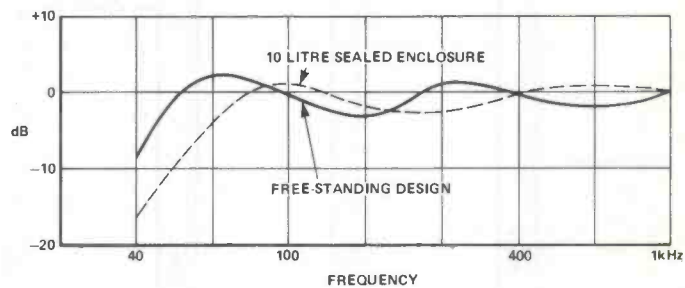


Fig. 2 Comparison of bass performance

only two angle cuts to be made, those at the top of both the long front and back panels. All the rest are simple 90° butt joints and it is left to the individual constructor to decide whether to attempt the angle joints or simply butt the joints and fill the wedge shape gaps with whatever technique and material is convenient.

The dimensions quoted are not critical provided everything is checked to fit as shown in the diagrams so that airtight joints are obtained, particularly in the high acoustic pressure areas in the tapered wedge and around the speaker unit.

The front, back, bottom, top and internal partition members are all made of nominally 1/2 inch thick chipboard and should all be matched to the same width of 7in. The two side panels are made of nominally 1/4 inch thick plywood and it is recommended that one of the panels is marked out to indicate where the 1/2 inch thick panels are located. These can then be cut to size and checked for fit and the assembly pinned and glued together to form the structure drawn in Fig. 2.

As the assembly progresses check it for squareness and, if necessary, secure one or two cross pieces of plywood offcuts with pins driven a little way in to hold the assembly square while the glue sets.

Being reasonably liberal with the glue should ensure airtight joints but pay particular attention to the pointed end of the wedge section and if necessary run a fillet of glue along this particular joint.

Finally complete the assembly by glueing and pinning the second 1/4 inch thick plywood panel into place. It will be noted that the enclosure is reasonably light and stiff and this minimises the energy

TOP PROJECT

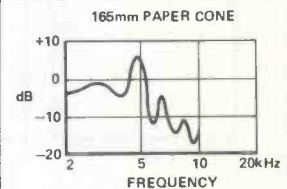


Fig. 3 Frequency response of paper cone unit

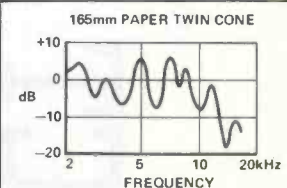


Fig. 4 Frequency response of twin cone unit

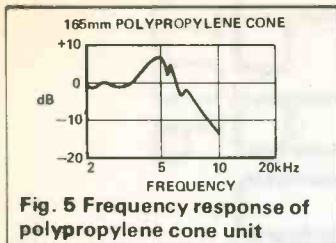


Fig. 5 Frequency response of polypropylene cone unit

storage in the enclosure walls. Tapping the sides of the enclosure produces different notes at different positions indicating that the internal bracing and asymmetry is working to minimise undesirable reflections and panel resonances.

Finishing tasks involve punching the pins home, filling and sanding prior to painting or covering with material or an iron-on veneer.

After several years experimenting with various drive units the best solution, both in terms

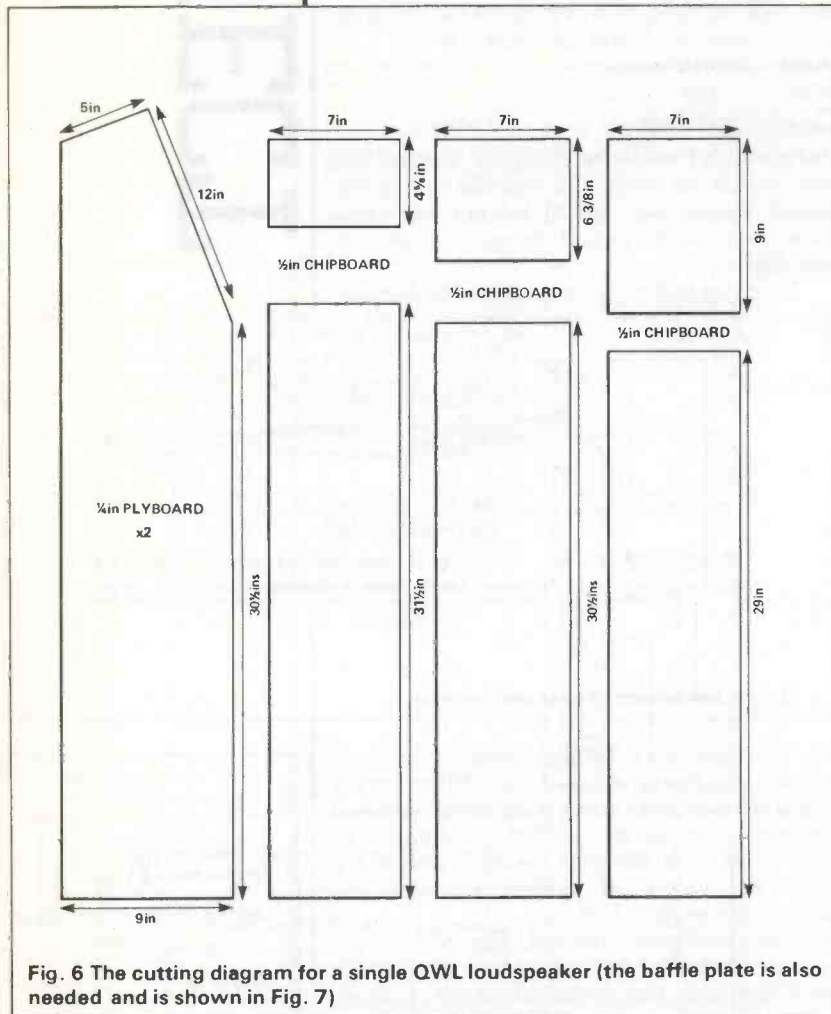


Fig. 6 The cutting diagram for a single QWL loudspeaker (the baffle plate is also needed and is shown in Fig. 7)

of cost and performance, seems to be the simplest of crossover arrangements with a direct connection to the bass unit and a capacitor feed to the tweeter.

The need for attenuation is avoided by choosing a sensitivity for the high frequency unit just below that of the bass unit. The speaker baffle is as small as possible for rigidity and minimum frontal area. The sloping of the baffle time-aligns the outputs from the two units, improves the coupling of the bass unit to the air column in the enclosure. It also exploits an improved smoothness in frequency response of the bass/mid frequency unit observed at this angle off its central axis rather than complicating the crossover.

The Response

Figure 8 shows the combined anechoic response of the two units as derived from the manufacturer's quoted responses as a dotted line, with the in-room frequency response as a solid line (in-room measured using 1/3rd octave noise with a calibrated mic at 0.9m height). The responses show good integration and smoothness. A further bonus of the simple crossover and small sloping baffle is an

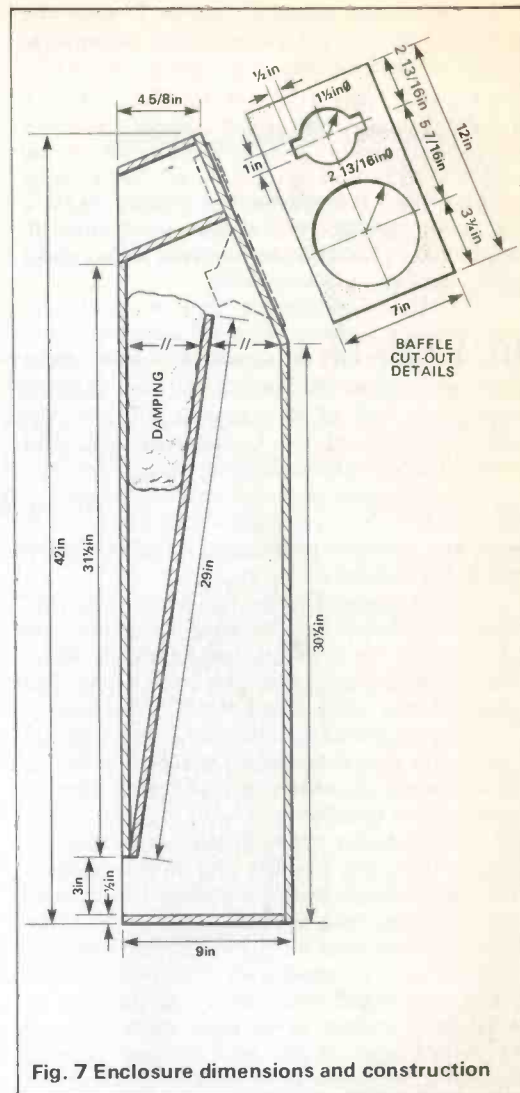


Fig. 7 Enclosure dimensions and construction

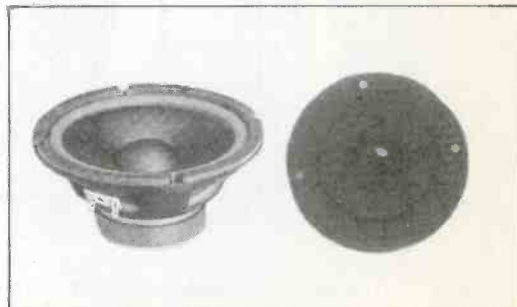
excellent off-axis response as shown in Fig. 9.

The modulus of the installed bass unit's impedance against frequency as shown in Fig. 10. A resonance was detected at about 250Hz but became inaudible with the insertion of damping material into the open end of the closed tapered section as indicated in Fig. 7. The effect of the damping is also shown in Fig. 10.

The damping material is a square metre of terylene wadding (from a dressmaker). It should weigh about 100 grams and is cut in two — a piece for each enclosure. Each piece is folded lengthwise in two and the resulting strip is folded again twice to form a 25cm square, ready for insertion.

The loudspeaker units are mounted from the outside of the enclosure and the bass unit needs a sealing gasket cut out of a thin sheet of plastic foam or paper depending on the surface finish of the baffle. Use chipboard screws and do not over tighten.

Electrical connections may be made to a



TOP PROJECT

connector block fastened just above the port. The bass speaker lead is simply passed down through the bass enclosure and out through the port, whilst the tweeter lead is secured by clips down the back of the enclosure. The series capacitor supplied with the tweeter is a non-polarised electrolytic and readers may wish to upgrade the performance by replacing this component by a better quality version. Readers may also wish to experiment with the provision of steel or plastic spikes in the base of the enclosure.

Performance

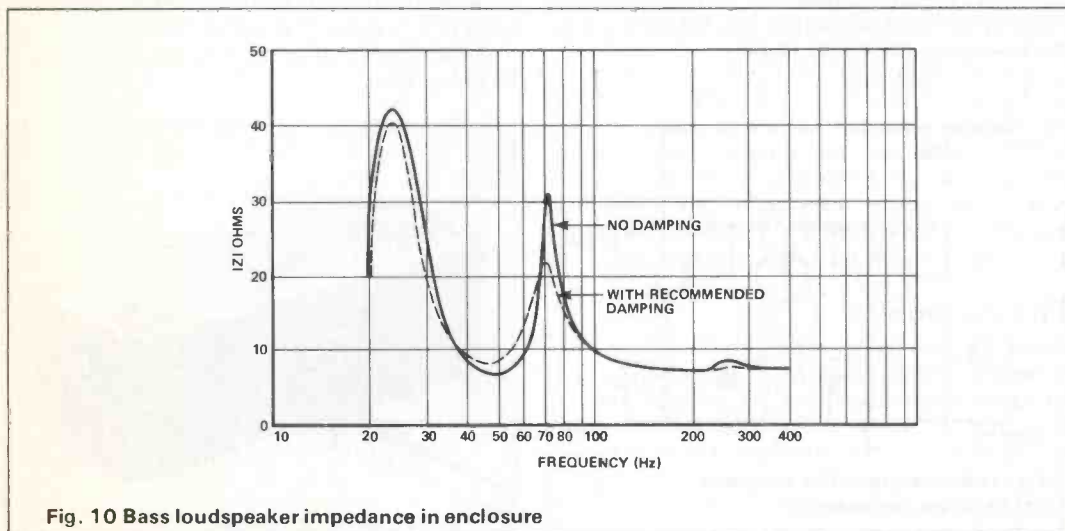
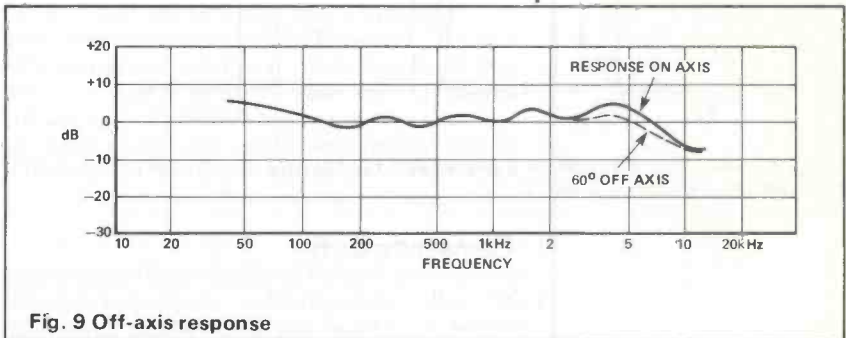
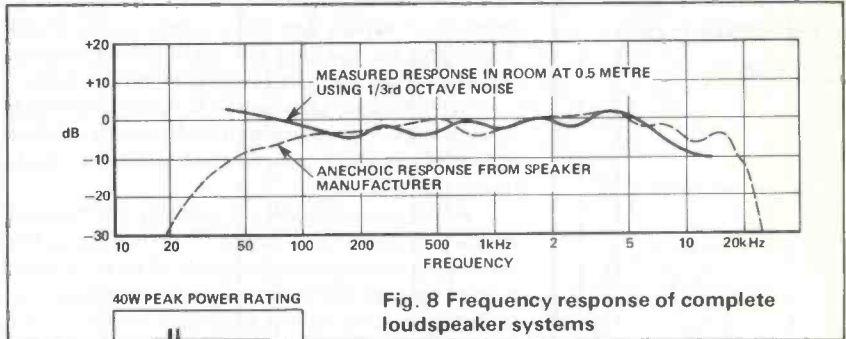
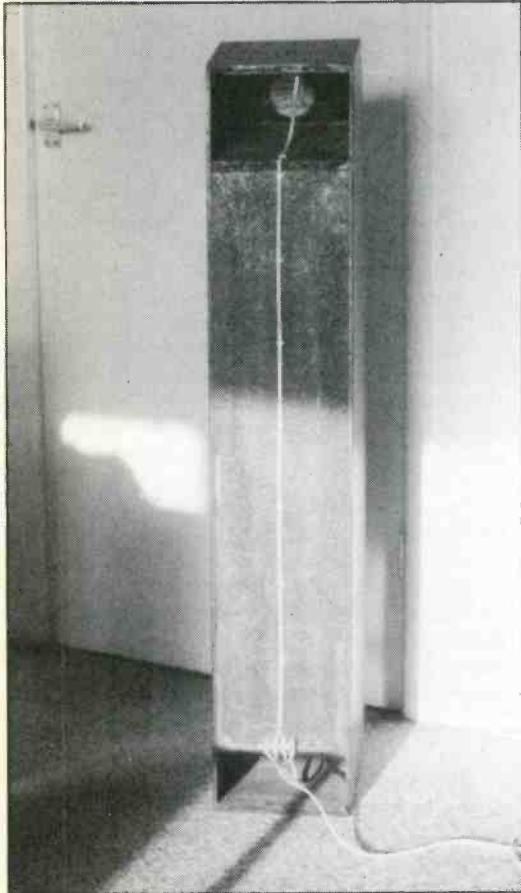
The choice of loudspeaker is often a very personal decision and the present design is the result of many hours of measurement and listening.

This QWL design is relatively cheap and easy to build but achieves a combination of good measured frequency response, stereo imaging, sound quality and efficiency. They occupy very little floor space, are easily moved and are the correct height to preclude the need for stands.

Happy listening.

BUYLINES

The loudspeaker units recommended for this project are Tandy's 6½" woofer (cat no 40-1011) and dome tweeter (cat no 40-1276). Tandy's mail order address is Tandy Centre, Leamore Lane, Bloxwich, Walsall WS2 7PS. Tel: (0922) 710000.



TRAVELLER'S AERIAL AMP

Keen caravanner Keith Brindley finds poor television pictures a bind. With this project he's guaranteed a good picture wherever he parks his van

TOP
PROJECT

Campers and caravanners alike will know the difficulties in picking up a strong enough signal to ensure good television reception when touring around the country. The main problem is, of course, that the typical touring aerial you use hasn't the same sort of gain which permanent aerials have. Permanent aerials can have gains up to 20dB, depending on size and the number of elements. Touring aerials, if you're lucky, give around 4dB.

What's more, your aerial at home is sitting at rooftop level — your touring aerial is at best stuck on the top of a caravan, at worst a tiny set top job, inside the van or tent.

Aerial pre-amplifiers are available but most are mains-powered — fine for home use but not so fine for touring where your only source of power is often a car or caravan 12V battery. Those which allow low-voltage operation have limited gain anyway — no more than about 10dB usually — so pictures can often be still marred if you happen to have pitched for the night in a location with poor signal reception.

The aerial amp featured here on the other hand gives a remarkable 23dB gain so, even with a limited touring aerial and situation, you should be watching acceptable television pictures when you're on holiday in next to no time.

The main component in the project is a thick-film hybrid IC, Mullard's OM335. It features an extremely wide bandwidth (wide enough that you can use it for amplifying VHF radio broadcasts, too) and wide operating voltage (around 9-28V). These make the IC ideal for the purpose here, although it can also be used to advantage as a masthead, set-back, or MATV preamplifier in the home or laboratory.

Construction

Construction couldn't be simpler. With the grand total of three — yes only three — components mounted on the circuit board, the project ideally qualifies for *1st Class* category. Nevertheless, a number of points need to be made and certain precautions must be taken to ensure the project works.

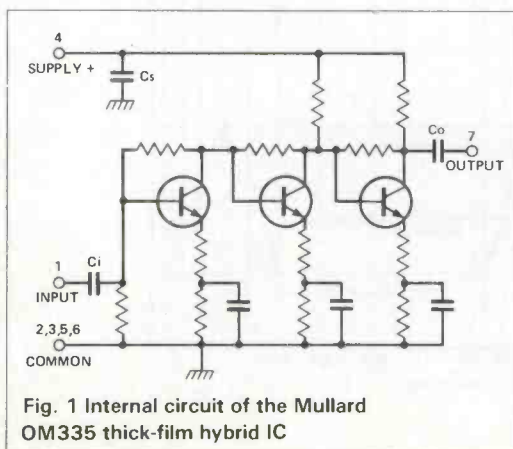


Fig. 1 Internal circuit of the Mullard OM335 thick-film hybrid IC

HOW IT WORKS

Figure 1 shows the internal circuit of the OM335. It is a complete wideband preamplifier, formed by three DC coupled transistor amplifying stages. The circuit really is wideband, amplifying with almost identical gain all signal frequencies between 40MHz and 860MHz. Gain still occurs outside these limits and the IC will make a respectable 10MHz to 1.4GHz preamplifier, albeit with a none-too-flat frequency response. For example, with a power supply of 24V, gain at 10MHz is 22.5dB, while gain at 1.4GHz is 13.2dB. Mid-band gain at this supply voltage is around 26dB

Input and output to and from the IC are AC coupled via capacitors C_i and C_o , while supply decoupling is performed by capacitor C_s . Figure 1 shows the overall circuit which features an extra supply decoupling capacitor and a diode to ensure no damage can be done if the power supply is accidentally reversed.

Note that the IC is formed by thick-film techniques which means the individual components you see in the diagram are real components, built into the circuit, one by one, at manufacture.

The IC's characteristic input and output impedances are both 75R in common with UK VHF and UHF practice and this means it is vital to match these impedances to steer clear of mismatch problems. This could be done by soldering standard 75R coaxial cable direct to input and output pins of the IC but this makes construction a bit tricky, not to mention messy.

Instead, the circuit board designed for the project has tracks which themselves have characteristic impedances of 75R too. For standard 1.6mm thick epoxy glass board, an impedance of 75R corresponds to a track dimension of 1.5mm width with an earthed layer either side and underneath of the track. Using such a board with input and output connection track dimensions like this, it is then an easy job to mount the IC onto the PCB, then make coaxial cable connections direct to the board.

You must remember that a high-gain amplifier working at the sort of frequencies which televisions receive (450-900MHz) can often be subject to oscillation if adequate screening and mounting techniques are not followed. This is the reason why the project can *only* be built using a PCB — a double-sided PCB at that — and *not* on Veroboard. The ins and outs are explained more deeply in the *How It Works* section.



TOP PROJECT

PARTS LIST

CAPACITORS		
C1	100n ceramic	
SEMICONDUCTORS		
IC1	OM335	(OM335) 12V.
D1	1N4001	£12-3L
MISCELLANEOUS		
Aluminium alloy diecast box (89x35x30mm). Two coaxial aerial sockets. PCB. Grommet. PCB pins. Nuts and bolts.		

BUYLINES

All parts should be easily obtained. The OM335 IC is available from Electronix on (0536) 201234. The PCB is available from the ETI PCB service.

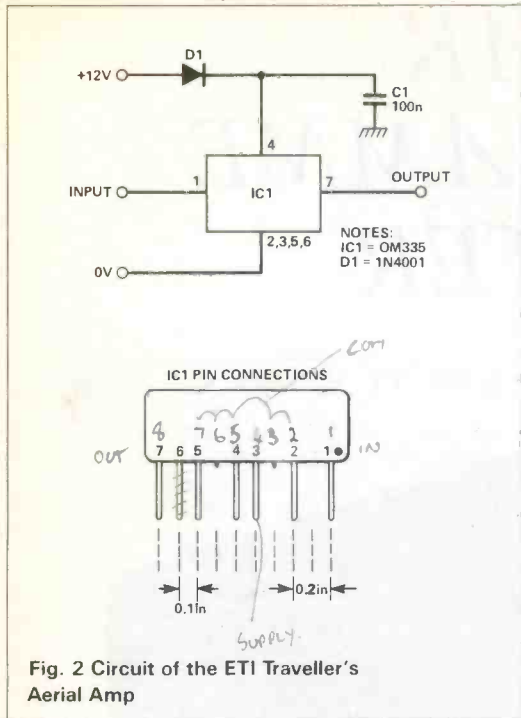


Fig. 2 Circuit of the ETI Traveller's Aerial Amp

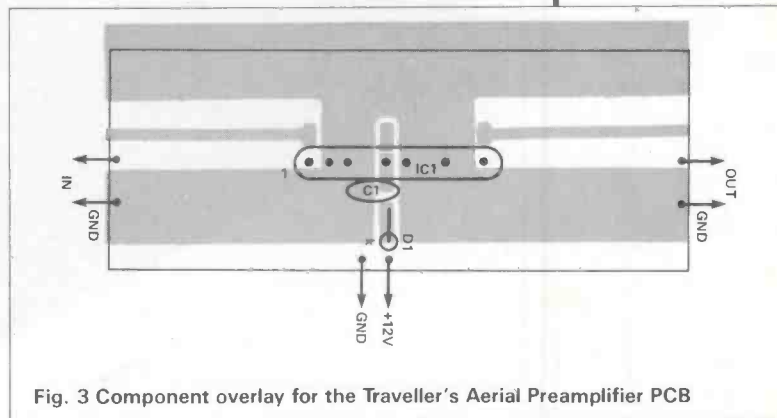


Fig. 3 Component overlay for the Traveller's Aerial Preamp PCB

Start with the case. In our prototype, an aluminium alloy diecast box was used. This not only gives a suitably tough enclosure for portable use but also allows total electrical screening of the internal circuit. The PCB (see Fig. 3) was designed for use with this case so it makes sense for you to use an identical one but anything larger will also do.

First, drill the case for the two co-axial aerial sockets and power input lead. The aerial socket fixing holes must be drilled at about 45° angles to allow the bolts to pass through the case without touching the threaded supports inside the case at each corner. Fit a grommet into the power input hole.

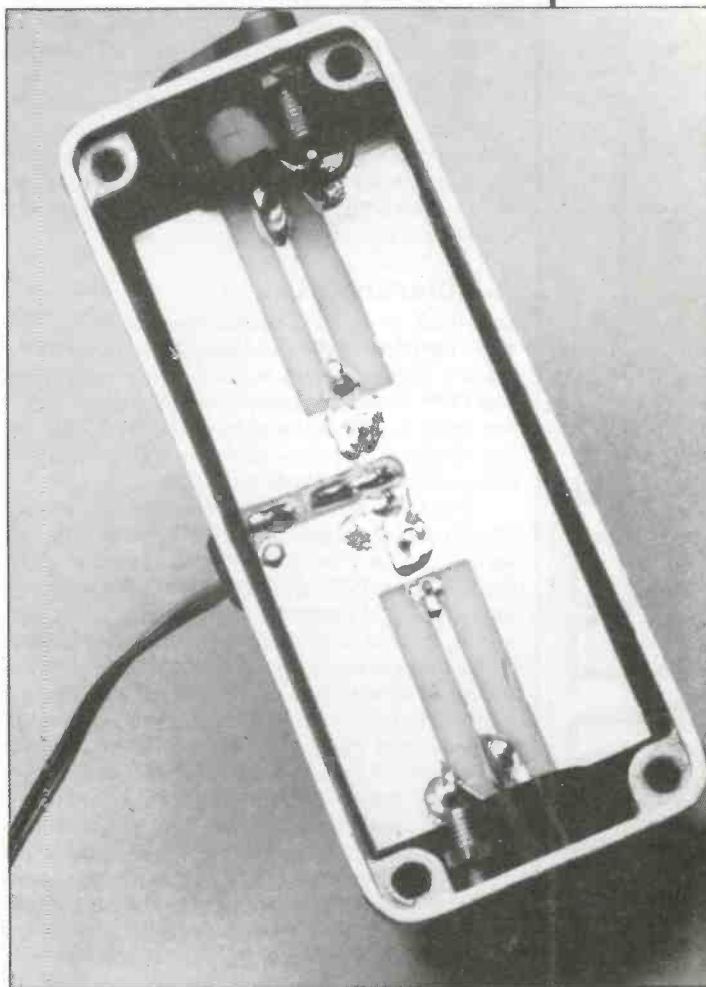
Next, file the PCB (without any components, at this stage) to fit the case, between the two inside edges of the two aerial sockets. The board must be a fairly good fit, because it is to be held in position between the two sockets simply by soldering the sockets' terminals to the board.

Now solder the components into the board. Be extremely careful with the amplifier IC. It's not particularly fragile but it can be damaged by excessive heat. Solder it in one pin at a time, letting the IC cool in between. Pins should be soldered on both sides of the board (component side and underneath) so you'll need a fine-tipped soldering iron to avoid touching the IC when soldering on the component side.

Mount and solder the other two components (ensuring the diode is the correct way round) and solder in two PCB pins, to which the earth terminals of the two aerial sockets can be soldered. Solder in power connections. About an inch from the board, tie a knot in them to prevent them from being pulled out and feed them through the grommet. Now, insert the PCB between the aerial socket terminals (the components should be on the underside).

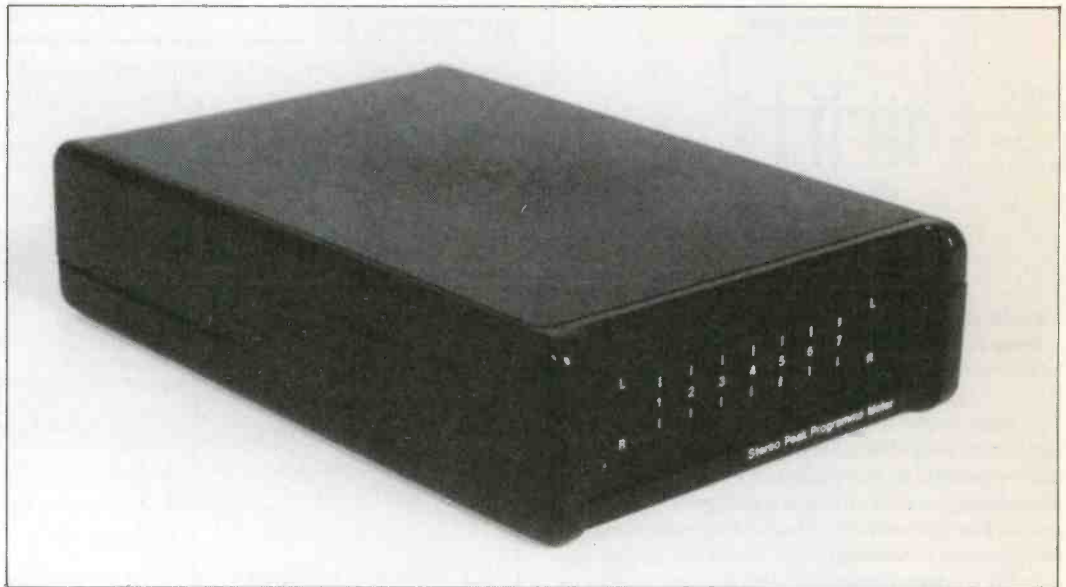
Solder the aerial socket terminals to the PCB at each end. Finally, earth the case to the PCB with a short connection from one of the socket mounting nuts and bolts to the board. For your own reference, mark the case so that input and output sockets cannot be confused.

No setting up is required, simply connect a power supply of 9-28V and plug in your aerial and television leads.



PEAK PROGRAMME METER

*Ian Coughlan
peaks at the right
time with his high
quality stereo
meter*



There are two major differences between the typical peak programme meter and the VU meters that are more familiar to most people. The PPM has very different ballistics — it attacks quickly and decays slowly so that peak signal levels are clearly displayed. In addition the PPM's scale is roughly linear whereas the scale of a VU is anything but.

A Different VU

Let's look at the VU meter in more detail. The audio signal is rectified and integrated to produce a reading corresponding to the average signal level (the PPM shows the peak level). At the left end of the scale is -20, at the right end is +3VU. About two-thirds of the way along is 0VU, which by convention corresponds to +4dBm.

Put a sine wave into the VU meter at a level of +4dBm and it will read 0VU. Simple. Put a typical audio signal in at an average level of +4dBm and it will still read 0VU, although the needle will jump around a bit in response to the signal.

A typical audio signal however, contains peaks that will be rather more than +4dBm. Since a VU meter integrates, these peaks will not produce a proportionate increase in meter reading and the audio system can be driven into overload even though the VU meter says everything is fine.

This may be relatively unimportant — analogue tape recorders for example exhibit a 'soft' overload characteristic and the distortion is not too objectionable. Other media are not always so forgiving. Digital recording systems, radio transmitters and indeed audio amplifiers have very sharply defined upper limits. Drive them even a little above their limits and they simply will not go

— the signal will clip and the resulting distortion is very nasty indeed.

Obviously the best signal-to-noise ratio from an audio path is obtained running as close to the upper limit as you can, short of overload. If all you've got is a VU meter, the peaks are not going to register so you'll have to allow a considerable amount of headroom above the average signal level for these peaks and that's going to compromise the performance at the bottom end.

Enter The PPM

The fast response of the PPM means that the magnitude of peaks within the signal can be monitored with precision and if you know where your system's upper limit is (it's easy to find — just increase the signal until the output clips), adjust the level so that the peaks are just below the limit. You may want to allow headroom for extra large peaks, but with pre-recorded or broadcast material the recording engineers will have squashed those out long before they get to you!

Not just any old meter can be used for a PPM. Only specialised (and expensive) movements have the necessary ballistics, most ordinary movements being far too slow. The PPM to be described in this article uses LEDs in place of a meter movement and they're as fast as anyone could want! Cheap too — the cost of producing this stereo PPM with built-in power supply is less than the price of one PPM meter with drive card. True, it doesn't have the ultimate accuracy of such a meter but in side-by-side comparisons monitoring typical programme material, no visual differences could be observed. Besides, LEDs look pretty.

The PPM scale is quite distinctive. Unlike the VU meter which tends to squeeze the area of

interest into the top half of the scale, the PPM stretches this area out so that it spans the full width of the scale as shown on the photos.

PPM1 on the left corresponds to -12dBm , PPM7 on the right is $+12\text{dBm}$. In the centre of the scale is PPM4, which is 0dBm . The scale markings are equally spaced, each 4dBm from its neighbours.

PPM	Volts RMS	Volts Peak	dBm
1	0.195	0.275	-12
2	0.308	0.436	-8
3	0.489	0.69	-4
4	0.775	1.095	0
5	1.228	1.736	+4
6	1.946	2.752	+8
7	3.084	4.36	+12

Note:
0dBm is referred to 1mW in 600R, accepted as 0.775V RMS.

Table 1 PPM display levels

Table 1 shows the PPM numbers with their corresponding dBm levels and voltage levels (RMS and peak). To achieve this linear scale a non-linear amplifier is needed and Fig. 1 shows the desired transfer function of this amplifier. The function is realised in this design by a technique known as discontinuous approximation. The output of the non-linear amplifier does not change in a smooth, continuous manner, instead the transfer function consists of a series of straight lines, designed to approximate to the desired curve as shown in the dotted curve. The slope of the amplifier is made to change at each breakpoint and the more breakpoints and slopes there are the more accurate will be the approximation.

This design uses three breakpoints and four slopes, which is quite adequate for the application. Figure 2 illustrates the technique.

For all input voltages up to $+1\text{V}$, the gain of the amplifier will be -1 since Q1 will be non-conducting (its base is held at -0.3V). As the output falls below -1V , Q1 will begin to conduct providing an extra feedback path around the amplifier. The feedback resistance is now effectively R3 in parallel with R2, so the gain becomes -0.5 . Further breakpoints can be added as shown.

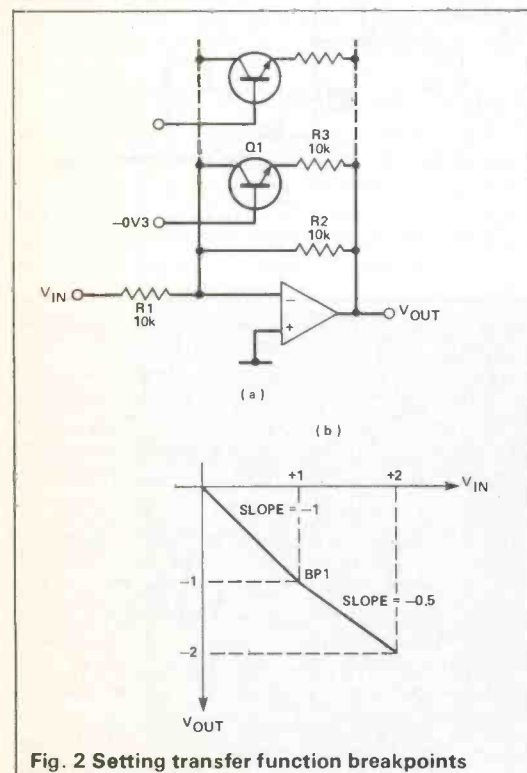


Fig. 2 Setting transfer function breakpoints

Construction

The front and rear panels (supplied with the recommended box) should be cut and drilled as shown in Fig. 5. Drilling the holes in the front panel will not be as easy as it looks. The trick is to drill the four large holes first and fix stripboard to the panel with the holes aligned with the positions of the LED holes. Now drill pilot-holes in the panel, 1mm in diameter, using the strip as a jig. Remove the stripboard and drill the holes out to 2mm. But be warned — don't just rush ahead and do it. Practise on a piece of scrap material first. I ruined four or five pieces before I got it right!

When you're happy with the panels, rub them down with wet 'n' dry paper, clean them and then prime and paint them. Spray-painting gives a much better finish than brush-painting. When the paint is dry, apply dry-transfer lettering and protect this with a light spraying of Letracote or Letfix aerosol varnish.

Fix the phono sockets, slide switch, and IEC mains inlet to the rear panel. Also, fit a solder-tag to

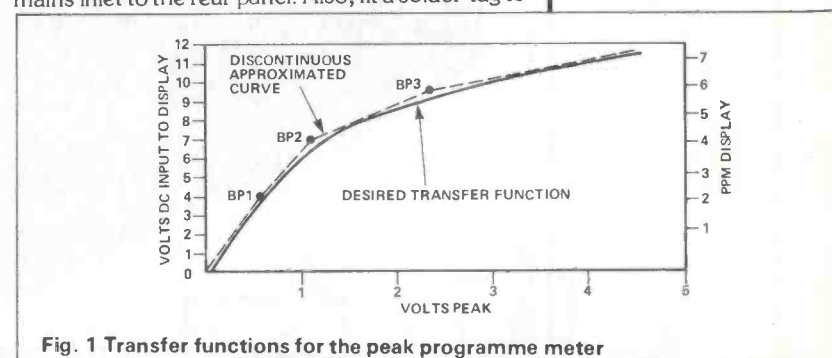


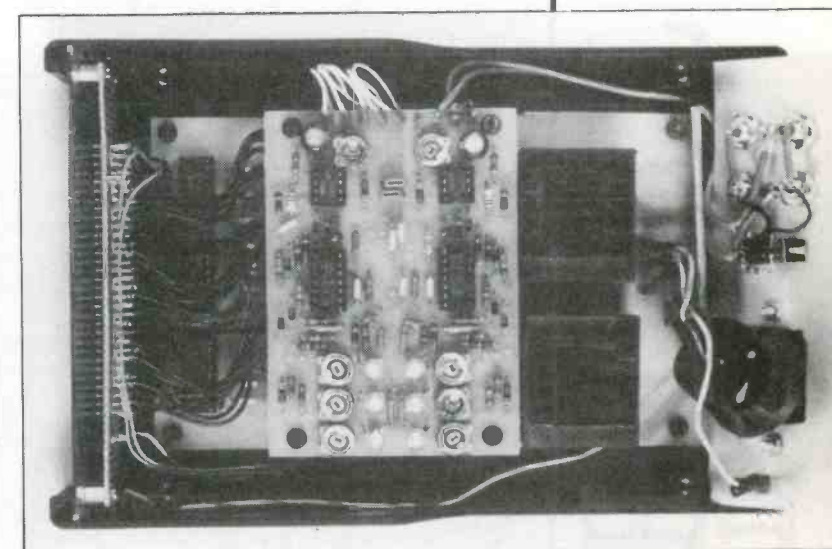
Fig. 1 Transfer functions for the peak programme meter

the rear panel for the earth connection: mains voltages are present within the unit and it's up to you to see that it is safe to use.

Solder R55 and R56 to the slide switch, SW1. Put all the LEDs into a piece of stripboard (observing polarity) but don't solder them yet. Guide the LEDs through the holes in the front panel, and fix the stripboard to the panel using countersunk screws from the front and 6.35mm ($\frac{1}{4}\text{in}$) spacers. Fix a solder-tag to one of the screws — this is the earth connection for the front panel.

If all the LEDs fit snugly, solder them to the stripboard and cut the tracks between the cathodes. The tracks connecting the anodes can be left intact, since all anodes are commoned together anyway.

Now is a good time to check that all LEDs work using a power supply of about 12V and a



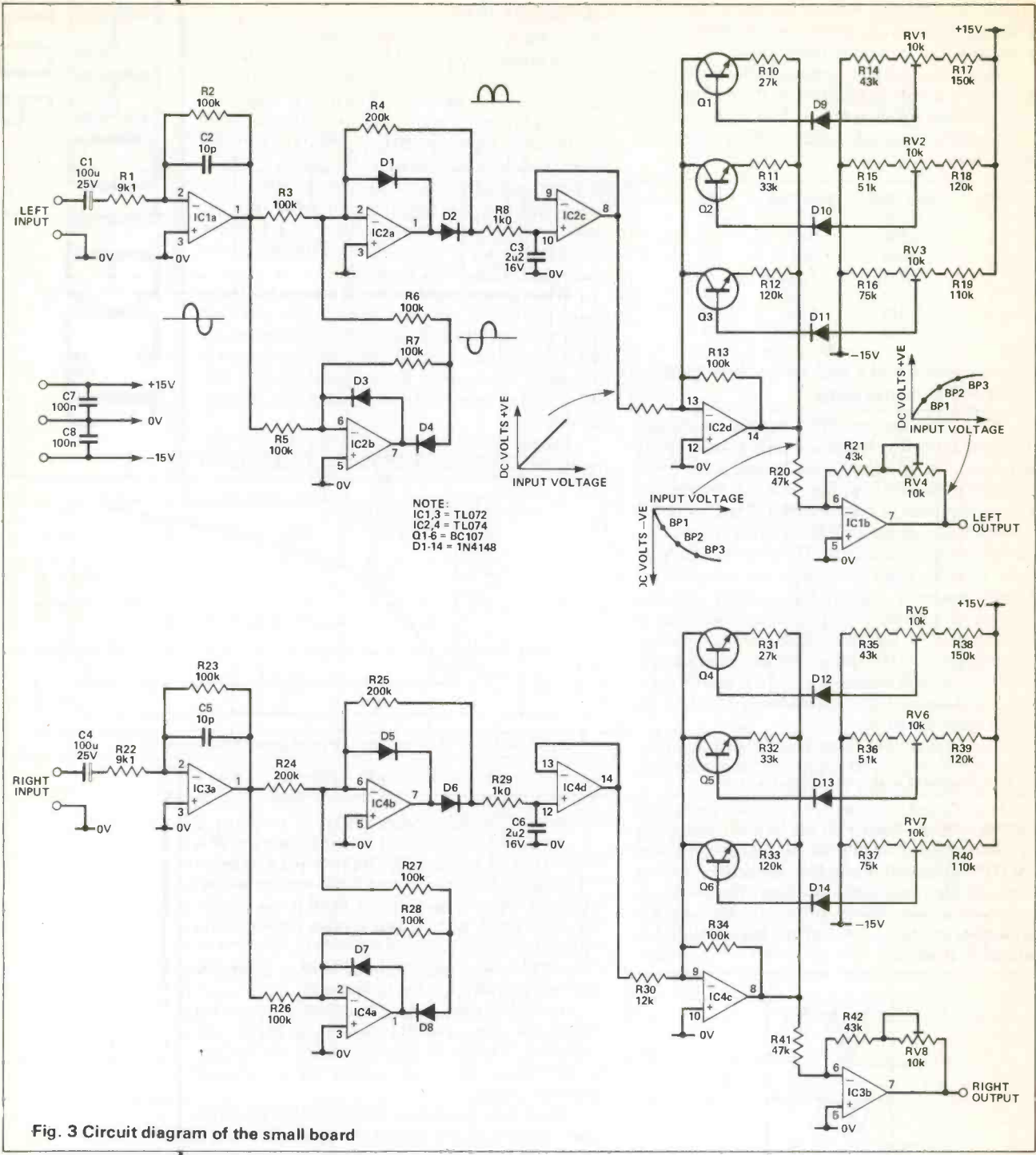


Fig. 3 Circuit diagram of the small board

TOP PROJECT

HOW IT WORKS

The circuit diagrams of the two boards are shown in Figs. 3 and 4. Apart from the power supply, the PPM consists of identical circuits so for reasons of clarity only one half will be described.

IC1a is an inverting amplifier with a gain of about 20dB when SW1 is in the -20dBm position and unity gain when in the 0dBm position. In this way the PPM can be used on professional equipment with signal levels of 0dBm and also on domestic equipment which has a much lower signal level. Note that the input impedance will be 9.1k in the -20dBm position and 100k in the 0dBm position.

IC2a and b are configured as a full wave rectifier. IC2a will ignore the positive half-cycle of the signal waveform, but will invert the negative half-cycle. IC2b will do just the reverse. The resulting signal on D2's cathode will be positive-going and is used to charge C3

via R8. The voltage on this capacitor is equal to the peak input signal level.

The charging time-constant is determined by R8 and C3, the discharge time-constant is determined by R4 in series with R8 and C3. This is what gives the PPM its fast attack/slow decay characteristic. IC2c buffers the voltage on C3.

IC2d is the non-linear amplifier and its operation is described elsewhere in the article. RV3 sets breakpoint 1 (BP1), RV2 sets BP2 and RV1 sets BP3.

Before BP1 is reached, the gain of the stage is R13/R9. Above BP1 but below BP2, R12 is in parallel with R13 and the gain falls accordingly. Above BP2 but below BP3, R11, R12 and R13 are all in parallel. Above BP3, R10, R11, R12 and R13 are in parallel.

Thus as the input rises, the gain of the stage drops to a lower value at each breakpoint.

NDTE:
 IC5-10=LM3914N
 IC11=78L15
 IC12=79L15
 D15-22=1N4002

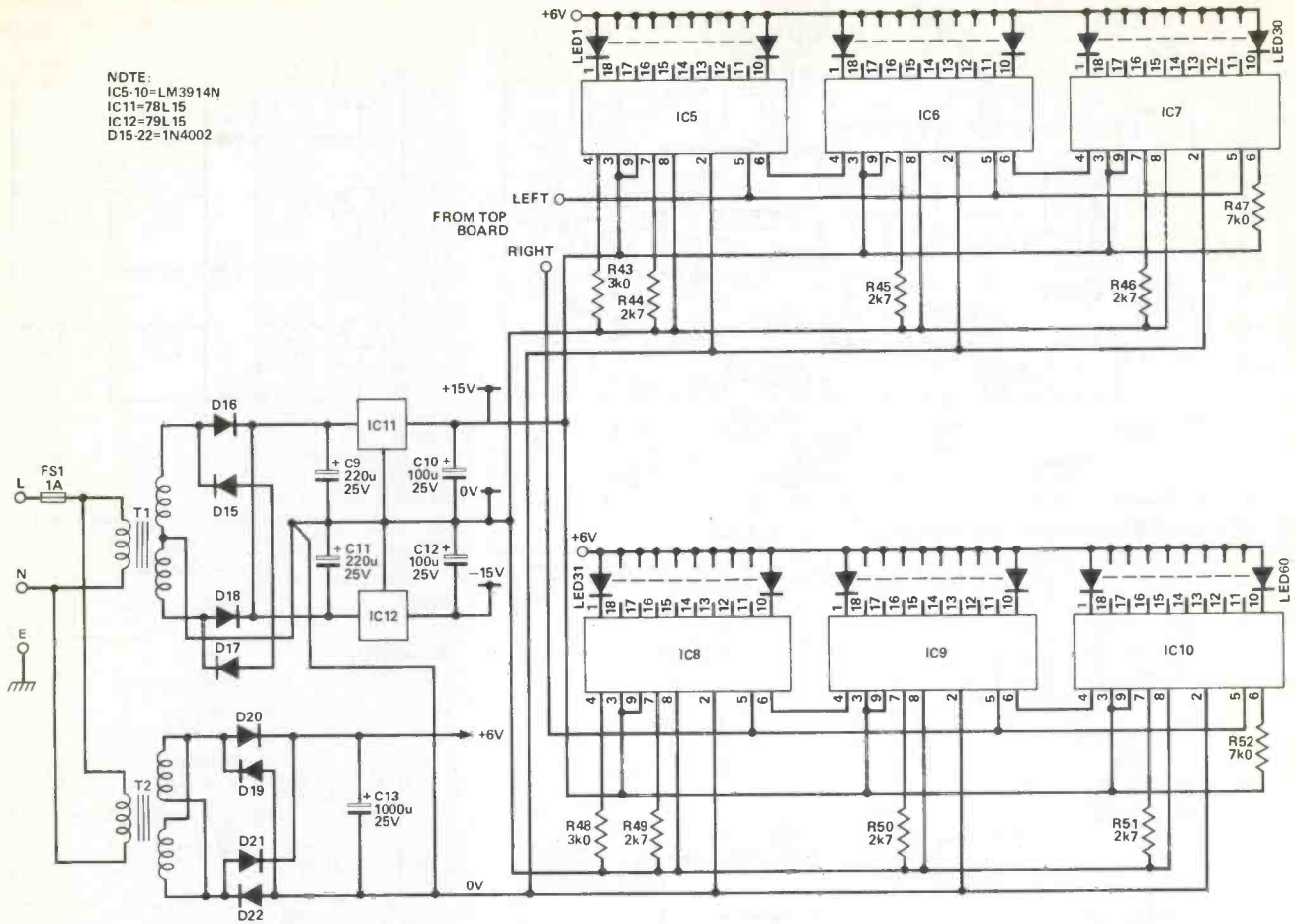


Fig. 4 Circuit diagram of main board

series resistor of say 4k7. If all is well, slide a piece of thin card down between the two rows of LEDs, to prevent light from one row spilling into the next. Put the front and rear panels to one side.

Check both PCBs for short circuits before you start on then. The overlays are shown in Figs. 6 and 7. Insert the through pins from the copper side of the large board and from the component side of the small board. This will keep all the wiring between the boards, resulting in a neater overall appearance.

Fit and solder links, resistors, capacitors, DIL sockets, presets, fuse-clips, transformers and semiconductors (except ICs) to both boards. Connect the lettered points on the underside of the small board, using insulated 7/02 wire, and put this board to one side.

Note that two resistors on the large board (R47, 52) are select-on-test, so these cannot be fitted until their value is known.

Some initial tests should be made at this stage. Pop a 500mA fuse into the fuse-clips and connect a pair of insulated wires to the live and neutral pins. Be careful! A healthy respect for high voltage is a good thing.

Apply power and check for +15V and -15V on the appropriate pins. If all is well, disconnect the power and insert the LM3914s into their sockets, being careful to put them in the right way round (they're quite expensive devices).

Temporarily connect an LED to the LED3 position and another to the LED27 position. Connect a potentiometer (preferably a multiturn preset about 10k) between +15V (clockwise end) and 0V (anti-clockwise). Connect the wiper to the LEFT input pin.

Switch on the power again and adjust the potentiometer for +11.25V on its wiper. R47 must

now be selected so that LED27 is only just on. Another preset (20k) will make this easier. When the value is known, solder R47 into place. It may be necessary to fit two or more resistors in series or parallel. Now check that LED3 is on above a voltage of +1.25V on the wiper of the multiturn preset.

The above procedure must now be repeated for the RIGHT channel, so move the LEDs over to LED33 and LED57 and move the wiper of the multiturn preset to the other input. Once you're

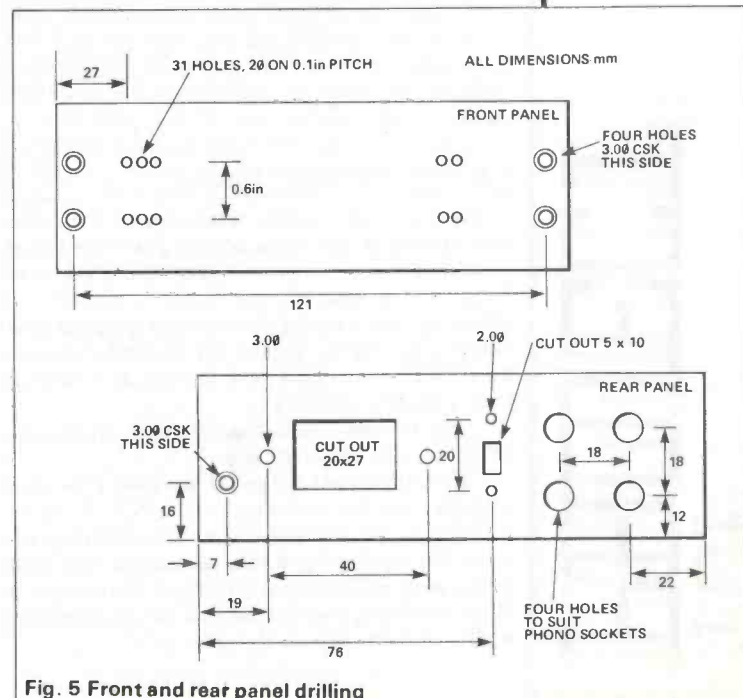


Fig. 5 Front and rear panel drilling

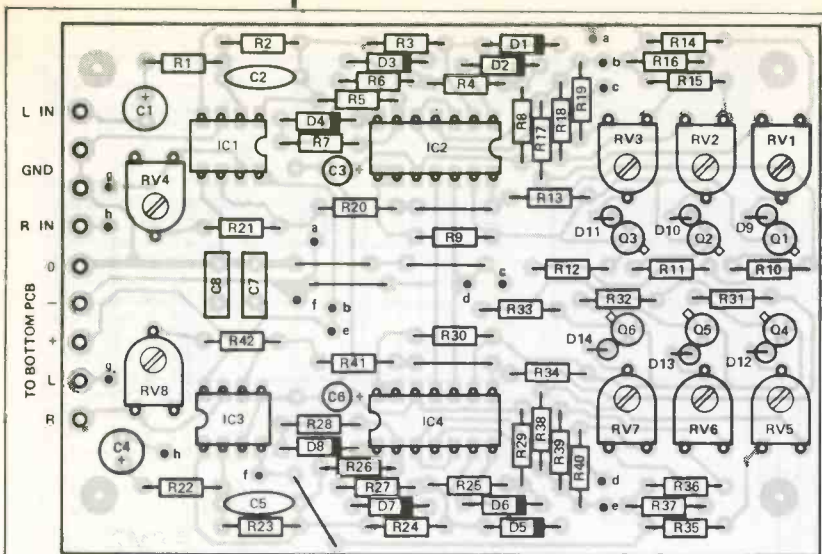


Fig. 6 Component overlay for the small board

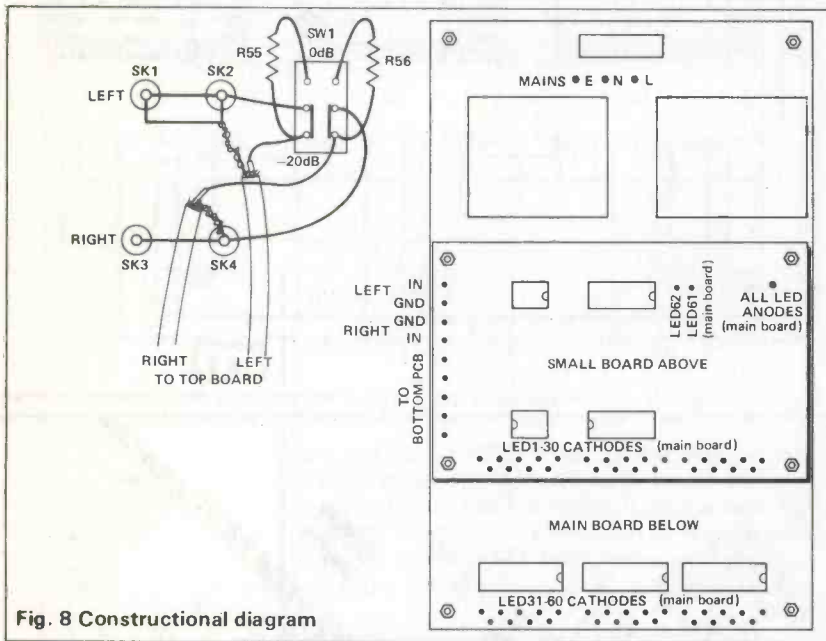


Fig. 8 Constructional diagram

BUYLINES

Most components should be available from any supplier. The transformers used in the prototype were from Electromail (Tel: (0536) 204555), order codes 207-841 and 207-829. The LEDs are order code 588-689. The case used was from West Hyde ((0296) 20441), code BB0710. The prototype was actually built used two lids and no base, but the size of case given here is recommended. Note that voltage ratings given for capacitors represent minimum ratings.

happy with both channels, disconnect the power and remove all the other temporary connections.

Wire in the cathodes of the 62 LEDs. The left hand LED of each channel (LED61, 62) are lit at power on and connect to the centre of the main board. The display for the left channel then runs from LED30 to LED1 and for the right channel from LED60 to LED31.

Fix the two boards together with 1in spacers. Fit the ICs to the small board.

Cut a piece of card and fit it to isolate the input sockets from the mains end of the PCB. Drop the two PCBs into the box and fix the assembly into place. Fit the front and rear panels and wire them to the large PCB as shown in Fig. 8. Remember to fit an insulating boot to the IEC mains connector and to connect the earth wires.

PARTS LIST

RESISTORS (all 1/4w 5% unless specified)

R1, 22	9k1
R2,5,6,7,13,23,	
26,27,28,34	100k
R3,4,24,25	200k
R8,29	1k0
R9,30	12k
R10,31	27k
R11,32	33k
R12,18,33,39	120k
R14,21,35,42	43k
R15,51	51k
R16,37	75k
R17,38	150k
R19,40	110k
R20,41	47k
R43,48	3k0 2%
R44,45,46,49,	91K
50,51	2k7
R47,52	7k0 (Nominal: see text)
R53,54	3k9
R55,56	91k
RV1-8	10k skeleton preset

CAPACITORS

C1,4,10,12,13	100µ 25V electrolytic radial
C2,5	10p polystyrene
C3,6	2.2µ 16V tantalum bead
C7,8	100n ceramic
C9,11	220µ 25V electrolytic radial
C10	100µ 25V electrolytic radial

SEMICONDUCTORS

IC1,3	TLD72
IC2,4	TL074
IC5-10	LM3914N
IC11	78L15
IC12	79L15
Q1-6	BC107
D1-14	1N4148
D15-22	1N4002
LED1-62	red 2mm flat top LED

MISCELLANEOUS

FS1	1A 20mm fuse
SK1-4	Phono sockets
SW1	DPDT sub-miniature slide switch
T1	0-15 0-15 3VA PC mounting transformer
T2	0-6 0-6 3VA PC mounting transformer

Case. IEC mains connector and insulating boot. 20mm fuse clips. 20mm spacers. 6.35mm spacers. IC sockets. Solder tags. Stripboard. Cardboard. Pins. Silicone rubber sleeving. 16/02 & 7/02 insulated wire. Nuts and bolts. 22swg link wire.

Calibration

Calibrating the PPM is very straightforward. You'll need an audio oscillator, capable of producing up to +12dBm (3.08V RMS). The procedure is identical for both channels, so do the left channel as described here and then the right channel, with appropriate changes to component references.

Set the slide switch on the rear panel to the 0dBm position. Apply a sine wave at a level of -8dBm (308.4mV RMS) to the left input, and adjust RV4 until the meter reads PPM2.

Increase the signal level to 0dBm (775mV RMS) and adjust RV3 for PPM4. Increase the signal level to +4dBm (1.228V RMS) and adjust RV2 for PPM5. Increase the signal level again to +12dBm (3.084V RMS) and adjust RV1 for PPM7.

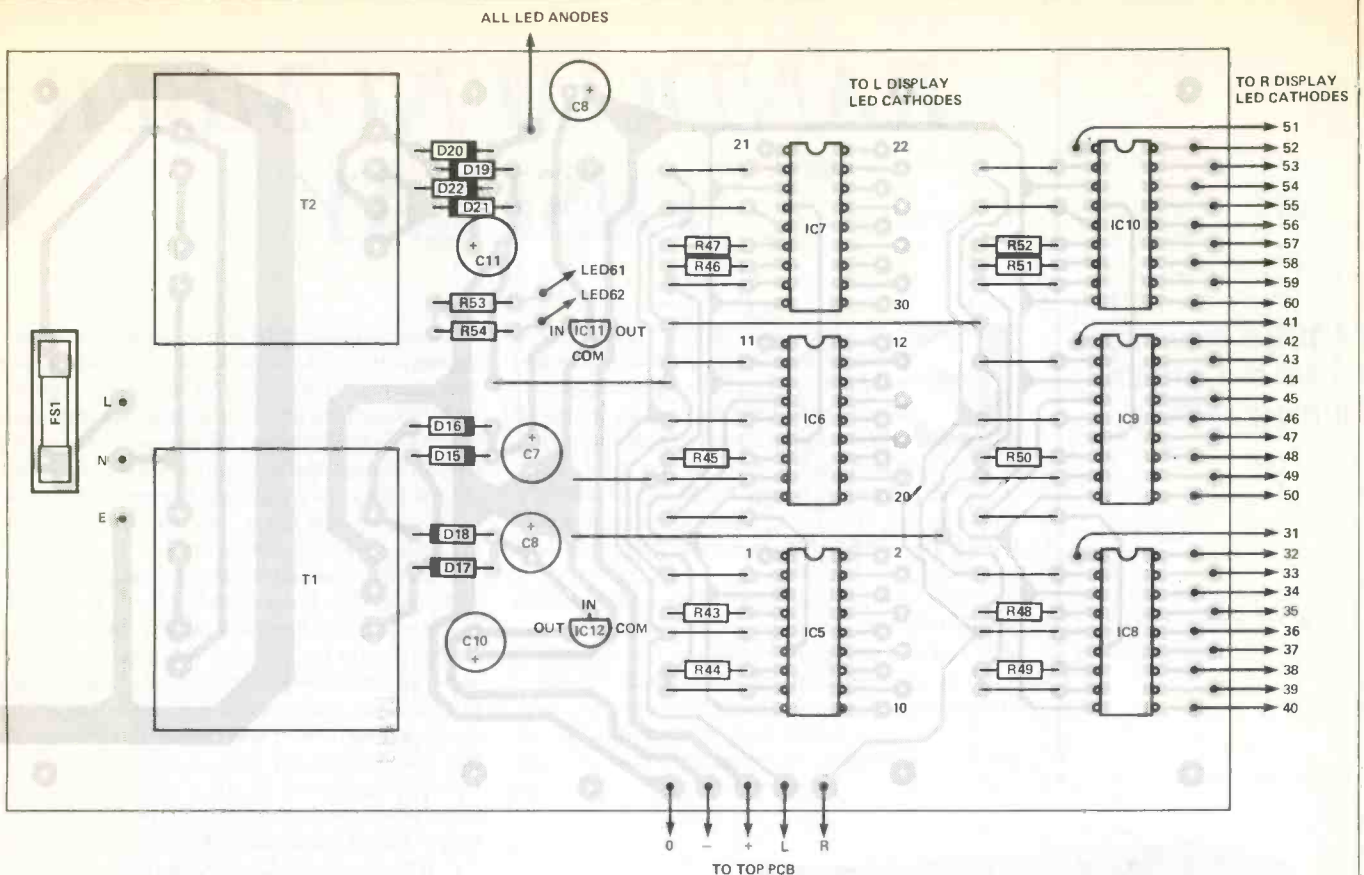


Fig. 7 Component overlay for the main board

Check the PPM points against the signal levels shown in Table 1 and if necessary repeat the above procedure. When you're happy with the left channel, move onto the right.

That's all, calibration is now complete. Fix the lid in place and the PPM is ready for use.

In use, the PPM simply connects into the audio circuit you want to monitor.



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RANDOM NUMBER DISPLAY

Geoff Phillips presents a tale from the country and a project to boot

Every week the Nether Wallop Grand Order of Tripe Trimmers and Offal Boilers held a prize draw. The committee were bored tripeless with laboriously tearing off all the ticket stubs every Saturday, folding up each one and placing them all in a hat.

They tried using a cage full of numbered balls, but some got lost during a ping-pong game and anyway the members were complaining that the draw wasn't fair.

"How can us members at the back of the hall be sure that the ball you've drawn has the number you say?" shouted one of the members. The integrity of the committee was in question and drastic measures were required. A special committee meeting was held.

"I think we should have one of them didgy-tell number machines like down that fancy new pub in the

Christmas disco party in the town. He wasn't too impressive at dancing, and the town girls seemed a little alarmed by the blood on his butcher's apron, but what did catch his attention was the one-armed bandit which stood in the lobby. He reasoned that each time the lever was pulled the time period before each drum stopped must vary slightly, otherwise a regular series of patterns would occur. The speed of the drums at each play probably varied too.

Kevin knew how to design an electronic counter which would cycle the digits 0 to 9 in a similar fashion to the wheels on the fruit machine, but the speed of cycling would be constant. He also knew how to generate a time delay electronically so as to simulate the time the drums spun, but again this would be constant each time it was triggered. He knew that if the members could spot a repetitive pattern of numbers generated by the machine he designed, there would be trouble (he might even be subjected to the Grand Order's ritual offal-dipping punishment).

If the numbers were cycling all the time however, and were stopped when a button was pressed, then the number should be random — the button pressing would not be linked to the electronic counter in any way.

But Kevin realised people would suspect foul play if the numbers were stopped by a committee

HOW IT WORKS

The circuit diagram is shown in Fig. 1. The timers IC1, 2 and 3 are connected as free running astable multivibrators which generate three separate clock signals for the BCD counters IC5, 7 and 9. These counters are running continuously and asynchronously irrespective of whether the start button has been pressed or not.

The outputs of the three counters are fed to three BCD to 7-segment decoders which drive the numerical display formed by the matrix of LEDs 1 to 84. Four series-connected LEDs make up each segment of each digit. The BCD decoders have built in latches which can store the BCD code for any digit from 0 to 9.

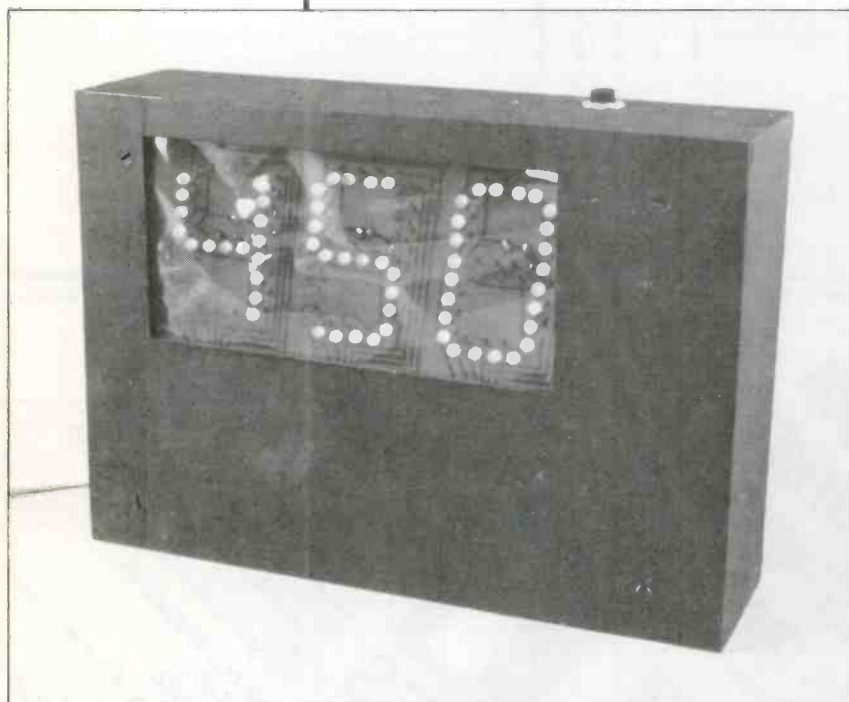
When the LE (latch enable) pin of the decoder is taken to logic 0, the latches are disabled and the decoder gives the 7-segment drive voltages to the LEDs equivalent to the BCD codes at their inputs A, B, C, D. The LED displays are seen to cycle through the digits 0 to 9 as the counters cycle through the BCD codes.

When the LE pins of the decoders are taken to logic 1, the latches are enabled and store the code which was present on the inputs A, B, C, D at the time of the logic 1 application.

The outputs of the decoders then cause the LEDs to continuously display the number stored. The LE pins of the decoders are controlled by IC4, 6, and 8 which are connected as monostables. When the start button is pressed, all three monostables are triggered and their outputs (pin 3) go to a logic 1 which (when inverted by Q1, 2 and 3) cause the LE inputs of the decoders to be taken to logic 0. The LED displays are then seen to cycle through the numbers.

The time of the monostable associated with the most significant digit of the display is arranged to be the shortest, so this digit freezes first, then the second digit and finally the least significant digit.

The counters cycle all the time and the randomness of the number frozen is due to the completely arbitrary time when a person presses the start button. It is similar to a blindfolded person being asked to stop a wheel of fortune which is spinning very fast (but this method is much less likely to cause an accident).



town," said the chairman of the committee. "But the club can't afford one of those things," the treasurer quickly added.

"The butcher's son Kevin fiddles with electronical things," said the steward. "Aye, and he goes to Polly-tick-nick too," chirped the chairman. So Kevin was asked to design and build an electronic random number generator.

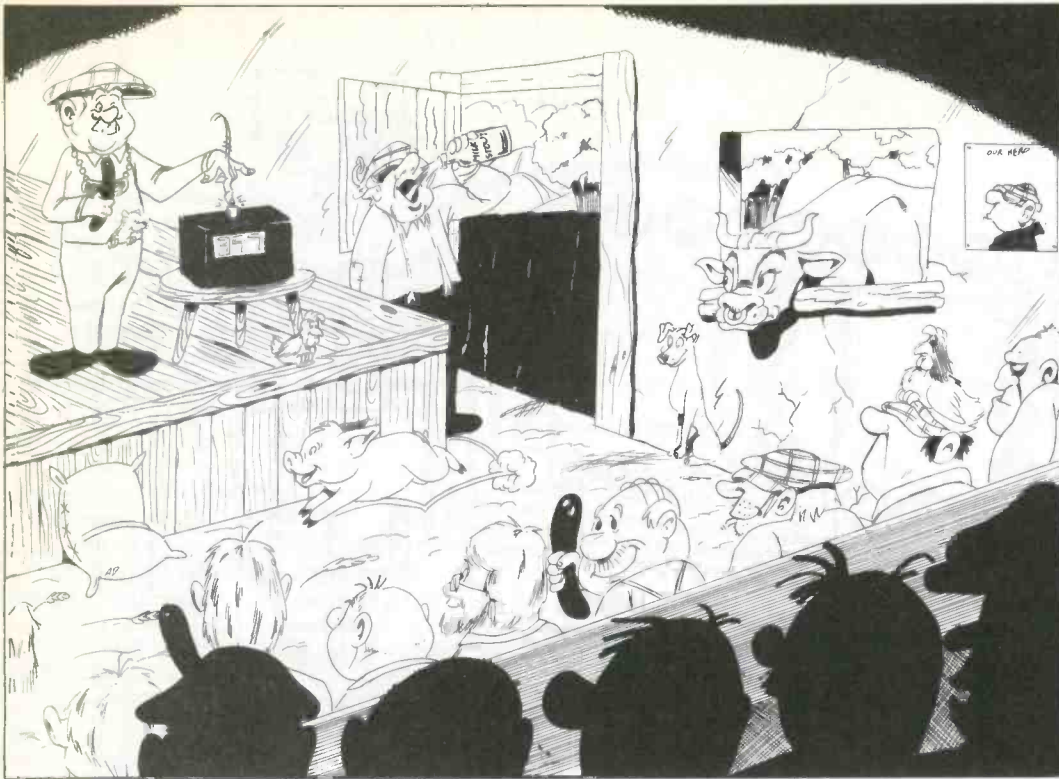
What Kevin Did

There are never more than 1000 tickets sold at the draw so a 3-digit number generator would be adequate. It had to be simple to operate (for the committee) and the numbers had to be big enough to be seen from the back of the concert room. Kevin decided to use a matrix of conventional LEDs for the display as the seven segment displays available from his hobbyist supplies were too small.

The next problem was how to generate random numbers. Kevin had once visited the young people's

TOP PROJECT

TOP PROJECT

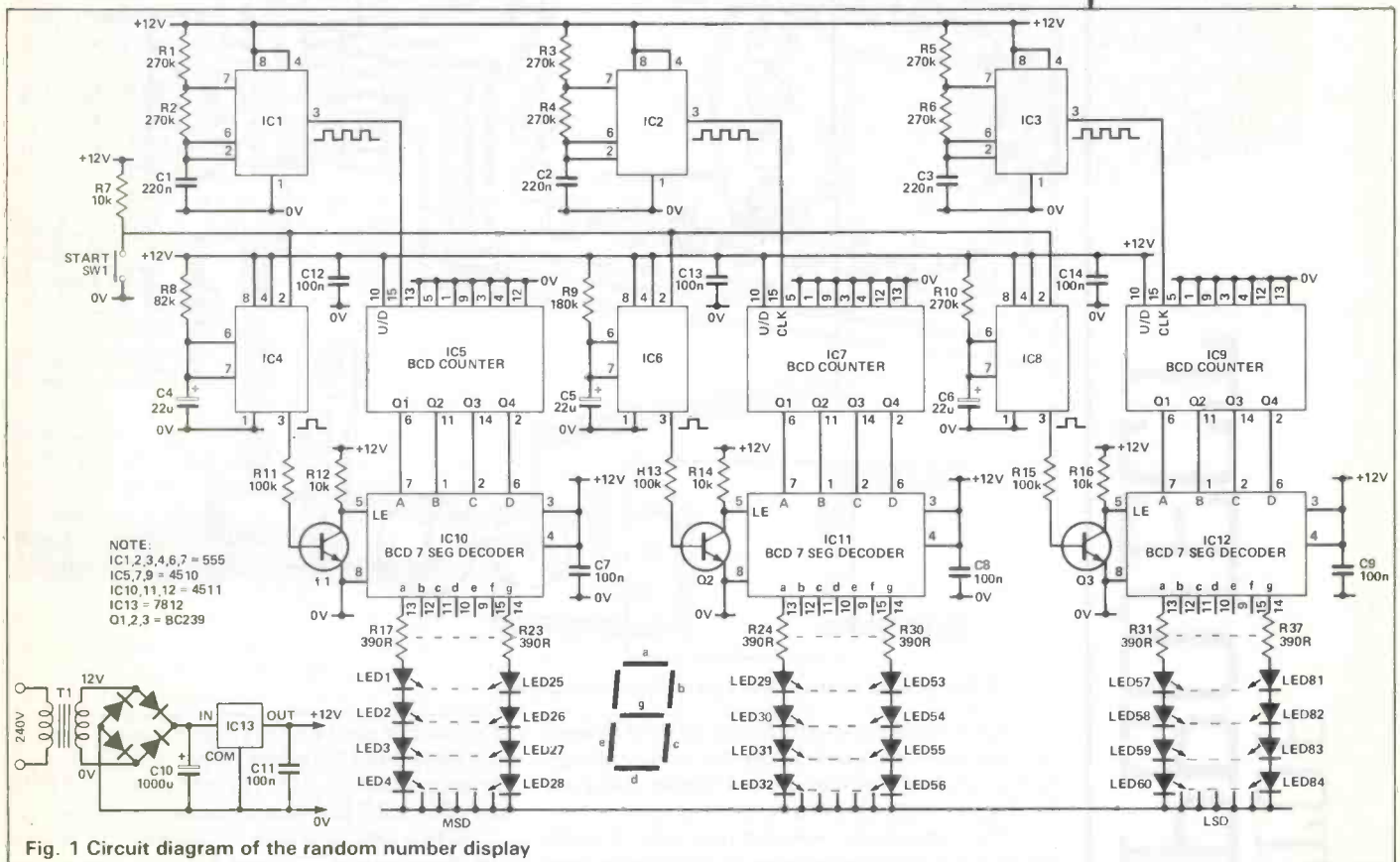


man. The machine had to appear to operate like the one-armed bandit with the numbers apparently stopping of their own free will.

For a few days this had Kevin stumped. Then, while he was trimming a particularly inspiring piece of rump, he had a brainwave. He could make the counters cycle all the time but only connect them to the LED display when the button was pressed. Using three separate time delay circuits would make the three digits freeze one after the other just like the fruit machine. Although the cycling time and the freeze delays would be constant, the final number displayed

would be completely random because the button would be pressed at random with respect to the constantly cycling counters.

He would need three separate square wave oscillators to clock the three counters. He used 555 timers for the oscillators and the monostable or time delay circuits, as he had dozens of them in his spares drawer. He used the CMOS 4510 BCD counters which were quite cheap. The CMOS BCD to 7-segment decoder was ideal for driving the LED display because it had built-in latches which could store the winning number.



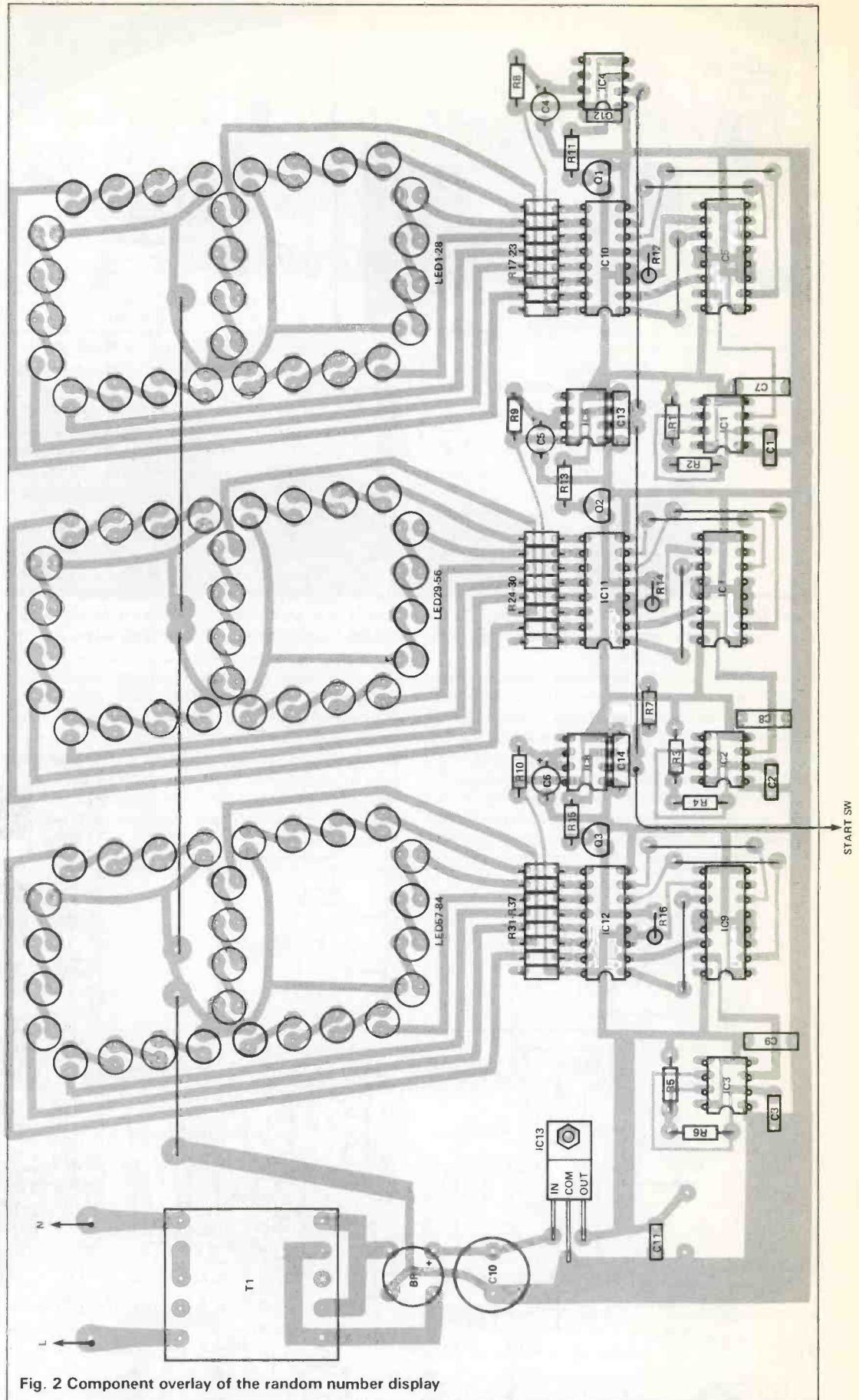


Fig. 2 Component overlay of the random number display

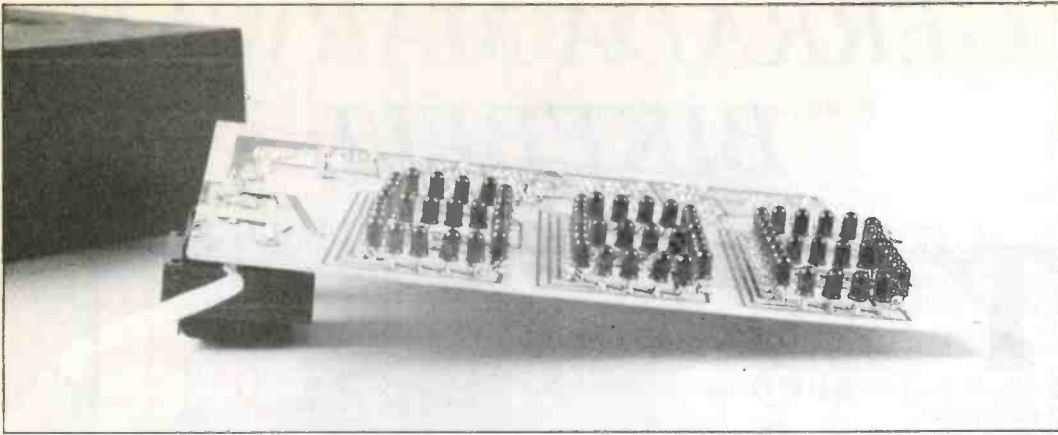
Kevin was quite good at laying out PCB artwork and with three identical channels, the amount of brain power required was reduced still further. Once the PCB was etched and drilled he set about construction.

The component overlay is shown in Fig. 2. Kevin writes: It is a good idea to build up the circuit a stage

at a time and get it working before moving on to the next stage. Build the power supply first and once you are happy with the 12V rail at the output of IC13, insert ICs 1,2,3 and their associated components.

If you have access to an oscilloscope, confirm that the outputs of IC1,2 and 3 (pin 3) is giving a low

TOP PROJECT



frequency square wave (it may be possible to observe the pulses with a good voltmeter).

Connect the counters IC5,7 and 9 and confirm operation by checking that pins 6,11,14 and 2 increment correctly.

Connect up the decoders IC10,11 and 12 and all the LEDs. Note that the LEDs are connected on the reverse (copper) side of the PCB. Keep the coffee handy... fitting 84 LEDs the right way round needs a fair amount of concentration! Fit the associated components but omit Q1,2 and 3 and connect temporary short circuits across the collector and emitter pads of each transistor (effectively connecting LE of each decoder to OV). The LED displays should then be seen to cycle through the digits 0-9.

If one of the segments is not working, check to see that all the LEDs have been connected the right way around.

Finally connect Q1,2 and 3, the monostable ICs 4,6 and 8 and all associated components. The displays should then only cycle when the start button is pressed. The MSD should freeze after a time delay of approximately one second, followed by the second and third digits at similar intervals.

The finished PCB should be mounted vertically in a suitable case with a 80mm x 180mm cut out for the LED display as shown in the photos. The aperture should be fitted with a suitable semi-translucent filter material which allows light from the LEDs to pass through but hides the PCB copperwork and soldered

PARTS LIST

RESISTORS (all 1/4W 5%)

R1-6,10	270k
R7,12,14,16	10k
R8	82k
R9	180k
R11,13,15	100k
R17-37	390R

CAPACITORS

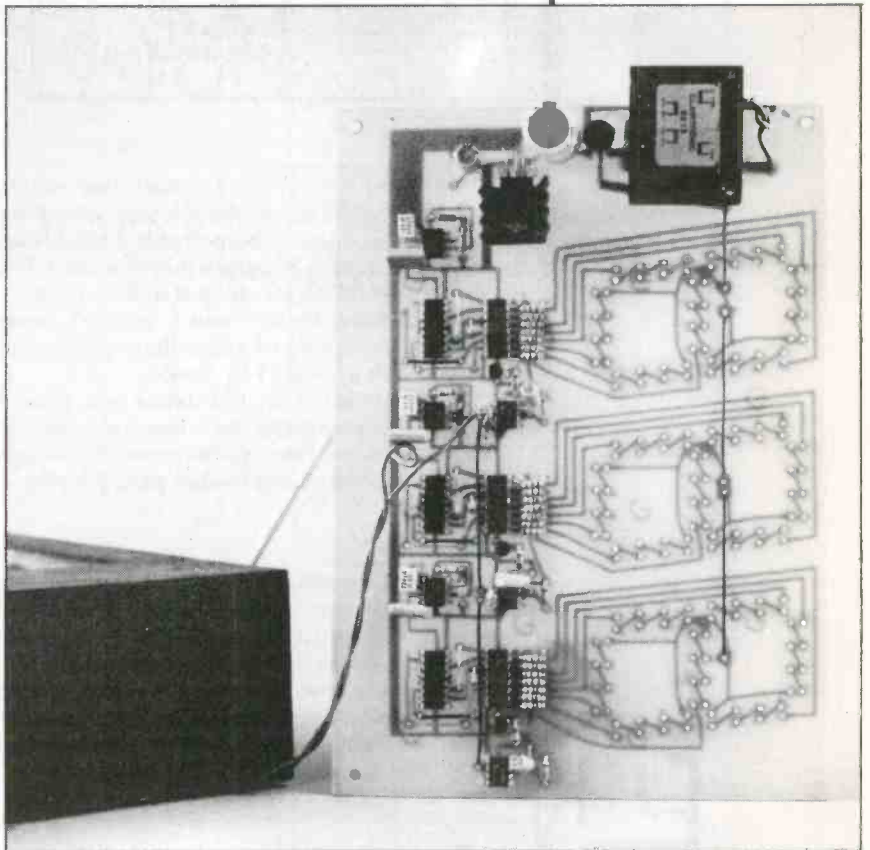
C1,2,3	220n polyester
C4,5,6	22 μ 16V aluminium electrolytic
C7,8,9,11	100n polyester
C10	1000 μ 25V aluminium electrolytic
C12,13,14	100n ceramic

SEMICONDUCTORS

IC1,2,3,4,6,8	555
IC5,7,9	4510
IC10,11,12	4511
IC13	7812
BR1	1KAB10 or similar 1A diode bridge
Q1,2,3	BC239
LED1-84	red 5mm LED

MISCELLANEOUS

SW1	push button
T1	6VA mains transformer, 240V:15V
PCB. Case. Filter material. Nuts and bolts.	



BUYLINES

None of the components should prove difficult to obtain. The PCB mounted transformer is available from Farnell or from Trilogic on (0274) 684289.

The PCB is available from GP Electronic Services, 87 Willowtree Avenue, Durham DH1 1DZ.

joint. Professional red filter plastic is very expensive and it may be worthwhile experimenting with red cellophane or other red plastic material.

The ideal place for the start button is on the top of the box so that the operator can bring his hand smartly down on the button without fear of the box scooting across the table and into the audience (erroneous results and raucous laughter may result from such an occurrence).

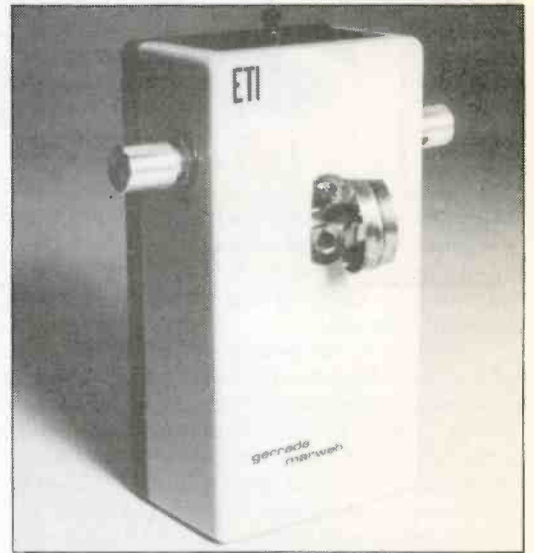


GERRADA MARWEH BIKEBELL

Fed up with peds in your path? Road hogs clogging up the roundabouts? Build Keith Brindley's electronic bikebell and make 'em jump

To classify this project as a push-bike bell is something of a misnomer, really. It certainly doesn't ring (or even sound like a bell!) and it has no moving parts, either. Nevertheless, it'll help you to be noticed as you pedal along and that's all a conventional bike bell is meant to do.

Apart from not sounding like a bell, the Gerrada Marweh is significantly louder than any mechanical counterpart fitted to your handlebars can ever be.



we're making is that ordinary dry-cells, which have quite a large internal resistance, won't be able to supply the power demanded. At the very least, the circuit will need an alkaline battery and a PP3-sized battery will give excellent results.

Readers may wish to go to the expense of a rechargeable NiCd battery. ETI has published the circuit for many a NiCd battery charger. One suitable for this project was published in the November 1988 issue. Photocopies of the project or a complete back-number can be purchased (see page 45 for details).

Construction

In this project design size was a major criterion. We wanted the project to be as small as possible (small enough to fit to a bike's handlebars) without sacrificing too much volume. The result is a fairly compact project which does need a little care in construction. By and large, development depends on the case you choose to house the project and if you use a different one to the case we used for our prototype, you'll have to adapt.

Start with the bare PCB or stripboard. Carefully saw, cut, file it to shape and make sure it fits into the case and can be bolted down. Next, mount and solder all passive components, that is, the resistors, capacitors, PCB pins, following the component layout shown in Fig. 2 or 3. If you use PCB pins for off-board connections (recommended!) you can leave the battery, speaker, switch, push-button and potentiometer wiring till later. If you don't use PCB pins, now is the time to solder in wires for the above.

Next, fit the semi-conductors in the order transistors Q1, Q2, then the UM3561 IC1. A word of warning about the UM3561 — it's a CMOS device and may be damaged by static discharges. In practice, fitting a CMOS IC merely requires it to be inserted without coming into contact with a large static voltage. Once in circuit it should be OK. Static voltages generated on the human body may be large enough to do damage to a naked chip, so take care. It's probably best to fit the chip into a DIL IC holder soldered into the PCB, as in this way you don't have to solder the chip itself.

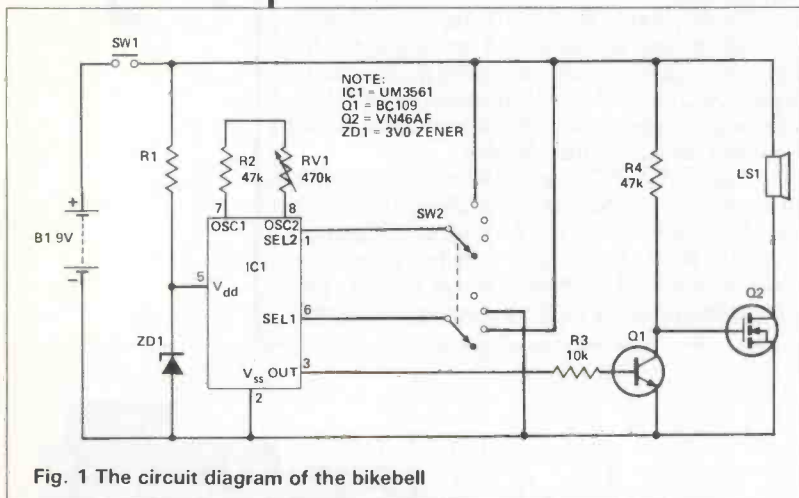


Fig. 1 The circuit diagram of the bikebell

It's based around the UM3561 siren sound generator IC, which allows selectable siren sounds and effects to be produced — namely police, ambulance and fire engine sirens and a laser gun-type effect. The output of the UM3561 is only just sufficient to drive a piezo sounder, though, which wouldn't create enough volume to scare off a fly, so the output's beefed up a little with a VMOS FET device.

The UM3561 is an LSI device (see *How It Works*) which is meant for use in toys and models as a simple-to-use and low-cost tone generator. Readers may have heard toys and models using this chip.

Power

The Gerrada Marweh is nothing if not power greedy. The circuit itself, in this form, will run from around 4V through to 14V so it is possible to run it from dry-cell batteries or even a car battery. Readers must bear in mind, however, that the circuit positively devours current — it *must* do to be able to produce this much volume for such a low voltage.

At 14V for example, around 600mA must be provided. At 9V around 400mA is required. The point

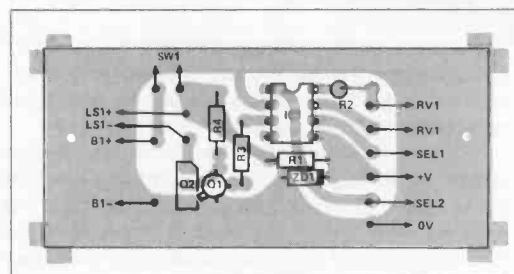


Fig. 2 The PCB component overlay

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HOW IT WORKS

Figure 1 shows the circuit of the ETI Gerrada Marweh push-bike electronic bell. It's not complicated. Integrated circuit IC1 is a UM3561 siren sound generator requiring a power supply of around 3V, so a voltage regulator comprising zener diode ZD1 with series resistor R1 is used to provide this from the battery voltage.

The UM3561 comprises a number of internal parts (shown in Fig. 2) including an oscillator, control circuit, counter, tone generator and ROM. The oscillator frequency is set by the value of an external resistance connected to the OSC pins of the chip. For defined sirens, the oscillator frequency should be about 100kHz, corresponding to a resistance of 240K. In the Gerrada Marweh a potentiometer and series resistance is used as the external resistance, providing a variable frequency oscillation whose maximum frequency (minimum potentiometer resistance) is set by the series resistance.

Two pins SEL1 and SEL2 on the IC allows a choice of one of four effects depending on how these pins are connected to each power supply rail. Rotary switch SW2 connects the pins accordingly. Table 1 lists the connections to the two selection pins, and the resultant effects.

Stored in the ROM are data patterns relating to the four available effects. As the oscillator output is counted by the counter, one of the patterns is cycled through, selected by the control circuit and then passed to the tone generator.

Output from the UM3561 is a variable frequency squarewave with an amplitude nearly that of the supply voltage (3V). This voltage is amplified to around that of the battery voltage with a single common emitter transistor amplifier formed around transistor Q1. A VMOS FET transistor Q2 is driven directly from Q1's collector giving sufficient current gain to power up a loudspeaker with around 4 watts of power.

PARTS LIST

RESISTORS (all 1/4W 5% unless specified)

R1	1k0
R2,R4	47k
R3	10k
RV1	470k lin pot

SEMICONDUCTORS

Q1	BC109
Q2	VN46AF
ZD1	3V0 zener diode
IC1	UM3561

MISCELLANEOUS

B1	PP3 battery
SW1	push button
SW2	4-way rotary (at least 2-pole)
LS1	5W 8R 3in mylar speaker

PCB or Stripboard. 8-pin DIL socket. Knobs. Case (150 x 80 x 50mm). Battery clip. Handlebar clamp. Nuts and bolts.

SEL1	SEL2	Effect
NC	NC	Police siren
+	NC	Fire engine siren
-	NC	Ambulance siren
NC	+	Machine gun

Table 1. Connections to the UM3561 siren sound generator IC selection pins and the resultant effects

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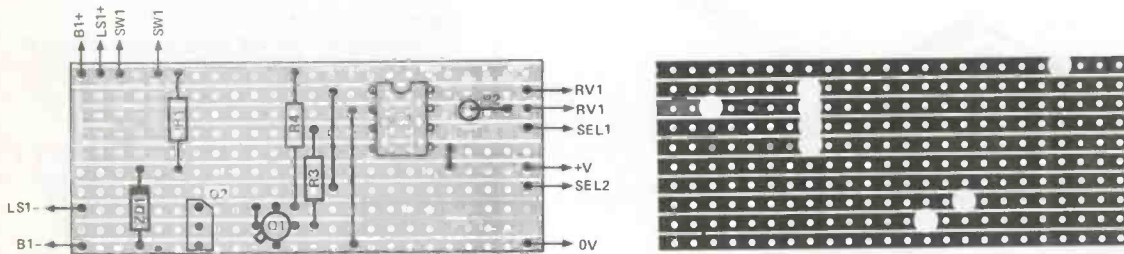


Fig. 3 The Stripboard component overlay and track cutting diagram

Now leave the PCB aside while you drill the case for all controls and fit the speaker. Holes for controls are self-explanatory and depend on how you intend to mount and fasten the project to your bike. Talking of fastening, it's a tricky problem. We found a number of solutions. The best appear to be plumbing clips for 22mm copper or plastic pipes. Another are awning clips found in caravan accessory shops. Inventive readers may have other ideas.

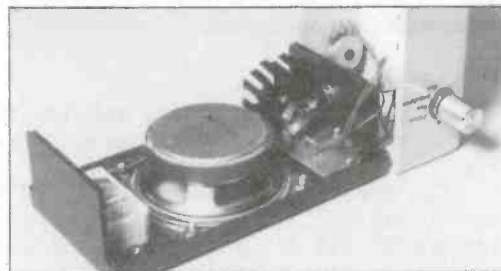
Fixing the speaker into the chosen case is not easy. The inside of the case must be partly milled away to accommodate it.

Once the speaker is shown to fit properly, the holes for mounting bolts and the hole for the cone itself can be drilled and filed out. The speaker used is a mylar cone type and is specifically intended for outside sirens and buzzer applications. The mylar cone provides weatherproofing and splashproofing, making it ideal for this project. With this in mind, the prototype's speaker cone is accessible directly from the underneath, making physical damage to the cone a possibility. It's not essential to fit a protective grill but some readers may feel the need, particularly if the Gerrada Marweh is to be fitted to a young child's bike where prying fingers, lollipop sticks, friends' toys and so on are liable to be encountered.

Once the speaker is fitted, the project can now be put together. Fit the PCB into the case, fit all

controls and wire up the switches according to the wiring scheme shown in Fig. 4. Now, fit a suitable heatsink to the VMOS FET transistor. This must be as large as possible, without obstructing other parts and the controls in the case. Smear the metal face of the transistor with heatsink compound before bolting the heatsink to it, to ensure maximum heat transfer.

No setting up is required. Merely select the effect you require, set the speed control to about mid-position, put in your ear-plugs and press the push-button.



BUYLINES

The UM3561 and mylar speaker are both available from Maplin. All other components should be available at your local supplies outlet. The PCB is available from the PCB Service.

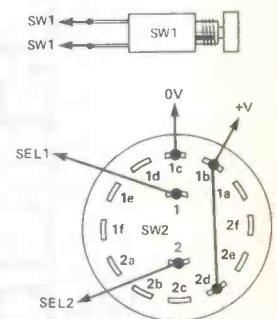


Fig. 4 Wiring up the switches

COMBO-LOCK

Chung Yiu Ko keeps his valuables safe and sound behind closed contacts with his combination lock circuit

Neighbourhood Watch schemes cover the land. Little orange stickers appear in the windows of every semi-detached in the Kingdom.

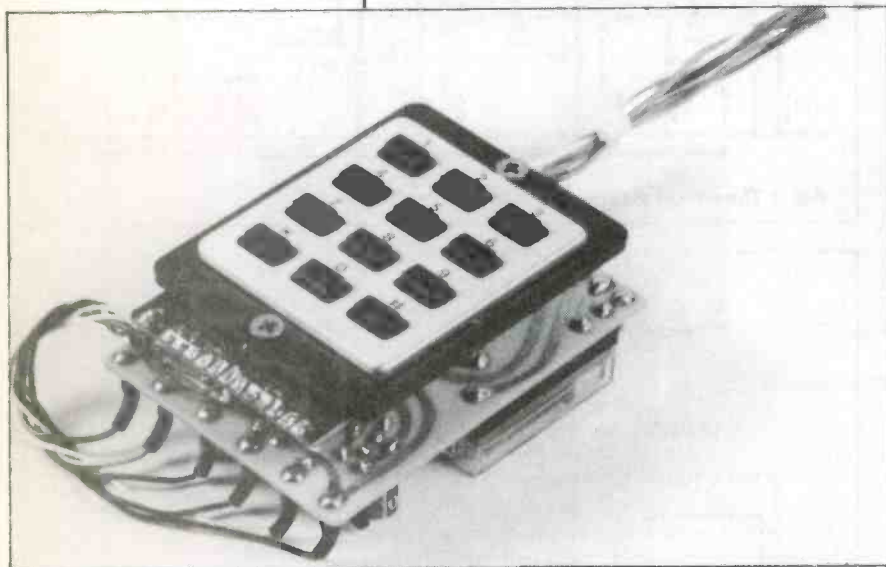
Security in the home has a higher profile today than ever before and a simple electronic locking device could be worth its weight in missing cufflinks.

This circuit detects correct sequence input and provides a relay output suitable to trigger an electronic lock. Its main beauty is that it uses no ICs and keeps things simple and cheap.

The correct combination is hardwired rather than programmed and the lock could be used to protect door openers, burglar alarms, car ignitions — the applications are limited only by your imagination.

The circuit diagram is shown in Fig. 1.

The heart of the circuit is the sequential detector which interprets the correct sequence inputs from the key switches, turns the output on and activates a relay. An indicator (LED1) indicates that the correct number sequence has been entered.



If the right numbers are entered but in the wrong order then the sequence detector is reset and the entire sequence must be repeated.

Alarm circuitry is incorporated in the design and this is activated if the digits not appearing in the combination are pushed.

Construction

Though stripboard could be used with care, the PCB is recommended and the overlay is shown in Fig. 2.

The specified relay (see Buylines) will fit directly onto the PCB. It is possible to use any relay having a 12V 300R or higher resistance coil, but it may be necessary to redesign the printed circuit layout or mount the relay off board.

The key switches are of push-to-make momentary action type and any switches of this type can be used. However a low profile keypad or keyboard is more desirable for ease of construction (again see Buylines).

HOW IT WORKS

The sequence sensing circuit is constructed around Q1 to Q6, the key switches and the relay.

Initially Q1 to Q6 are non-conducting. As soon as key 1 is keyed Q2 is forward biased, collector current flows through R4 and the base and emitter of Q1. C1 charges via R3 and R4 which provides sufficient bias to turn Q1 on. The voltage drop developed across R2 (due to Q1 collector current) briefly holds Q2 on and a constant current source is now available at the emitter of Q1, forming the power source for the remaining stages of the emitter follower.

The functions of Q3 and Q4, Q5 and Q6 are similar, except that the loading of the final stage is a relay coil and LED indicator.

Obviously the keys must be keyed in correct sequence (1, 6 then 8 as shown in Fig. 1) otherwise there will be no power source available from one stage to another and the relay will never energise.

The incorporation of the keypad or keyboard enables the user to select any three digits of any combination number he chooses while the remaining keys are connected to the reset/alarm mode input.

Whenever the unselected keys are pressed the circuit is reset by pulling Q1 base to negative (via D1 in alarm mode) and at the same time discharging C1. Q1 is biased off turning off Q2. At this stage the entire sequence must be repeated.

The second half of the circuit is alarm warning circuitry. Whenever a reset/alarm key is keyed (except the actual reset key 0) the alarm will sound for a short duration.

Q7 and Q8 form a basic astable multivibrator circuit. Initially the oscillator is inoperative, because Q8 is biased off via resistors R14 and R11 to the positive supply. As soon as a reset/alarm key is keyed, capacitor C4 charges via R16 with the polarity shown, Q8 becomes forward biased and the oscillation starts for a duration determined by the R11 and C4 network.

Gradually C4 discharges across R11 sufficient to cut Q8 off and the oscillator stops.

Q9 is a simple direct-coupling emitter-output power amplifier.

The circuit will operate well on 12V DC and draws a maximum standby current of 20mA. The maximum current is 400mA with the alarm and relay energised. This makes the device ideal for 12V car system or a mains derived supply.

After inspection of the PCB for short circuits, broken tracks and any damage, the resistors should be soldered onto the board, followed by the capacitors, then the diode and transistors (care being taken with polarity of these components).

Once all the components are securely fitted onto the board, connect the corresponding wirings to the desired sequence and reset key switches.

In Fig. 1 the sequence number is shown as 1-6-8. Zero is for reset and the remaining unselected invalid keys are connected in parallel to the reset/alarm warning circuitry input.

The PCB is purposely small so that it can be mated back-to-back with the keypad by two spacers, and tuck away in any suitable front panel.

For door opener applications the unit can be fitted in a metal blanking plate (as used in house wiring) and mounted in the doorframe, with the

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PARTS LIST

RESISTORS (all 1/4W 5%)

R1, 5, 8	470R
R2, 6, 9	150R
R3, 7, 15	1K0
R4	82R
R10, 12	510R
R11, 13, 14	56K
R16	5K0

CAPACITORS

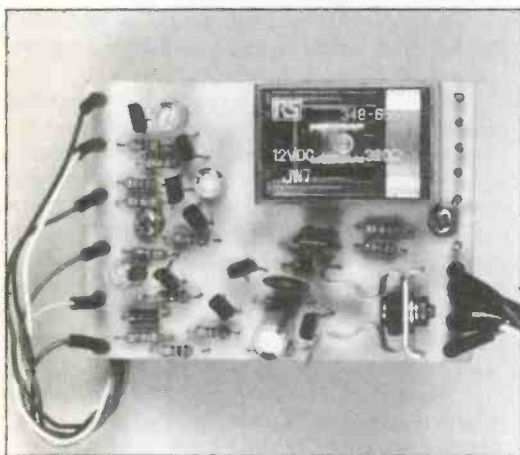
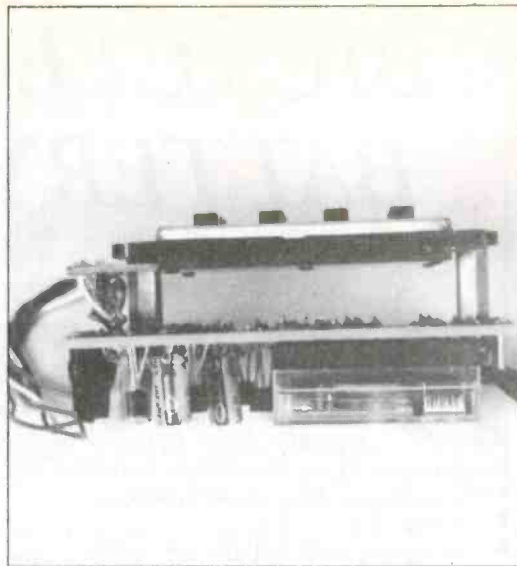
C1, 2, 3	3 μ 3 12V electrolytic
C4	100 μ 12V electrolytic
C5, 6	20n ceramic

SEMICONDUCTORS

Q1, 3, 5, 7, 8	ZTX400
Q2, 4, 6	ZTX500
Q9	BD135
D1	1N4001
LED1	red LED

MISCELLANEOUS

RLA1	12V relay 300R or higher
SW0-9	keypad or push-to-make switches
PCB, PCB pins (16), Wire, Nuts and bolts.	



speaker wired remotely indoors.

For automotive applications a small module case with metal front panel is most suitable. The base of the case can be secured onto the dashboard, with the metal front panel used to mount the complete unit.

The alarm in the circuit shown is not going to wake the street and alert the local alsatian brigade. In its present configuration it is more of a loud indication that the incorrect sequence has been entered.

It would not be difficult to fit a second relay into the alarm section of the circuit which could trigger a bell alarm, or a flashing neon arrow with 'Burglar' written on it, or even to release an enormous weight from the second floor onto the burglar (please note that ETI can take no responsibility for any visitors flattened by this method).



BUYLINES

The relay used in the prototype was from RS components, stock code 348-655.

The keypad used was also from RS, stock code 333-704.

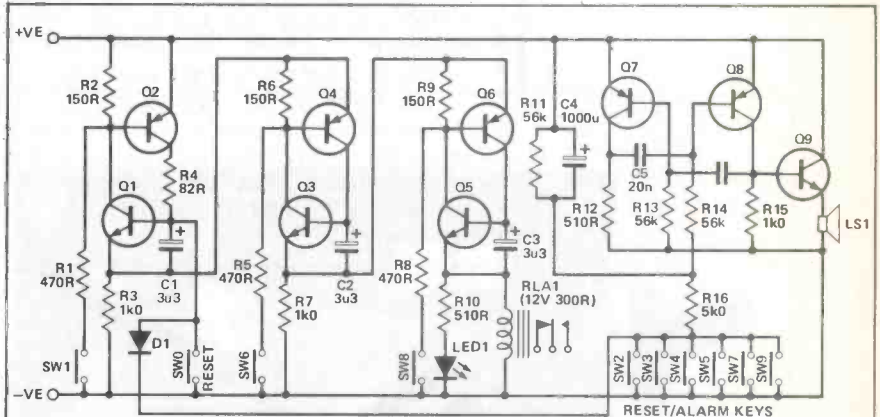


Fig. 1 The circuit diagram for the combination lock

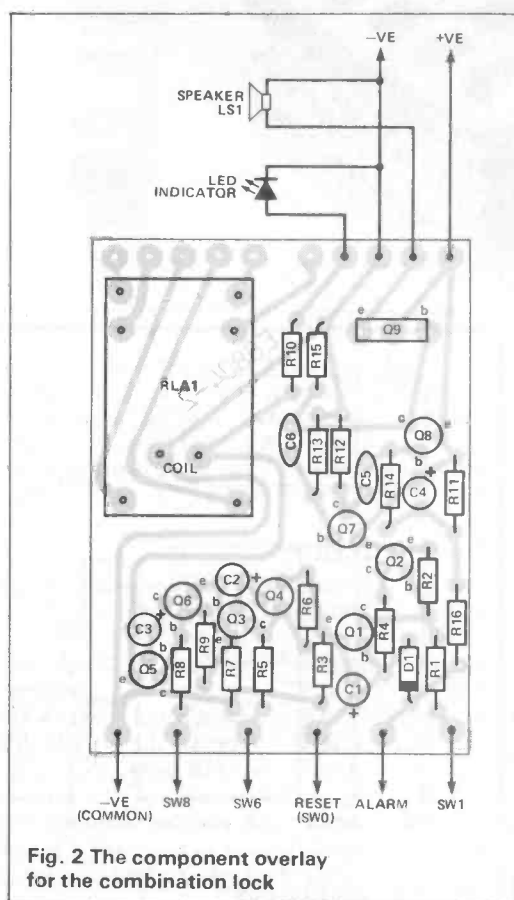


Fig. 2 The component overlay for the combination lock

BICYCLE DYNAMO BATTERY BACKUP

Ziad Mouneimne and Nick Flowers are visible at all speeds thanks to this bicycle dynamo backup unit

Dynamo lighting systems for bicycles suffer rather dangerously from the lack of output at standstill — when waiting at traffic lights or road junctions. Apart from this obvious disadvantage dynamos compete favourably with battery-powered lights because they:

- are lighter
- require no costly battery replacement
- provide higher light output (except at low speeds)
- are far more reliable than battery-powered

systems. The latter suffer from the infuriating habit of frequently needing a kick before they operate!

Because of the great similarity in the output characteristics of dynamos available on the market (see *Legal Lighting in Bicycle* magazine October 1983 for a comprehensive survey) the system described here will operate in conjunction with any dynamo set to provide safe lighting down to standstill. The supply to the front and rear lamps is switched from the dynamo to the rechargeable batteries as the bicycle speed (and so the dynamo output voltage) falls below a predetermined value.

The unit is cheap (about £5 plus the batteries), simple to make and install, and could prove to be a lifesaver.

Features

By using rechargeable batteries in the backup unit, the need for battery replacement is eliminated. The batteries are on charge whenever the dynamo operates.

To keep losses to a minimum, no electronic devices are placed in the source/lamps circuit.

On dynamo systems, the bicycle frame is normally used for the return current by solidly connecting one terminal of the dynamo to the frame. Some commercial backup units require that the dynamo is isolated from the frame — easier said than done. The system described here does not impose such a restriction thus making it easier to install by current and future dynamo users.

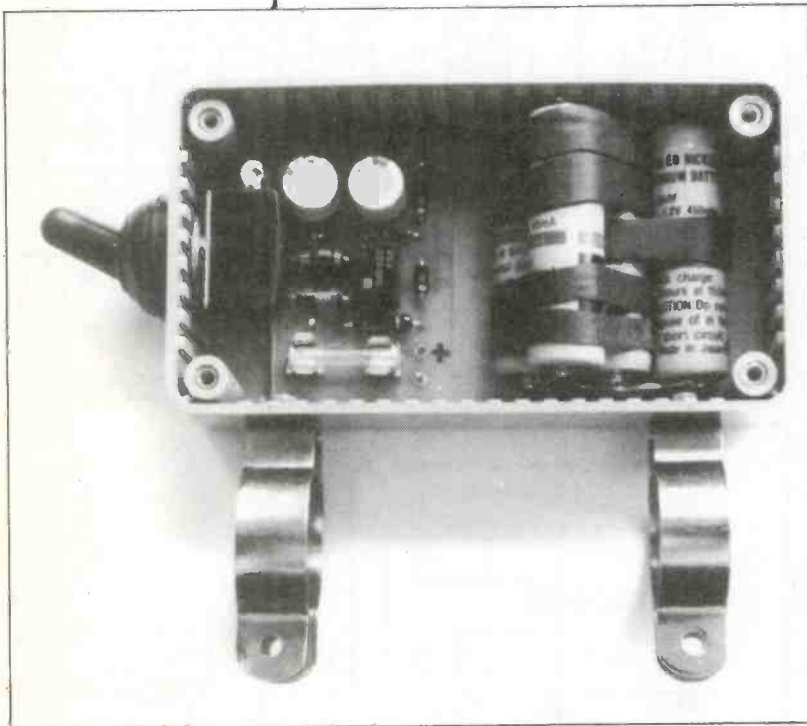
The output characteristics of all dynamos are closely matched to the lamp load. On most sets a 3W dynamo supplies a 6V, 0.4A, 2.4W front bulb and a 6V, 0.1A, 0.6W rear bulb. Unfortunately when the front bulb blows the rear bulb follows in seconds. When the rear blows the increase in brightness of the front bulb drastically shortens its life. In fact the authors measured the open circuit voltage of one wheel-driven dynamo and managed to read 180V peak-to-peak on the scope by pedalling in 10th gear!

Choosing The Battery

Typical AA-size NiCds have a capacity of 500mAh and recommended charging currents of 50mA and 150mA for 15 and 4 hours respectively. When the bicycle is at standstill, the total current to both lamps supplied by a battery of four NiCd cells is around 0.45A. So a fully charged battery will last for about 45 minutes without dynamo intervention. Obviously the battery will not be used like this in normal circumstances.

Where space is very tight the smaller 1/2A sized NiCds have the same capacity as the AA size but take up only about half the space.

Non-rechargeable cells can also be used if required. The charging circuit components D2, D3, R2 and C2 may then be omitted. If over-voltage protection is not required the zener's diodes can be also eliminated. The PCB overlay is shown in Fig. 2.



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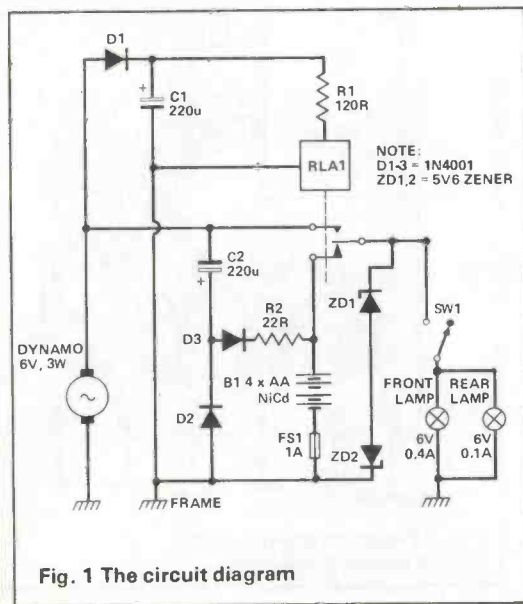


Fig. 1 The circuit diagram

Construction

The prototype is shown in the photographs. The PCB measures only 45x32mm so it was possible to fit all the items (PCB, battery and switch) in a compact box measuring 112 x 62 x 31mm. The unit can be neatly fitted on the bicycle tubular frame by two 25mm terry clips, chrome versions of which are available from any bicycle or hardware shop. Though less attractive (but cheaper) two capacitor clips were successfully used on the prototype.

The best position for the unit was found by the authors to be on the back of the seat down-tube

HOW IT WORKS

Figure 1 shows the complete circuit diagram for the unit. D1, C1 and R1 provide DC supply to the relay coil. The bicycle speed at which the supply to the lamps changes over from the battery to the dynamo is determined by R1. For the dynamo used (a Union model), 120R gave a smooth changeover with the least light flicker.

D2, D3, C2 and R2 constitute the charging unit. Voltage-limiting is achieved by the back-to-back zener diodes ZD1 and ZD2. There are two modes of operation:

a) Normal, SW1 on. When the dynamo is stationary the lamps are connected to the battery. When the dynamo voltage rises, the relay picks up and the lamps are connected to the dynamo. The peak charging current in this mode is about 50mA.

b) Fast charge, SW1 off. If the dynamo is engaged with SW1 off, the charging current increases to about 90mA. This is useful to accelerate the battery charging during daylight riding. ZD1 and ZD2 limit the voltage. Without them the charging current will reach excessive levels and damage the NiCd cells.

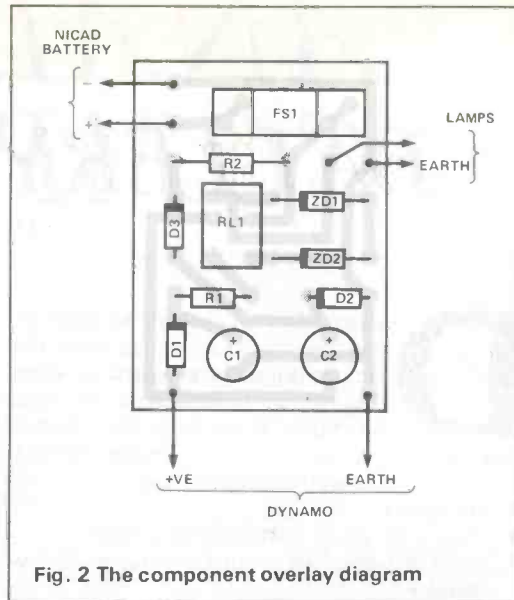


Fig. 2 The component overlay diagram

just ahead of the rear mudguard, as shown in the photograph. This gives the unit extra protection from rain — the seat (and rider) acting as an umbrella!

No battery holder is used. Instead, the NiCd cells are connected in series by soldered connections. This is deliberate. It eliminates the problem of bad contact which bedevils all battery systems and it is more compact. Obviously if non-rechargeable AA cells are used, a holder will be necessary and the box made larger.

At the time of writing three units had already been used for two years with excellent results.



PARTS LIST

RESISTORS (all 1/4W 5% unless specified)

R1 120R (see *How It Works*)
R2 22R 1/2W

CAPACITORS

C1, 2 22μ 25V electrolytic

SEMICONDUCTORS

ZD1, 2 1N5339B 5V6 5W
D1-3 1N4001

MISCELLANEOUS

B1 4x1.2V NiCds
FS1 1A anti-surge fuse
RLA1 6V 120R coil, SPDT ultra-miniature relay
SW1 SPST toggle switch
PCB. Case. Waterproof cover for switch. Mounting clips.
Fuse clips. Nuts and bolts.

BUYLINES

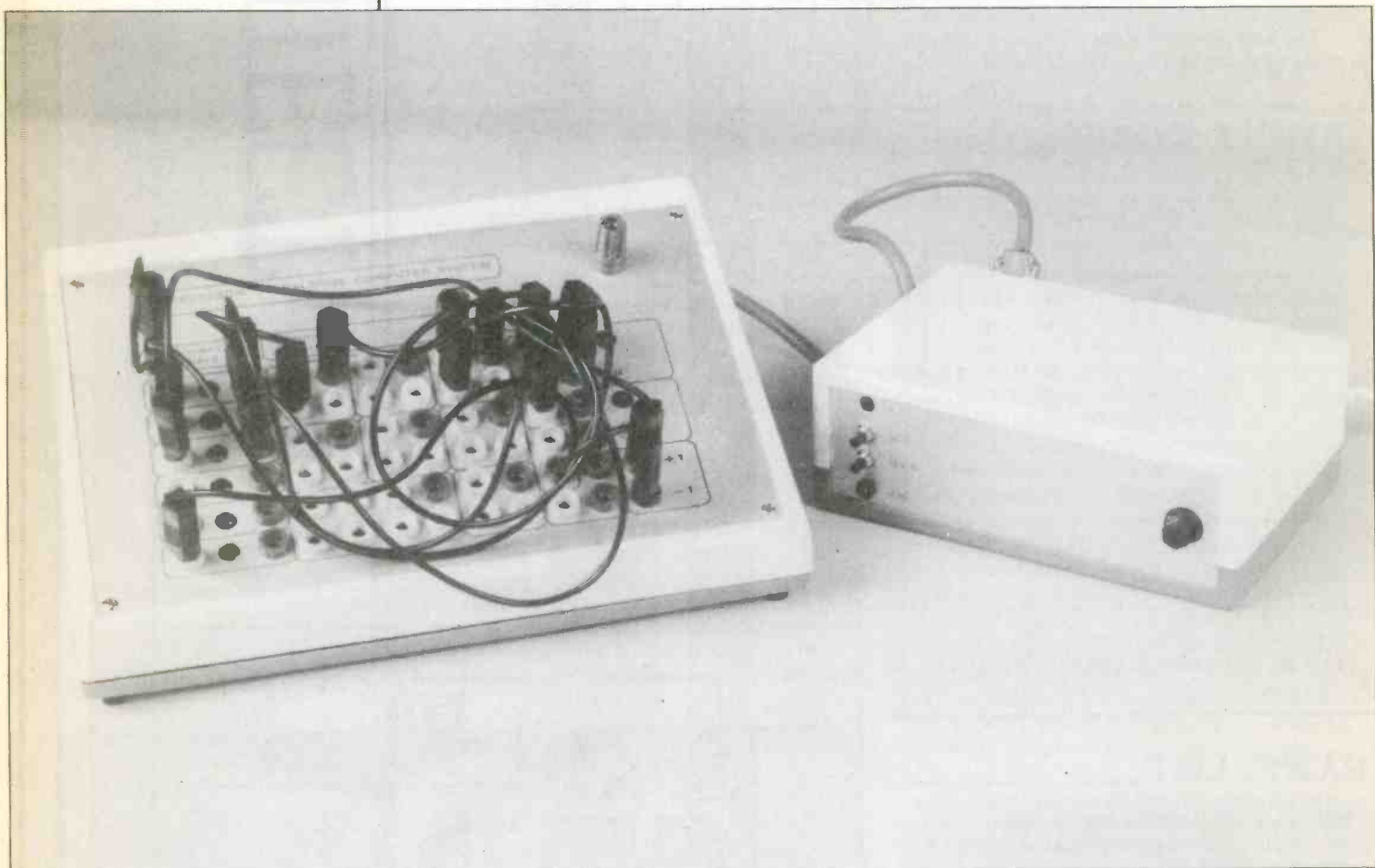
Most of the components for this project are easily obtainable from normal sources. The relay used in the prototype was from Electromail (Tel: (0536) 204555 part no.345-022) as were the zener diodes (283-148). The 1/2A size NiCds are also available from Electromail as part no. 592-335.

The PCB is available from the ETI PCB service.



ANALOGUE COMPUTER

Part I



*Paul Cuthbertson
describes a small
simple-to-build
analogue computer
for education or
experiment*

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Many of the early analogue computers were true monsters, requiring four strong persons to lift them — and then with some difficulty. Fortunately, modern integrated circuits have come to the rescue and we can build a sensible small computer which, although no match for the performance standards and facilities of the bigger ones, represents considerable saving in weight, cost and power consumption.

This computer provides eight summing amplifiers, six coefficient multipliers and four integrators with over and under voltage indication. It is housed in two boxes — the power supply and the computer itself — with a cable connecting the two. The PSU can power a number of other units if the user wishes to install extra connectors for this.

There are controls for SET and HOLD on the power supply. The front panel of the computer is rather more complex. There is an overvoltage indicator, the four integrators, eight summing amplifiers, six coefficient multipliers and outlets for the $\pm 10V$ references.

Such a small system is useful in a school or university laboratory or anywhere that experiments are done on control systems and such.

Mathematicians might like to note that in its present form the computer will solve linear differential equations, but not those which involve a

function of two variables. Nor does it provide exponentiation or sinusoidal functions. However, the equipment to do this can be easily designed and if there is sufficient call for it, perhaps a future article may be devoted to such a unit. Even in its present form the system can be usefully employed in a number of ways in the lab.

Construction

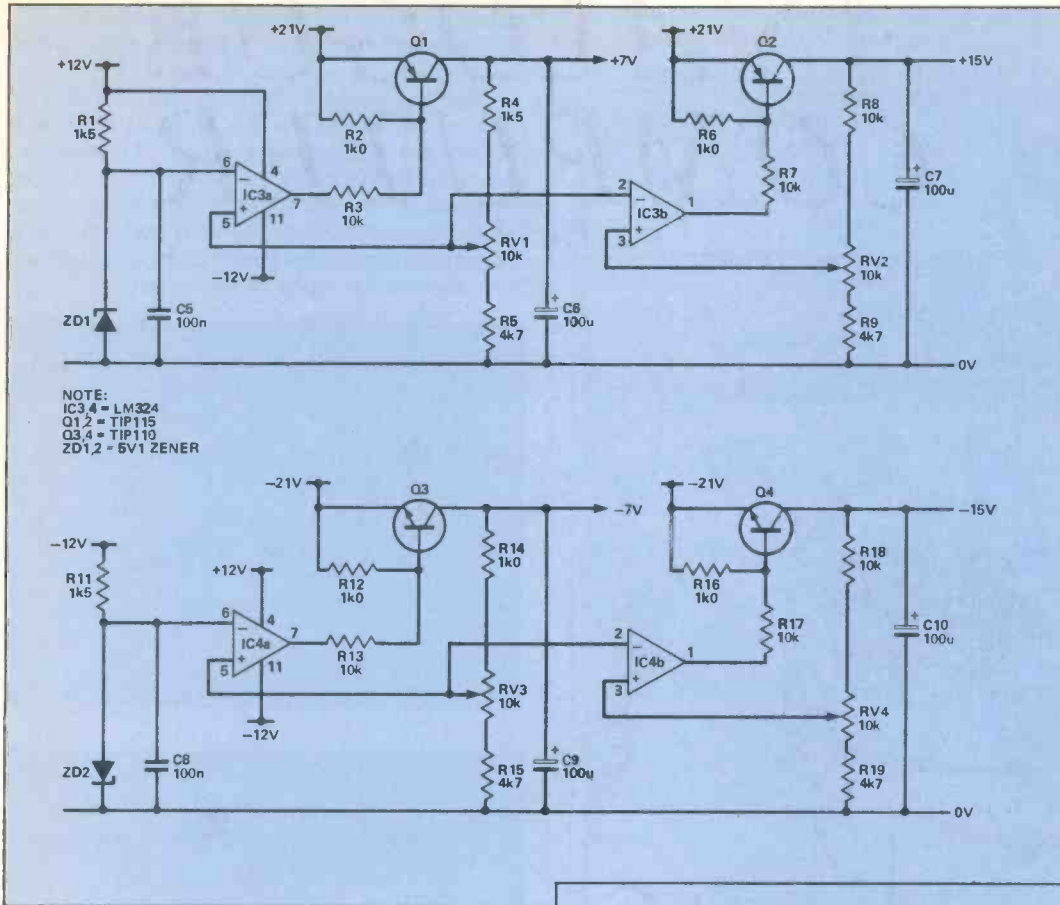
Start assembly with the PSU. Mount all the PCB components first. Figure 4(a) shows the component overlay for the PSU board.

Fit the wire links first. There are four holes by the transformer for links. The 240V operation, fit one diagonal link from northwest to southeast. For 120V, fit two links in a west-east direction. The link shown is for 240V operation. The link by the earth pads should not be fitted if you intend fitting the computer into a large system of controls.

Now solder the smaller components in place, making sure metal film resistors are fitted in the right places. Lastly, fit the transformer and the power transistors on their heatsinks. The transistors should be fixed to the heatsinks before inserting and soldering to the board. No insulator is needed.

Fit the board into the case with the transformer to the rear and drill the four fixing holes in the case base in line with the mounting holes in the PCB. Drill a hole for the mains cable, fit a grommet

TOP PROJECT



HOW IT WORKS: PSU

The power supply provides $\pm 7V$ and $\pm 15V$ for any computer unit to use as well as the SET and HOLD signals.

The circuits for positive and negative halves of the PSU are practically identical and are shown in Fig. 1.

Preregulators, IC1,2 give $\pm 2V$ to power the PSU op-amps as they cannot withstand the full unregulated supply voltage (approximately $\pm 21V$) across their supply pins.

A reference supply of 5.1V is generated across ZD1, which is then applied to the op-amp IC3. When the voltage at the wiper of RV1 is equal to that of the reference voltage, the feedback loop is in equilibrium. However if the output voltage tends to droop, the op-amp drives negative, causing more current to flow in the series pass transistor Q1 and thereby raising the output voltage. Similarly if the output voltage rises, the op-amp output goes positive, cutting down the current flowing in the pass transistor.

Resistors R2,3 are chosen so the pass transistor is able to cut off when the op-amp output is at or near the op-amp supply voltage.

Very little current flows in the 0V line. It isn't a power supply line as such, but provides a 0V reference for signals. This results in quiet, stable operation.

A similar circuit derives the $\pm 15V$ supply. A special feature is that the 15V supply tracks the 7V supply. The 15V supply will not reach its full voltage if the 7V supply is pulled down or has failed for any reason. This protects the CMOS circuitry which uses the 7V supplies but which may be fed from circuits employing the 15V supplies. The tracking is accomplished by using the feedback signal from the 7V supply as the reference voltage for the 15V supply.

The performance of the supplies as regards load regulation and drift is quite exceptional.

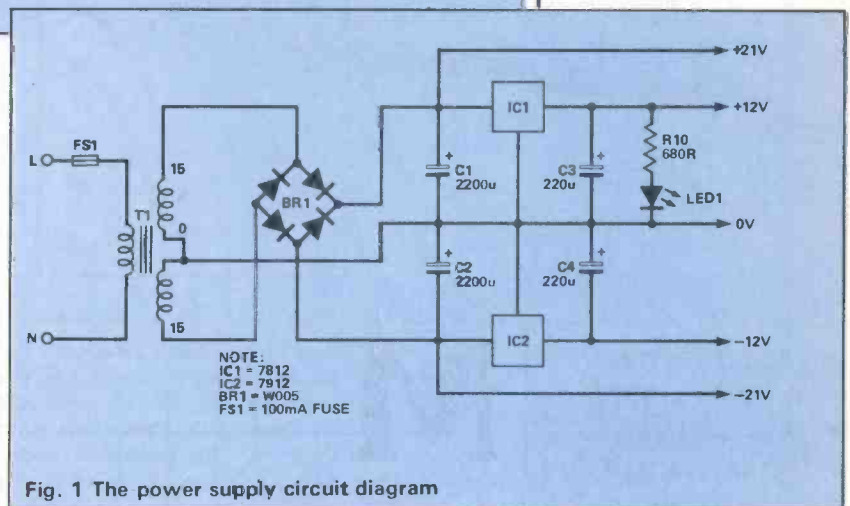
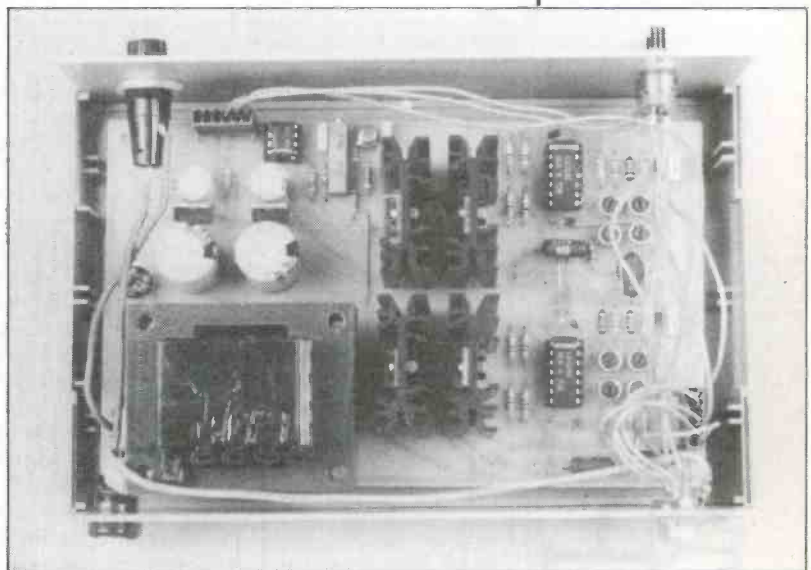


Fig. 1 The power supply circuit diagram



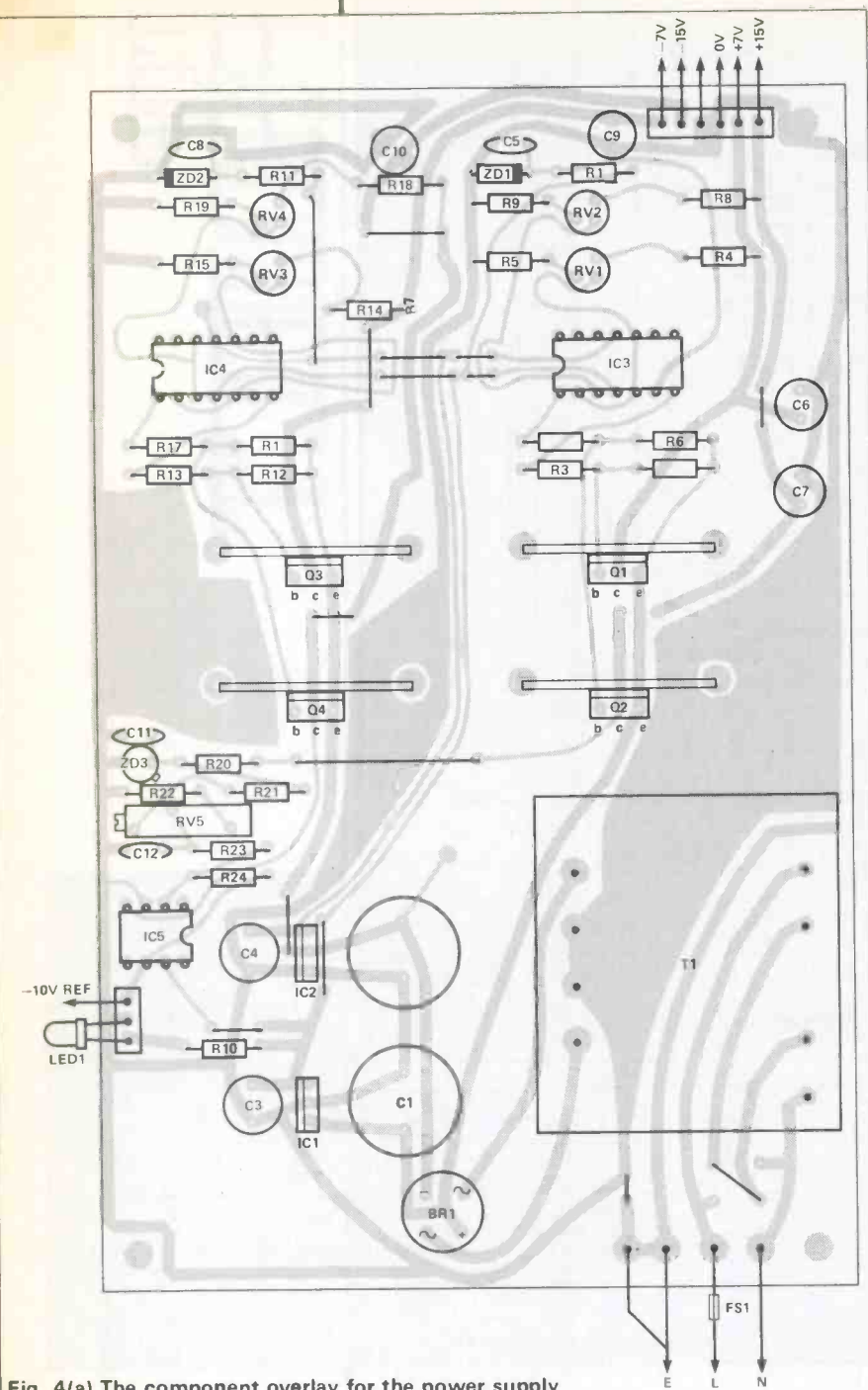


Fig. 4(a) The component overlay for the power supply

and solder the neutral and earth wires directly to the board with the 100mA fuse in line with the live connection.

Bolt the board to the case and after drilling holes and mounting the two switches (SET and HOLD), the LED and the power D-connector, wire them to the board as shown in Fig. 5. The connector blocks are not essential and the wiring can be made directly to the PCB but removable connectors enable the board to be easily taken from the case for repair or alteration.

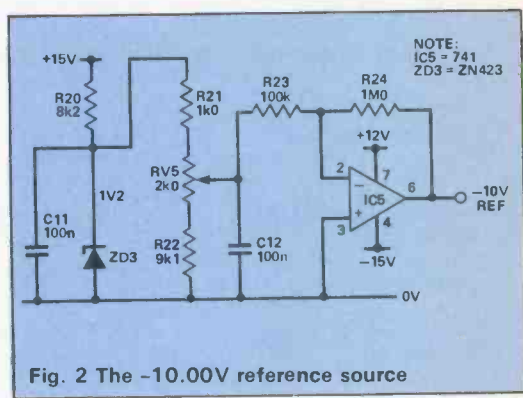


Fig. 2 The -10.00V reference source

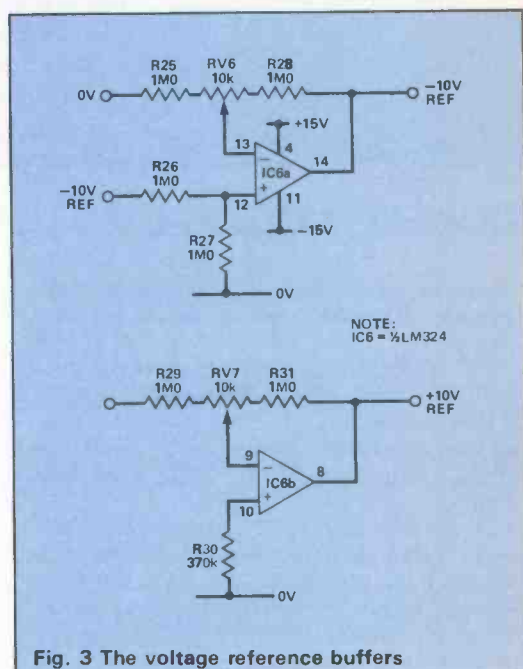
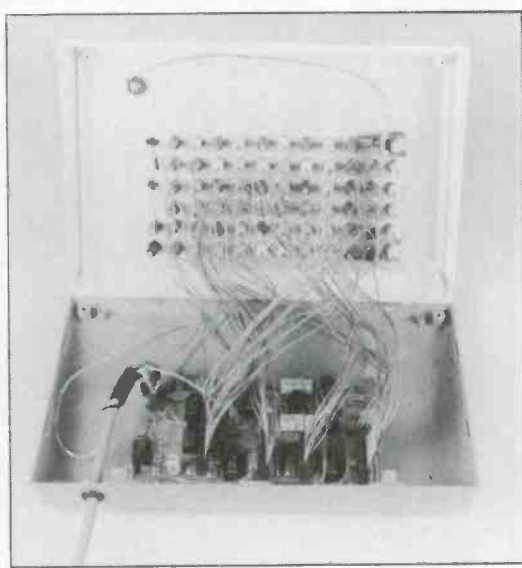


Fig. 3 The voltage reference buffers

TOP PROJECT



HOW IT WORKS: VOLTAGE REFERENCE

The voltage references are shown in Figs. 2 and 3. Fig. 2 shows the master reference providing -10.00V which is located in the PSU and Fig. 3 shows the two slaves located in the computer unit itself.

A band gap reference diode (ZD3) provides approximately 1.26V to an adjustable divider circuit (R21-RV5-R22) the output of which is buffered and multiplied by ten by IC5. This circuit is fed from the +12V and -15V supplies — if the -15V supply should fail then the master reference will be unable to provide possibly damaging voltages to other circuits.

The positive and negative slave references are an inverting and a non-inverting buffer respectively. Their gains are slightly adjustable (about 1% either side of unity) giving fine control over the reference voltage.

PARTS LIST: PSU

RESISTORS (all 5% 1/4W unless specified)

R1,11	1k5
R2,6,12 16	1k0
R4,14	1k5 1%
R5,9,15 19	4k7 1%
R8,18	10k 1%
R10	680R
R20	8k2
R21	1k0 1%
R22	9k1 1%
R23	100k 1%
R24	1M0 1%
RV1-4	10k sub-adjustable horiz preset
RV5	2k0 20-turn preset

CAPACITORS

C1,2	2200µ 25V radial electrolytic
C3,4	220µ 16V radial electrolytic
C5,8,11,12	100n ceramic
C6,7,9,13	100µ 16V radial electrolytic

SEMICONDUCTORS

IC1	7812
IC2	7912
IC3,4	LM324
IC5	741
Q1,2	TIP115
Q3,4	TIP110
ZD1,2	5V1 zener
ZD3	ZN423 voltage reference
BR1	W005
LED1	red LED

MISCELLANEOUS

FS1	200mA fuse and holder
SK1	15-way female D-connector
SW1,2	Push to make switch
T1	15-0-15 12VA PCB mounting mains transformer

PCB: Case: T022J heatsinks. Grommet: 6-way and 3-way minicon PCB connectors. Wire: Nuts and bolts.

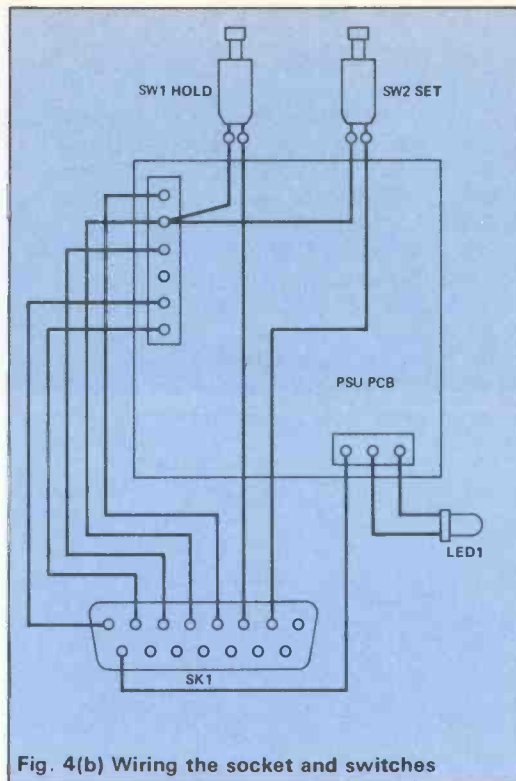


Fig. 4(b) Wiring the socket and switches

HOW IT WORKS: MULTIPLIERS

One of the coefficient multipliers is shown in Fig. 6. These are simply potentiometers with a buffer amplifier on the output. The potentiometer is mounted on a small board at the front panel. The op-amps are on the main board. The circuits for each are identical and numbered 900-1400.

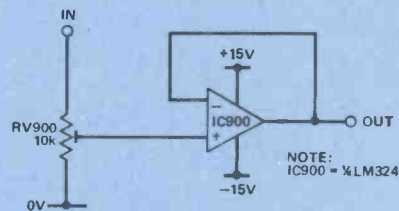


Fig. 5 Wiring the PSU switches and D-connector

BUYLINES

Most of the components for this project are easily available. The transformer used and a complete kit of parts for the whole computer is available from the Grampian Electronic Components, 266 Clifton Road, Aberdeen AB2 2HY (Tel: (0224) 495545). Further details are available from Grampian.

The PCB is available from the PCB service

HOW IT WORKS: INTEGRATOR

An integrator is shown in Fig. 7. The resistors R1500-RV1500-R1501 attenuate the incoming signal by a factor of two to render it safe for use in the analogue switch, IC1500. RV1500 adjusts the time constant of the integrator. When the HOLD pushbutton is released, the analogue switch IC1a is closed, allowing a current to flow in R1502, charging the parallel integrating capacitors C1500, 1501 and causing the output voltage of op-amp IC1502 to ramp. Pressing HOLD opens IC1a and integration stops, regardless of the input voltage.

Pressing SET closes IC1501, shorts the integrating capacitor and discharges it. The SET line also forces a reset of the overvoltage circuit.

Initial conditions (the 'starting point' of the integrator) are summed with the integrator output by IC1503. When IC1502 output is at 0V, the initial condition voltage appears at IC1503 output inverted.

The four diodes connect to the overvoltage circuit.

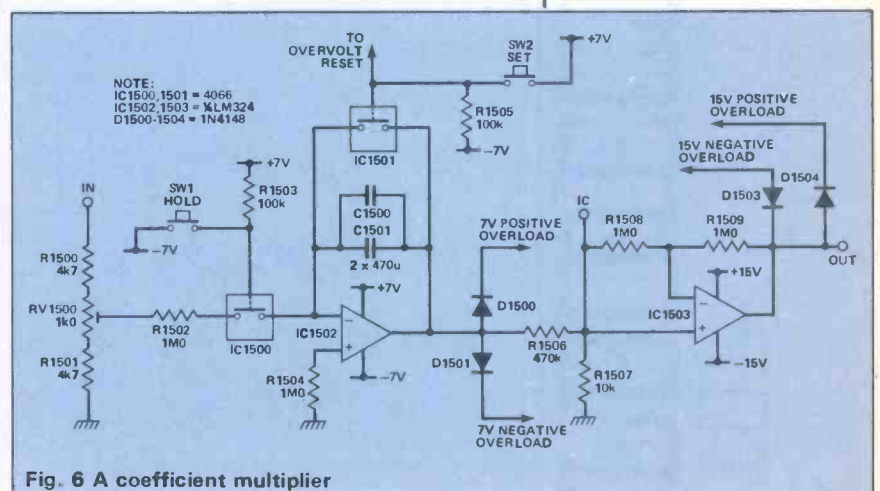


Fig. 6 A coefficient multiplier

HOW IT WORKS: SUMMING AMPS

The summing amplifiers (see Fig. 8) are the classic inverting circuit. Each of the inputs is either a $\times 1$ or a $\times 10$ input depending on the value of the input resistor (R107-113). Eight summers are provided — three 2×1 , 1×10 , four 3×1 and one 5×1 , 2×10 . Summer 1 (5×1 , 2×10) is shown. The circuits for the others are identical and the components numbered 200, 300 ... 800 with resistors R100-103 and R107-110 omitted and the value of R111-113 and R115 altered.

The inverting input of the op-amp (IC100) is maintained as a virtual earth point. The currents from all the inputs are summed at the inverting input of the op-

amp. The sum of these current flows in the feedback resistor (R114).

When inputs are unused, offset voltages due to bias currents might be a problem. These tiny currents need an external path to flow in. We need not tie unused inputs to 0V when using the computer, since the grounded 10K (resistors) R101-107) provide a path for the input bias currents to follow.

Looking at it another way, when an input is unplugged, the impedance seen by the op-amp input does not change as much as it might, as there is a (relatively) small resistor shorting the other end of the input resistor to 0V. A similar technique is employed at the integrator inputs as well.

The resistor on the non-inverting input (R115) of any op-amp is always chosen to be approximately equal to the parallel value of all the input resistors (R107-113). See Table 1 for a list of the values used in these circuits.

The two diodes D100, 102 route the output voltage to the overload detector. More on this later.

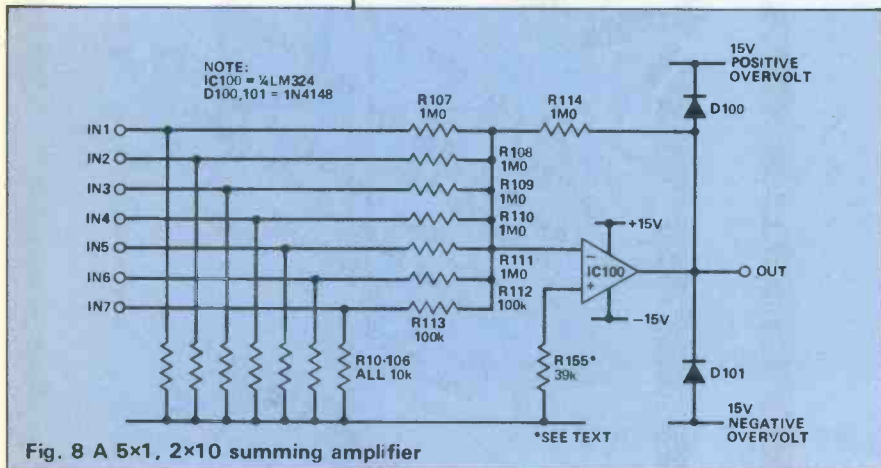


Fig. 8 A 5×1 , 2×10 summing amplifier

Next month the construction of the main computer unit and use of the whole system will be described.

HOW IT WORKS: OVERVOLTAGE

The overvoltage circuit is shown in Fig. 9 and consists of a window comparator and a latch. The potential divider R36-38 develops approximately +5.1V at the non-inverting input of IC7a and -5.1V at the inverting input. Two rails carrying information about the maximum voltages present on any of the outputs of the summers and integrators, are applied to the potential divider R32, 33. A similar pair of rails concerned with minimum voltages is applied to the divider R34, 35.

Normally the outputs of the two op-amps IC7a, b are positive. Whenever a voltage greater than about 10.2V plus one diode drop appears on the 15V overvolt rail or a voltage greater than about 5.1V plus one diode drop is applied to the 7V overvolt rail, the op-amp IC7a will go negative, pulling down the inverting input of IC7c via D1 and R39. The output of IC7c will swing positive, turning

on Q5 and LED2.

Due to the hysteresis (positive feedback) applied by R41, IC7c stays latched in the positive condition, even when the output of IC7a swings back positive. R40 ensures the inverting input of IC7c stays at 0V when not disturbed by an overvolt condition. Should the SET button now be pressed, +7V is applied to the anode of D3, causing the latch IC7c to be reset, turning off Q5.

Negative voltages out of range are dealt with in the same way with IC7b output swinging negative. The diodes tied to the overvolt rails provide an analogue wired-OR preventing the monitored circuits from interfering with one another. Sections of the integrators which are powered from $\pm 7V$ (and cannot be expected to attain $\pm 10V!$) are tied to the 7V overvolt rails. All others are tied to the 15V overvolt rails.

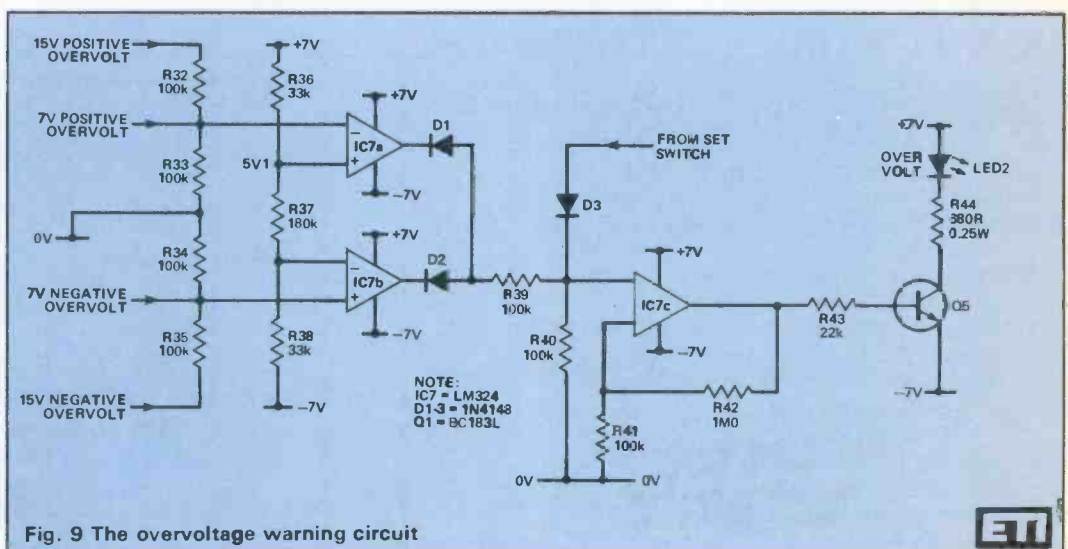


Fig. 9 The overvoltage warning circuit

TOP PROJECT

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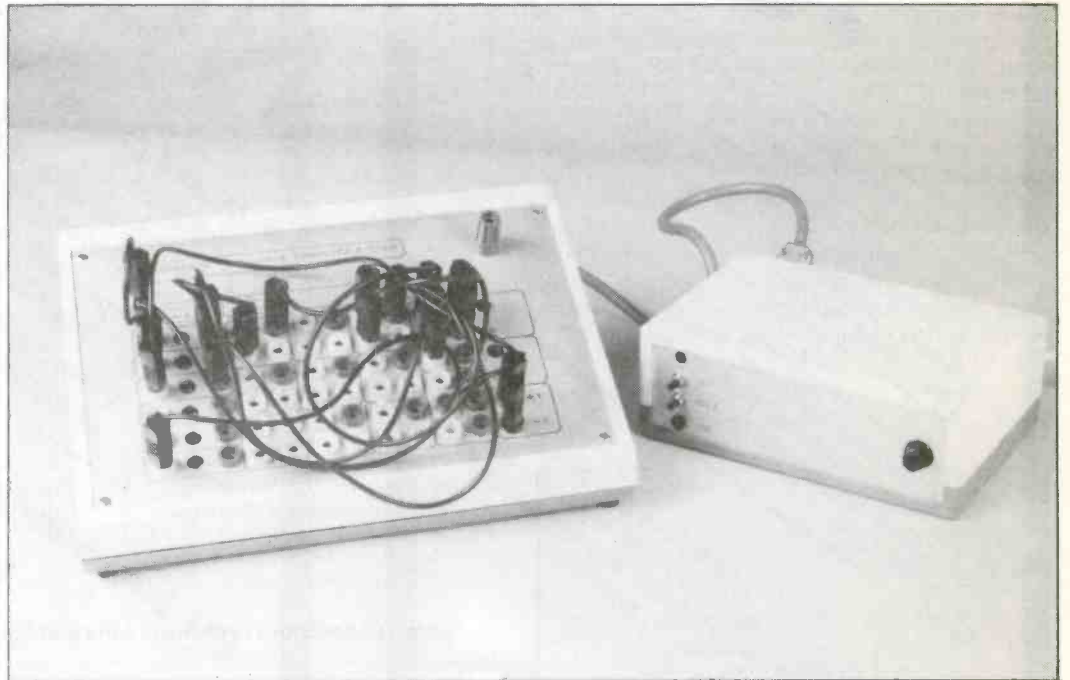
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ANALOGUE COMPUTER

PART II

*Paul Cuthbertson
continues to build his
small analogue
computer for use in
the classroom or the
laboratory*



Last month I described the construction of the analogue computer's power supply. This month it is the turn of the main computer unit itself.

The suggested front panel layout is shown in Fig. 1. It can be quite tedious to mark out the front panel neatly yourself and so this panel is available as part of the kit from Grampian (see Buylines). However, you'll still have to drill your own holes!

Use a punch to mark the centre of each hole and a hand drill to drill a 2mm pilot hole at each position. Hold the panel firmly in a vice near the hole position (with a clean piece of rag in the vice to prevent marking the panel) to prevent it bending. With a little care good results can be had. Be particularly careful with the potentiometer holes as these have the edges showing.

Drill 6.5mm holes for the green terminal and the LEDs, 8mm for the 4mm sockets and large holes up to a limit of 8mm or 9mm for the pots. If in doubt drill a hole too small, try it out and then work up. Use an instrument file or similar to cut a small slot in the edge of the hole for the spigot on the terminals.

Fit and tighten all the panel components except for the yellow sockets at the top and bottom of the coefficient multiplier section. A $\frac{3}{8}$ in socket spanner held in the hand can be a good tool to use here. Don't overtighten them as the threads can strip.

Now solder the six potentiometers in place on the pot board (Fig. 2). To fix the pot board to the front panel, you'll need a couple of special brackets made from scrap aluminium — see Fig. 3. There's a left handed bracket and a right handed one.

No precise measurements are given because these will depend on your exact front panel layout. The last two yellow sockets tighten down on the fork, and the pot board then screws down to the small holes. Make sure the brackets do not connect to tracks on the pot board.

Solder a 15-way D-plug on the end of the 15-way cable trapping the braid in the cable clamp for earthing.

Drill a hole in the back right of the case, no further than 50mm from the end of the case for the 15-way cable. Use a grommet. Solder a length of earth wire to the braid and either trap the other end of this between the bracket and the pot board or use a solder tag onto the bolt which secures the pot board. Trim all but the -10V REF wire down to about 40mm length. Strip and crimp tags to the ends of the wires and push them into a 10-way cable shell in accordance with Table 1 (connections 63-72).

The +7V wire (position 63) needs a 8in piece of wire to reach the overvoltage indicator (LED2). The -7V wire (position 67) needs a slightly longer piece in with it. The 0V wire (position 72) needs a piece of wire about 250mm inserted with it. The -10V REF wire goes to the next cable shell at position 61 which is why it is longer than the rest. Cut the wings off this shell before using it.

Begin populating the main board by fitting all the connectors and all the IC sockets as shown in Fig. 4. Next fit all the links using insulated single strand wire.

Fit all the other components as shown in Fig. 4 making sure all the diodes and the translator are the right way round. Don't fit the ICs yet.

Several points on the board (labelled A-I) must

TOP
PROJECT

be connected with insulated wire on the underside of the board. Some of these are corrected mistakes, some are there because there is no room elsewhere on a single sided board and others are an attempt to preserve the designers sanity!

Connect the pads with the same letters. There are two of most but five each of pads B and C and three each of D and E.

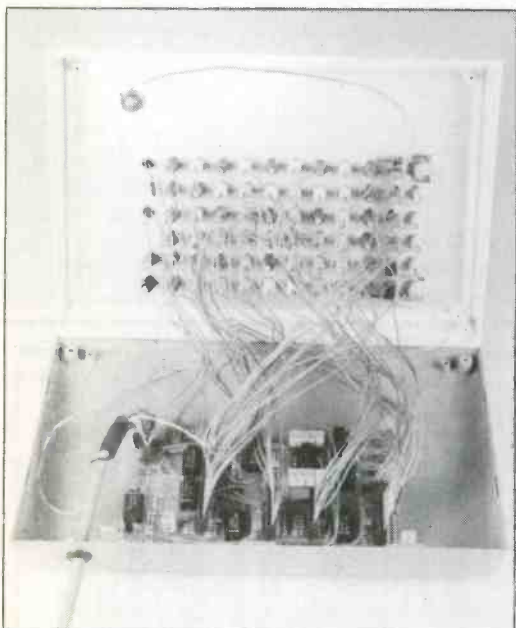
Testing

Most parts of the system can be tested at this stage before the front panel wiring goes in. Don't insert the ICs to their sockets yet but plug the leads from the power supply into the board.

Switch on the supply and quickly check that all supplies are present in the right places. If not, switch off immediately and investigate.

A rather strange property of all the ICs used in this project is that they are symmetrical. If the supplies are present but the wrong way round, you can plug the IC in upside down rather than rewiring!

Make yourself a couple of test links by crimping tags onto 200mm or so pieces of wire. Bare about 10mm at the other end. Now you can push each of these into a six way cable shell or other test position as appropriate, to apply signals to the various parts of the circuit. Refer to Fig. 3 and Table 1 to see whereabouts you are and to Table 2 to see which quarter of the op-amp is responsible for different functions.



Insert IC6/1300/1400. Power up and check you have about $\pm 10V$ at each of the corner pins on the right of the IC. Then adjust the two pots at the bottom of the board to give precisely 10.00V. Do look at the 10V master reference too to see it has not changed. Power down each time before inserting the next IC.

Insert the top left IC (IC100/200/300/400) into its socket. Power up and check that all the outputs are at 0V by probing the corner pins of the IC. (In reality you may expect up to about 10mV either way — about 0.1% full scale). Now apply each of the \pm references to each input in turn, monitoring at the output connector pin. +10V in should give -10V out, and vice versa. The outputs should be well within 1% of full scale, for $\times 1$ inputs. Applying this input to a $\times 10$ input will result in about 14V output or so but it does mean the input is connected properly. Strange results can be due to misconnection, solder bridges or a reversed diode.

1	Summing amplifier input 1,1	37	Integrator output 1
2	Summing amplifier input 1,2	38	Integrator output 4
3	Summing amplifier input 1,3	39	Integrator initial conditions 2
4	Summing amplifier input 1,4	40	Integrator initial conditions 1
5	Summing amplifier input 1,5	41	Integrator output 2
6	Summing amplifier input 1,6	42	Integrator output 3
7	Summing amplifier input 1,7		
8	Summing amplifier input 2,1	43	Summing amplifier input 7,1
9	Summing amplifier input 2,2	44	Summing amplifier input 7,2
10	Summing amplifier input 2,3	45	Summing amplifier input 7,3
		46	Summing amplifier input 8,1
11	Integrator input 4	47	Summing amplifier input 8,2
12	Integrator input 3	48	Summing amplifier input 8,3
13	Integrator input 2	49	Coefficient multiplier input 1
14	Integrator input 1	50	Coefficient multiplier output 1
15	Integrator initial conditions 4	51	Coefficient multiplier output 2
16	Integrator initial conditions 3	52	Coefficient multiplier input 2
17	Summing amplifier output 1	53	Coefficient multiplier input 3
18	Summing amplifier output 3	54	Coefficient multiplier output 3
19	Summing amplifier input 3,1	55	Coefficient multiplier output 4
20	Summing amplifier input 3,2	56	Coefficient multiplier input 4
21	Summing amplifier input 3,3	57	Coefficient multiplier input 5
22	Summing amplifier input 4,1	58	Coefficient multiplier output 5
23	Summing amplifier input 4,2	59	Coefficient multiplier input 6
24	Summing amplifier input 4,3	60	+10V Reference output
25	Summing amplifier output 4	61	-10V Reference input
26	Summing amplifier output 2	62	Coefficient multiplier output 6
27	Summing amplifier output 7	63	+7V Supply
28	Summing amplifier output 5	64	Overvoltage warning LED
29	Summing amplifier input 5,1	65	NC
30	Summing amplifier input 5,2	66	SET
31	Summing amplifier input 5,3	67	-7V Supply
32	Summing amplifier input 6,1	68	HOLD
33	Summing amplifier input 6,2	69	-15V Supply
34	Summing amplifier input 6,3	70	+15V Supply
35	Summing amplifier output 6	71	-10V Reference output
36	Summing amplifier output 8	72	OV

Table 1 Connections to the main computer board

Insert IC7 into its socket. This is the window comparator and latch. Remember this one is reversed relative to the rest (unless you've reversed any others yourself!). By applying $\pm 10V$ to a $\times 10$ input of a summing amp or the $\pm 15V$ supply to a $\times 1$ input, you should be able to see the leftmost corner pins of the IC dropping negative. They should be positive normally and respond momentarily to overrange outputs. It isn't necessary to test all the inputs this way incidentally, just one for each summing amp.

Next monitor pin eight of IC7. It should be positive if SET has not been pressed since the last overvolt condition. Press SET and check it goes negative.

Insert IC500/600/700/800 and use the same

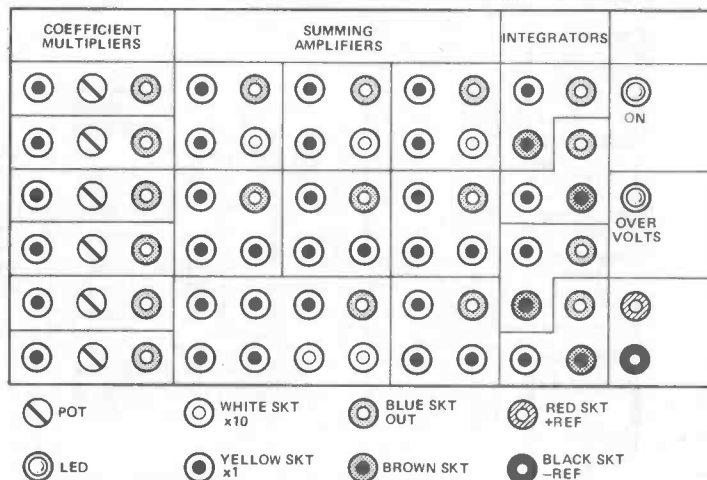


Fig. 1 The front panel layout

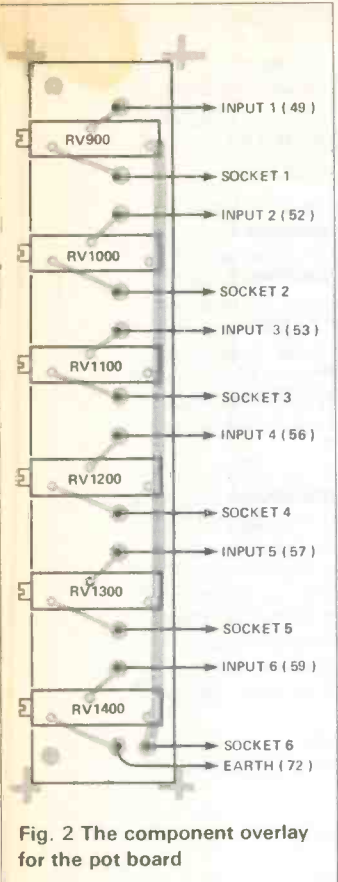


Fig. 2 The component overlay for the pot board

procedure for each summing amp — checking for zero, checking all inputs and finishing with an overvolt check on one input of each amp.

Now insert IC1500/1501/1600/1601, IC1700/1701/1800/1801 and IC1502/1602/1702/1802. These form the heart of the integrators. Power up, press SET and see that the four corner pins of the LM324 go close to 0V. You can expect a good 30mV here actually — about 0.3% full scale. Release SET. The op-amp outputs should drift very slowly. (In an

ideal world this drift would be zero).

Apply +10V to the integrator input at the connector pin. The op-amp output should attain -5V in a second (approximately). Press SET a few times to verify the op-amp output returns to zero and ramps from there each time. It may be easier to monitor this on a scope or an analogue meter rather than a DVM. While this is in progress check the overvolt system responds to the op-amp output voltages.

Check HOLD by attempting to catch the op-amp

PARTS LIST

RESISTORS (all 1/4W 5% unless specified)

- R25-29, 31, 107-111, 114, 207, 208, 214, 307, 308, 314, 407, 408, 414, 507-509, 514, 607-609, 614, 707-709, 714, 807-809, 814, 1502, 1508, 1509, 1602, 1608, 1609, 1702, 1708, 1709, 1802, 1808, 1809 1M 1%
- R30 470k 1%
- R32-35, 39, 40, 41, 1503, 1505 100k
- R36, 38 33k
- R37 180k
- R42, 1504, 1604, 1704, 1804 1MΩ
- R43 22k
- R44 680R
- R100-106, 200-202, 300-302, 400-402, 500-502, 600-602, 700-702, 800, 802, 1507, 1607, 1707, 1807 10k
- R112, 113, 209, 309, 409 100k 1%
- R115 39k
- R215, 315, 415 82k
- R515, 615, 715, 815 330k
- R1500, 1501, 1600, 1601, 1700, 1701, 1800, 1801 4k7 1%
- R1506, 1606, 1706, 1806 470k
- RV6, 7, 900, 1000, 1100, 1200, 1300, 1400 10k 20 turn pot
- RV1500, 1600, 1700, 1800 1kΩ 20 turn pot

CAPACITORS

- C1500, 1501, 1600, 1601, 1700, 1701,

1800, 1801

470n

SEMICONDUCTORS

- IC (61300/1400), 7, (100/200/300/400), (500/600/700/800), (900/1000/1100/1200), (1502/1602/1702/1802), (1503/1603/1703/1803) LM324
- IC (1500/1501/1600/1601), (1700/1701/1800/1801) 4066
- Q5 BC183L
- D1-3, 100, 101, 200, 201, 300, 301, 400, 401, 500, 501, 600, 601, 700, 701, 800, 801, 1500-15004, 1600-1604, 1700-1704, 1800-1804 1N4148
- LED1, 2 red LEDC

MISCELLANEOUS

- PL1 15-way D-type plug
- PL2-22 stacking 4mm plug
- SK1-4 green 4mm socket
- SK5-9 white 4mm socket
- SK10-27 blue 4mm socket
- SK28-50 yellow 4mm socket
- SK51 green 4mm socket

PCBs. Case. 6x10-way, 2x6-way PCB connectors. IC sockets. Connecting wire. Flexible wire. Nuts and bolts.

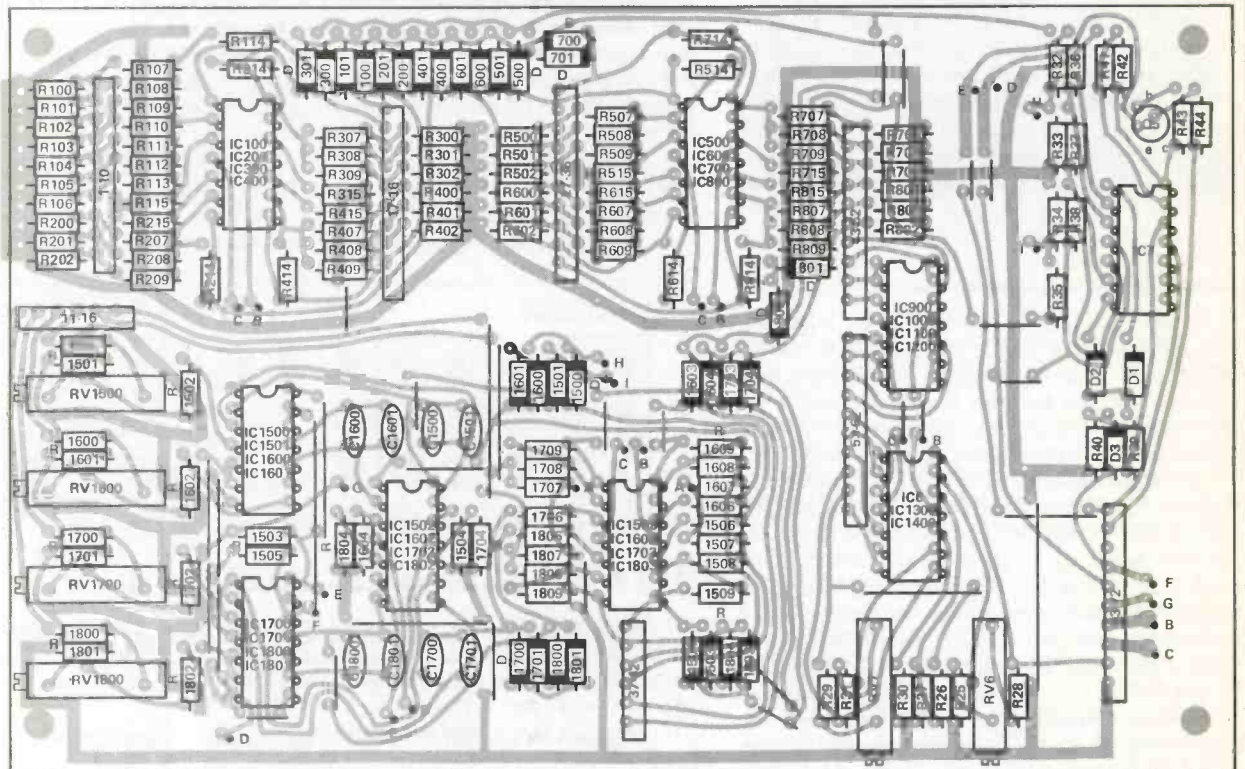
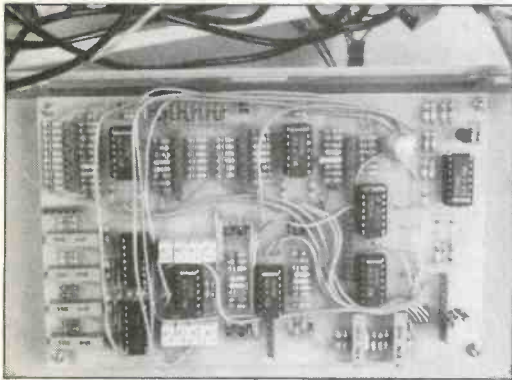


Fig. 4 The component overlay for the main board

halfway through its headlong rush. When in HOLD the integrators do drift — in an ideal world they would not — and this looks quite bad on a DVM (the drift rate can be about 50mV/s) but look at it with a scope and I would defy anyone to see it drifting from moment to moment.

On the plus side, the integrators behave very well if you apply 0V to the inputs — drifting about 1mV/s — so left to their own devices they will take about two hours to drift up to an overvolt condition! It is wise not to use HOLD for extended periods of time but see my comments on performance improvements below.

Insert the last IC (IC1503/1603/1703/1803) and check the outputs follow those of the previous stage (x2) and that when an input is applied to the IC (initial conditions) connector position this voltage appears inverted at the output. Keep SET asserted for



The prototype showing the internal overboard wiring

this, using a shorting link if you like, as it is easier to see what's going on.

Also put $\pm 15V$ in at the initial condition inputs (without SET asserted) to check the action of the overvolt connections. Calibration of the integrators must wait until the internal wiring is installed.

Wiring

Drill holes in the base of the case and bolt in the board, using spacers. The board should lie right at the back of the case where it just clears the 4mm sockets nicely.

Use small lengths of bare single strand wire to connect each of the yellow coefficient multiplier sockets to the clockwise end of each potentiometer on the pot board. Trim down the anode (long) leads of both LEDs and solder a 680R resistor between them. Lay the front panel face down with the back edge just leaning on the front of the case, so that it can 'hinge' back into position when the time comes.

Starting with those sockets and connections at the back, which would be awkward to reach with the rest of the wiring in place, cut and solder an appropriate length of wire to the socket. Refer to Fig. 3 and Table 1 continuously. I have chosen to number the inputs to the summing amps starting at the top left working right, then bottom left working right. The really essential thing is that groups of connections to one amp or integrator are kept together and a white (x10) socket always connects to an input with a 100k resistor.

The coefficient multipliers are numbered one to six from top to bottom. Connect a wire from each pot wiper pad to the input connector. The outputs go direct to the blue sockets. Connect a wire between the thick 0V track on the pot board and the green terminal. Connect the 0V wire from position 72 to the green terminal as well. Trim and connect the overvolt LED cathode to the appropriate connector position. Trim and connect the power LED cathode to the -7V

position. Connect the +7V position to the overvolt LED anode along with the 680R resistor which is already in place.

Carefully lower the panel into position. Now is a good time to make up the patch leads. Two metres of extraflex wire will make ten leads of various lengths; I used six 0.25m lengths and four 0.125 ones. Connect 4mm plugs on both ends of each lead.

More Testing

All that remains is to check the summing amp and coefficient multiplier connections by applying inputs, checking outputs and by checking the integrator wiring and calibration of the integrators. Calibrate the integrators by applying a 0.50V signal derived from a voltage reference passed through a coefficient multiplier. Use your nice new patch leads to do this!

Using a stop watch, release SET, wait for 20 seconds and press HOLD. Make a quick mental note of the voltage attained before it wanders too far off. Adjust the integrator, using one of the four pots at the left edge of the board, using the 20s check each time an adjustment is made, until the integrator reaches ten volts plus the offset apparent when SET is asserted. That's the simplest method. If you've stuck with the wiring scheme outlined, you'll see that the pots are numbered one to four from back to front.

If you have a pulse generator which will give you a good pulse of known and stable amplitude and duration, you could use it to pulse the integrator and adjust the potentiometer to give a known final voltage. A +1V pulse for one second should result in -1V on the output. The important thing is that the integrators are the same. The only reason for having adjustment here, and not for any other circuit, is to remove the effects of the tolerance of the capacitors (5%) and to account for using two 470n rather than $1\mu O$.

Improvements

The LM324 ICs used in the computer are the biggest

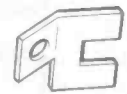


Fig. 3 Brackets to hold the pot board to the front panel

PIN FUNCTION

	IC100/200/300/400	7	Integrator 4 first stage output
1	Summing amp output 1	8	Integrator 3 first stage output
2	Summing amp output 2	14	Integrator 1 first stage output
8	Summing amp output 4		
14	Summing amp output 3		
	IC500/600/700/800		
1	Summing amp output 5	1	IC1503/1603/1703/1803
7	Summing amp output 6	7	Integrator 3 output
8	Summing amp output 8	8	Integrator 4 output
14	Summing amp output 7	14	Integrator 1 output
			Integrator 2 output
	IC7		
1	This output not used	1	IC900/1000/1100/1200
7	Latch output (drive to overvolt LED)	7	Coefficient multiplier 2 output
8	Upper (+ve) comparator	8	Coefficient multiplier 3 output
14	Lower (-ve) comparator	14	Coefficient multiplier 4 output
			Coefficient multiplier 1 output
	IC6/1300/1400		
1	Integrator 2 first stage output	1	Coefficient multiplier 5 output
		7	Coefficient multiplier 6 output
		8	+10V reference output
		14	-10V reference output

Table 2 Useful test point locations

BUYLINES

Most of the components for this project are easily available from usual suppliers. All the components are available individually or in a complete kit from Grampian Electronic Components, 266 Clifton Road, Aberdeen AB2 2HY (Tel: (0224) 495549).

The PCB is available from the ETI PCB Service as detailed at the back of this issue.

source of error, particularly in the integrators where their bias currents cause drift in the HOLD mode and very slight asymmetric operation and drift when running.

If any improvement is considered necessary, the biggest single step would be to replace those op-amps in the critical positions of summing amplifier and integrator. Some possibilities might be the LF347 which offers vastly improved bias currents or the OP400 with its very low offset voltage of $150\mu\text{V}$ maximum. If selecting an improved op-amp do not be concerned with bandwidth or slew rate for this application.

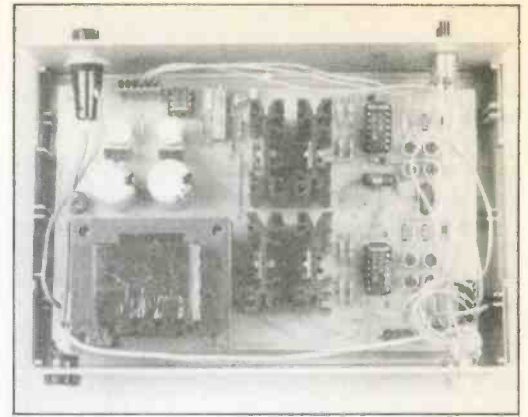
There are no other easy or relatively cheap roads to improvement. The next item on the list is perhaps the capacitors but closer tolerance types at 1μ are likely to be bulky and expensive. Using 100n instead of the 1μ in the prototype will speed up the computer by a factor of ten but will also express drift rates ten times faster. The important resistors could be replaced by 0.1% types but these are likely to be expensive too.

Having said all this, the computer is still more than adequate for control experiments and, dare I say it, a lot better than certain offerings I have come across recently.

Further Uses

The individual building blocks of the computer can be used for many other purposes. Variable and fixed gain amplifiers are easily implemented. There are sufficient integrators to build two rather fine, high Q state variable filters, although the range of operating frequencies may be restricted.

Don't be afraid to use external components in the patching. For example, a 10k resistor in series with any input will attenuate the signal by a factor of two, 90k

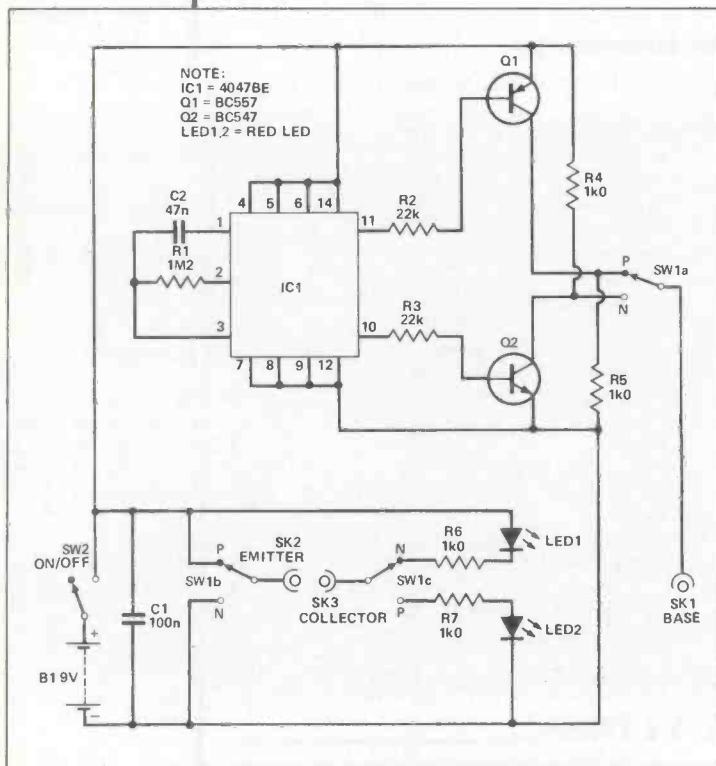


by a factor of ten. This can be used to slow down integrators.

A very low frequency sine wave generator is another possibility, with the added advantage of quadrature outputs and high spectral purity (since it is a 'proper' sine wave and not something cobbled up from a triangle wave) but the amplitude will change slowly. Set up a state variable filter with a damping of zero for this. (By the way, ten out of ten if you recognised the computation in the article in the June issue as just that — a state variable filter!)

The whole computer can be easily expanded adding further main boards operating off the same power supply unit. Wiring up further D-connectors in the power supply is the way to do this.

Other functional blocks could also be added either to this main board or to an additional one. The possibilities are almost boundless. One thing is certain. Once the analogue computer is built, you will never again look at a digital computer with quite the same admiration.



Transistor Checker

This simple gadget is an in-circuit transistor checker. It alternately forward biases the test device and short circuits its base and emitter terminals. An LED indicator is connected in the collector circuit of the transistor under test and should flash if the device is serviceable.

The circuit has IC1 operating in the free running astable mode with an output frequency of a couple of Hz. Switching transistors Q1 and Q2 are driven from its outputs, and these provide the base-emitter short circuiting for PNP and NPN devices respectively. R4 or R5 provides a forward bias to the base terminal of the test transistor during the half cycles when Q1 and Q2 are switched off.

Separate LEDs are used for the NPN and PNP modes. This helps to simplify the NPN/PNP switching and reduces the risk of the unit being inadvertently used while switched to the wrong mode.

When making in-circuit tests it is important to realise that components connected to the device under test can affect results. This will sometimes result in the LED not fully switching off and could result in it not switching on properly (although this never seems to happen in practice).

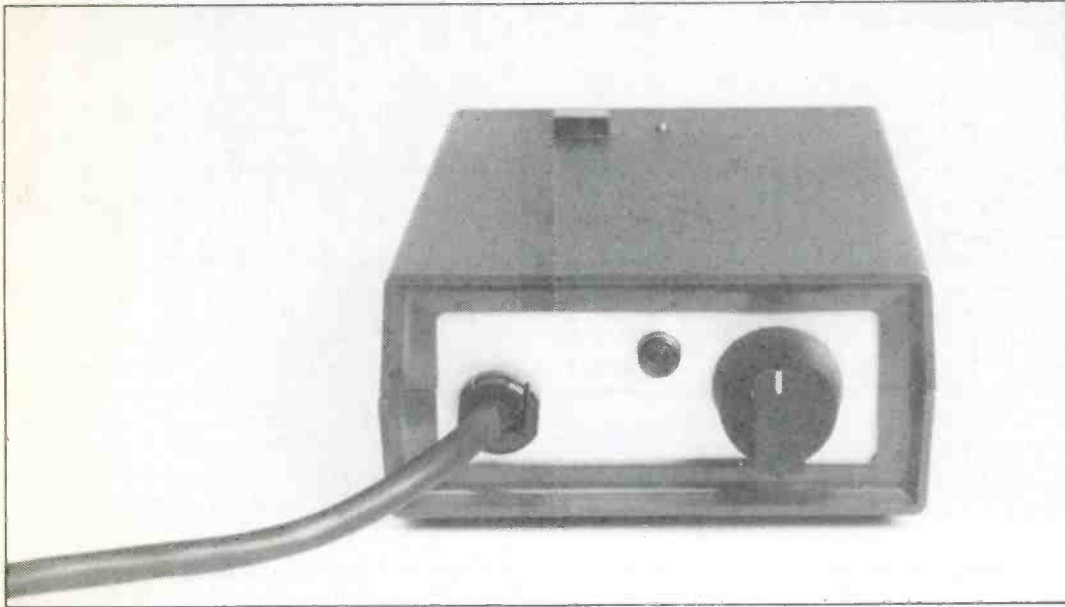
If the LED switches on and off properly it is highly unlikely that the tested device is faulty.

If the LED fails to switch properly, check the suspect transistor out of circuit to make quite sure it really is a 'dud.'



THE VARIATION-ION

TOP PROJECT



The most spectacular demonstration of an ioniser's powers has got to be the vanishing smoke trick. It's what got me hooked, anyway. Ionisers are usually promoted as health aids — they heal the sick, make the blind see, cause the lame to dance the hornpipe and probably raise the dead too if some of the more frenzied hype is to be believed. But it's the odd way they behave that really grabs your attention.

You don't need to be a member of the magic circle to baffle people with the smoke trick. The only equipment you need is an ioniser, a glass jar and a cigarette. Pass the ioniser around your audience. Look: no fans, no filters, no moving parts. Puff cigarette smoke gently into the glass jar until the air inside is a thick, grey smog. Invert the jar over the ioniser. The smog swirls around for a few seconds and suddenly the air is crystal clear again!

This, you explain to your audience, is one of the ioniser's minor powers. For an encore it will cause the blind to dance, the dead to see and may even heal the hornpipe. Or will it?

The Great Ion Debate has been aired (pun slightly intended) at one time or another in just about every science publication from *New Scientist* to the *International Journal of Biometeorology*. Research papers on the subject have appeared in almost any medical journal you care to name. Air ions have been investigated by such diverse bodies as NASA (when looking at the environment needed in space capsules), Mercedes Benz (ditto in cars) and the World Health Organisation. Yet still there's no overall agreement on what ions can do for you or just how important they are.

Ions In The Air

Air ions are nothing more than gas molecules which have either gained or lost an electron. Add an electron and you get a negative ion, or neg-ion for short. Subtract an electron and you end up with a pos-ion.

Ions occur naturally from a variety of causes: by the friction of one layer of air on another (like school electrostatics experiments where charges are generated by rubbing glass or plastic rods with a cloth), by the action of ionising radiations (ultra-violet rays

from the sun or nuclear 'background' radiation from naturally occurring minerals), from the electrical discharges associated with thunderstorms, from waterfalls and from many other sources.

The natural ion density in open countryside, far from city pollution, varies from around 300 to 1000 ions/cc of air. Close to vast ion generators, like the Niagara falls or the sea, levels of 2000 ions/cc and above can be measured.

In man-made environments the ion count is likely to be much lower. In cities, the life of each ion is much shortened by air pollution — smoke, dirt, traffic fumes and so on. In houses, whether in town

Paul Chappell is fit and healthy thanks to this super powerful, variable and ion-counting air ioniser

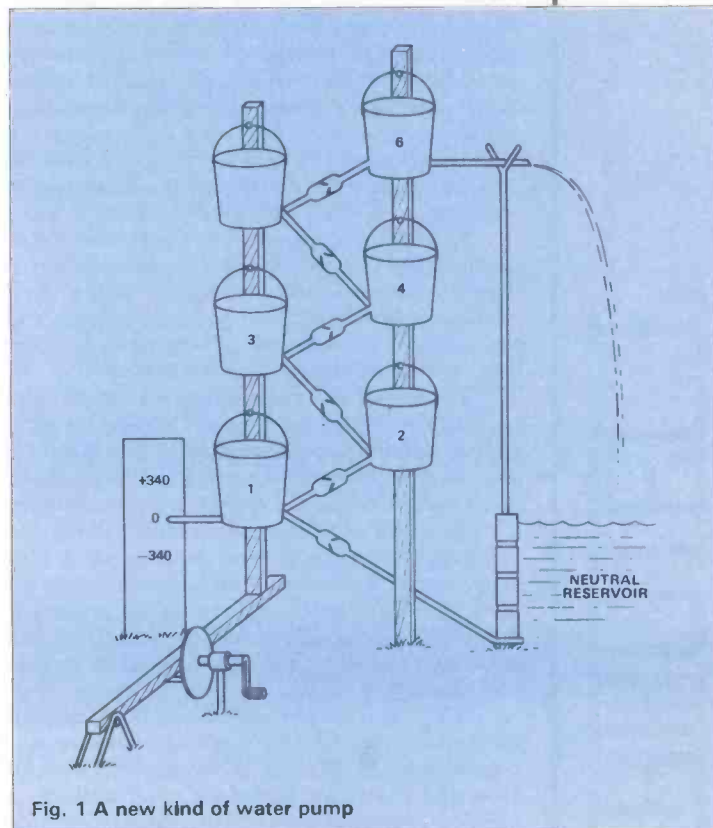


Fig. 1 A new kind of water pump

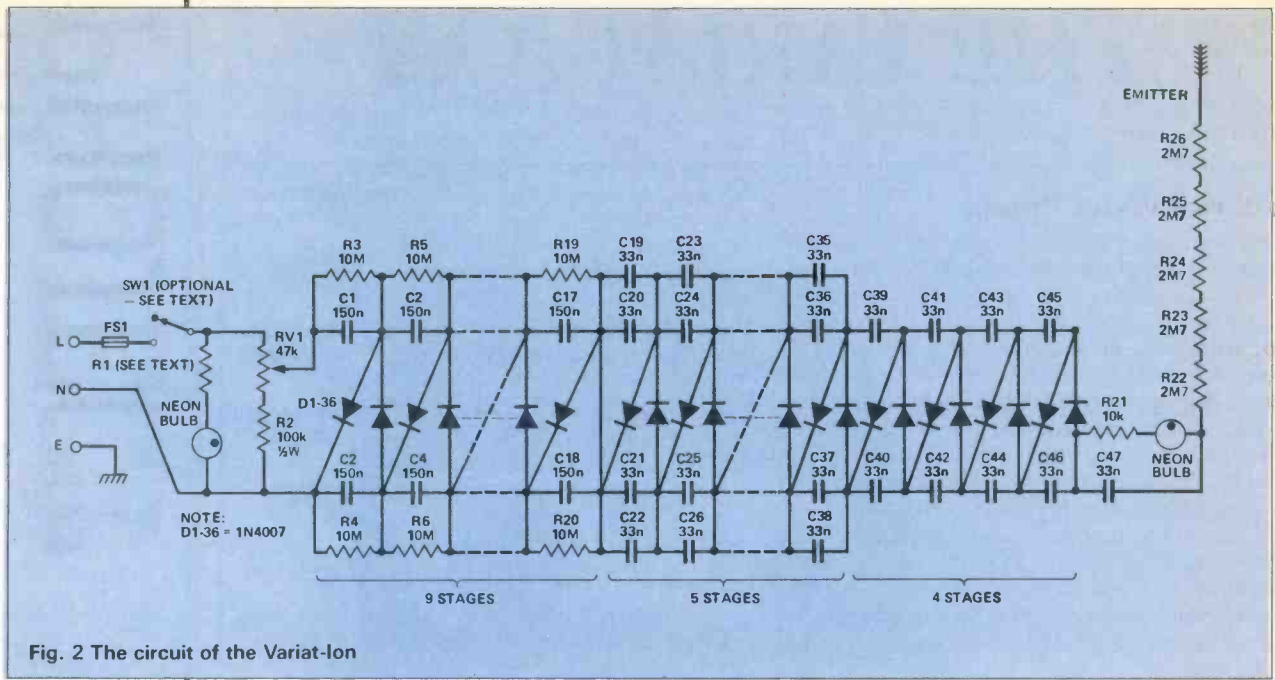


Fig. 2 The circuit of the Variat-Ion

or country, the effects of modern building and furnishing materials all act to remove ions from the air quicker than natural processes can replace them. The undisputed result is that most people spend most of the time breathing ion impoverished air. The case for owning an ioniser, then, is that living in ion-starved air has bad effects, whereas breathing ion-rich air has good ones.

Vitamins Of The Air

A demonstrably beneficial effect of ionising the air is the one you've already seen. Ionisers remove dirt, fumes and dust that might otherwise end up in your lungs. What happens is that as the particles come into contact with air ions, they pick up a greater and greater negative charge until they are drawn, by electrostatic attraction, to the nearest uncharged surface. Inside a jar, with an ioniser producing half a billion ions every second, this happens very quickly indeed. In a room the process takes a little longer, perhaps half an hour to remove most of the dust but it happens just the same. In a city street the pollution producers (cars, for instance) work so fast that the process doesn't stand a chance.

The effects of the neg-ions themselves are so profound that they are often described as 'vitamins of the air'. In a normal healthy person they seem to bring about feelings of tranquility and freedom from stress and worry — general state of well-being. In short, breathe in those ions and you'll feel great!

The evidence is partly anecdotal (people who have ionisers say they feel good and who am I to argue with them?) and partly physiological. The two main demonstrable effects are a reduction in serotonin levels and an increase in alpha activity in the brain.

Serotonin is a neurohormone which is produced in response to emotional stress. It has its part to play in the normal functioning of our bodies but when too much is produced too often the results can be counter-productive. The effects range from depression and irritability to (at worst) migraine headaches, nausea and vomiting.

Neg-ions help to prevent over production of serotonin — the hormone responsible for these unpleasant feelings. The way this is measured, if you're interested, is by detection of serotonin itself and a harmless by-product known as 5HA in urine samples

(don't you wish you hadn't asked?). Measurement of the quantities of these two substances shows how much serotonin is being produced and how effectively the body is breaking it down. The effects of neg-ions in reducing serotonin levels and aiding its breakdown are well documented.

As far as alpha activity is concerned, ions have the effect of increasing the duration and amplitude of this type of brain activity. Broadly speaking, electrical brain activity (as picked up by electrodes on the head) can be split (on the basis of frequency) into four main types: beta, the highest frequency associated with active thought; alpha, linked to pleasure and relaxation; theta, which indicates a state of reverie and delta, which only appears during sleep. For choice, unless you're driving a car or doing something else that needs your full attention, alpha is the state to be in.

Neg-ions have been recommended for all kinds of specific complaints but the strongest evidence for their beneficial effects is in the treatment of respiratory complaints (asthma, hay fever, bronchitis), migraine and, surprisingly, burns. The action of cleaning the air has to be of benefit in itself for any kind of respiratory disorder and the further effect of speeding up the action of the cilia (the cleaning cells in the respiratory tract) helps too. As far as burns are concerned, the rapid healing and reduced scar tissue seems to arise from ions absorbed directly by the skin rather than inhaled. Next time I burn my finger on the soldering iron I'll hold it above the ioniser and let you know...

My latest ioniser is one for the connoisseur. If you just want a small ioniser for your bedside the Direct-Ion (ETI, July 1986) will fit the bill admirably (and is quite a lot cheaper in parts). If you want one with enough power to run several multi-point emitters, variable ionisation potential and a built-in ion counter, the Variat-Ion is the ioniser for you.

There are all kinds of ways of producing ions, from radioactive sources to water sprays but by far the most convenient, predictable and safe method is to do it electrically. The principle is to create a high voltage and to apply it to one or more sharp points. Since charge density increases as radius of curvature gets less, the surplus electrons will be crammed tightly into the points and will gladly step off onto any passing air molecule. The molecule, now negatively charged, will be repelled from the point to make way for the next,

This accounts for the 'ion breeze' you feel if you put your hand close to the emitter.

Positive ions have an initial stimulating effect but after a while feelings of tiredness and irritation set in, which is why ionisers go for the negative ones.

A Novel Water Pump

I really must tell you what happened to me earlier this week. I was passing the Neutral reservoir when I saw a group of people gathered around what looked like a lot of buckets hung on a pair of wooden posts. I stopped to take a closer look and discovered that the water board were trying out a new kind of manual pump. From memory, it looked something like Fig. 1.

Close to the reservoir was a tall wooden post on which had been hung a number of buckets, one above another. A few feet from the first post was a second one, similarly hung with buckets. The first post had been driven into the ground, whereas the second was supported on a kind of lever arrangement so that it would move up and down as the operator turned a crank. With the crank in the resting position, the bottom bucket was at just the same level as the water in the reservoir.

When the operator turned the crank, the second post fell and the bottom bucket immediately began filling with water through a hose from the reservoir. By the time the post was at the lowest extent of its travel, the bucket was full. As the crank lifted the post to its highest level with bucket 2 at the same height, the water began to transfer from bucket 1 to bucket 2 until the levels in each were the same. I asked why the water didn't simply go back the way it came into the reservoir and was told that each hose was fitted with a non-return valve which only let the water through in one direction.

With each movement of the post, a quarter of the water in each stationary bucket was moved into the one above. After three complete cycles of the crank, the bottom of the top bucket had just a little water in it. It will never catch on, I thought. Too much work for too little water! Now, if they made the lower buckets bigger than the higher ones...

The Circuit

The internal workings of the ioniser are shown in Fig. 2. It is based on a Cockcroft-Walton diode and capacitor ladder, which is similar in some ways to a string of buckets (capacitors) connected by hoses (wires) with non-return valves (rectifiers) in them. The action is not as inefficient as the water pump analogy might lead you to believe — each capacitor is 'floating' on the voltage of the one before, so a more accurate analogy would have a load of nested buckets, each floating on the water contained in the one below! The analogy gives a general idea of the circuit in operation, though — enough for you to work out the details for yourself if you're interested.

The circuit is quite tricky to analyse in any detail but one principle that does emerge, and is applied in the Variat-Ion, is that the circuit is at its most efficient when the capacitors lower down in the chain are as

PARTS LIST

RESISTORS (all ¼ W 5%)

Note: All resistors, with the exception of R1, R2 and R21, should have a proof voltage of at least 1kV and a working voltage of 500V or more.

R1	150k (not needed if complete panel lamp used)
R2	100k ¼W
R3-R20	10M (33M slightly better, if you can get them)
R21	10k
R22-26	2M7
RV1	47k 1in pot

CAPACITORS

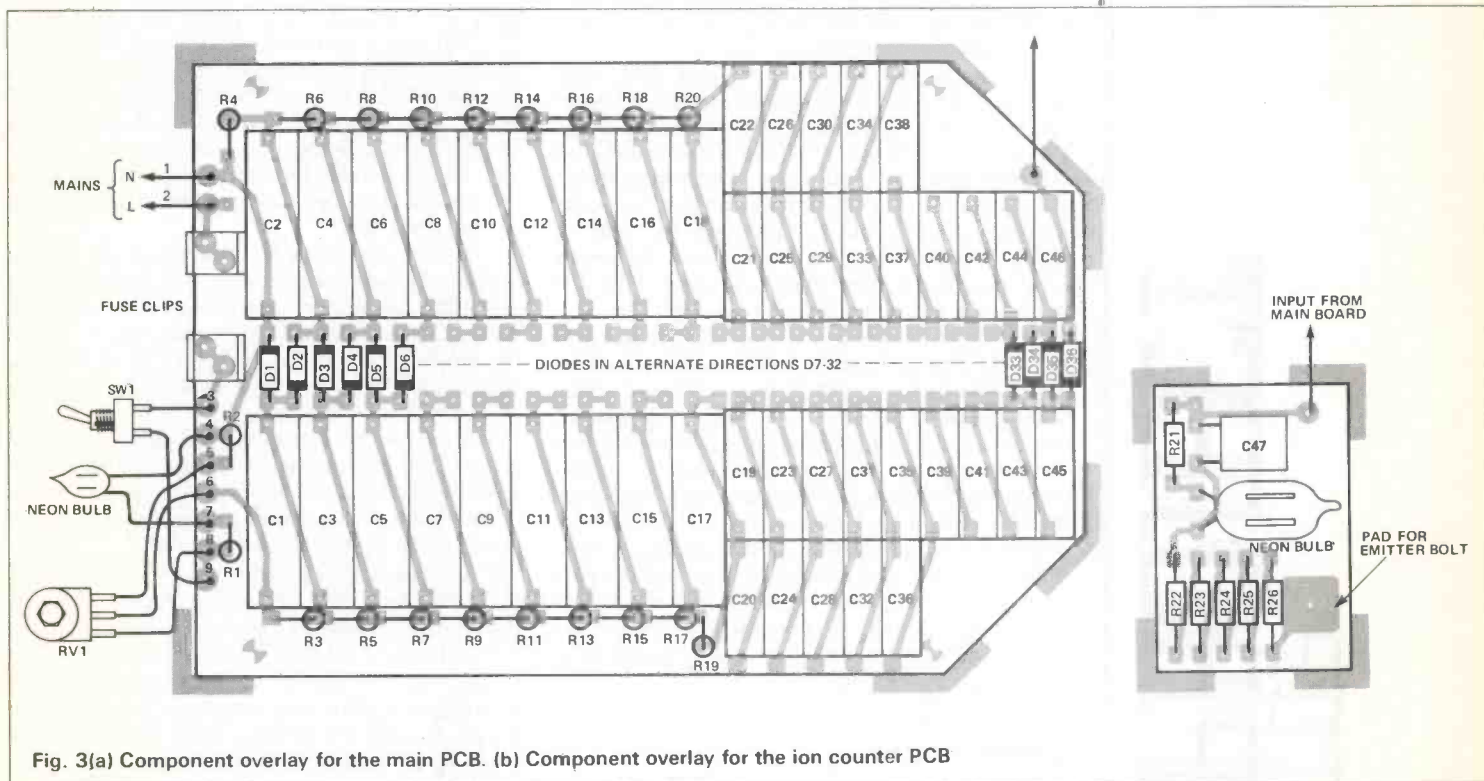
C1-C18	150n X2
C19-C46	33n X2
C47	47n 250V

SEMICONDUCTORS

D1-D36	1N4007
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MISCELLANEOUS

PCBs. Retex 'Elbox' 145 x 90 x 41mm case. Neon lamp. Plastic lens. Fuse and clips. Knob. Strain relief bush. Mains flex. Connecting wire. Emitter brush. Plastic offcut for rear panel. Nuts and bolts.





The original Direct-Ion ioniser (July 1986) on which the Variat-Ion is based

TOP PROJECT

large as possible. Increasing the value of the higher capacitors has diminishing effect, so the place to spend your available space and money is at the beginning of the chain where the effects are enormous! The first 18 capacitors in the chain are 15 times as large as those used in the earlier Direct-Ion, giving this ioniser plenty of spare power — enough to drive several multi-point emitters.

At the very top of the chain (the junction of D36 and C46) comes the ion counter. As the emitter ionises the air, the electrons attached to passing molecules are supplied by a current drawn through the resistor chain R22 to R26. The more ions created, the higher the current.

Most of the time the emitter current is supplied by C47, giving a steadily rising voltage across it. Sooner or later the voltage will rise high enough for the neon bulb to strike. The bulb draws current from C47 for a short time until the voltage across the capacitor will no longer sustain conduction. The neon, having discharged the capacitor by about 50V, goes out and will not conduct again until the voltage across C47 has once more risen to its striking voltage.

The value of C47 should be somewhere between 10n and 100n. If it's less than 10n, the flashing will barely be bright enough to see. If it's much above 100n, the time between flashes is too long — you have to sit by the ioniser for minutes at a time to judge the output. The value I've specified in the parts list is 47n, which will give about one flash every thirty seconds with an average emitter — a lot quicker with a good emitter and quicker still if you bring your hand or face within a foot or so of the tips to draw the ions away.

Assuming that each electron emerging from the emitter results in the creation of one ion, the number of ions generated between successive flashes of the counter is easily calculated. To bring a 47n cap from the neon's extinguishing voltage to its striking voltage — a difference of 50V — requires a total charge of 2.35×10^{-6} Coulomb (this is just calculated from $q = CV$). The number of electrons which will have a total charge of 1 Coulomb is 6.24×10^{18} , so multiplying this by 2.35×10^{-6} gives the total number of ions created: 1.47×10^{13} or roughly fifteen billion ions. If the counter flashes at its average rate of once every thirty seconds, the Variat-Ion is creating thirty billion ions every minute!

Let's suppose you have a larger than usual bedroom of 100m^3 . How long will it take the Variat-Ion to produce enough ions to establish an average ion density of 1000ions/cc? (This is the kind of level you might find on mountain tops or other areas of high ion density.) The volume of the room is 10^8cc , so for a density of 1000 ions/cc there must be a total of 10^{11} ions in the room. The time taken for this ioniser to produce this number of ions, at a rate of 3×10^{13} per minute, is just one fifth of a second!

Of course, this assumes the ions are going to diffuse to all parts of the room within a fifth of a second and unless there's a gale force wind blowing, they won't. Initially there will be a very high concentration of ions around the ioniser itself and the rate at which these spread out will depend on the convection currents and other air movements in the room. There will also be a steady loss of ions as they hit particles in the air, walls, positive ions and so on. But at a rate of five times the total number of ions needed being produced every second, I'm sure I don't need to do any more arithmetic to convince you that the ion density will built up quickly and will be sustained at a very high level indeed.

Construction

The component layout for the main PCB is shown in

Fig. 3a. Put in the rectifiers first or you'll find yourself trying to poke them between two tall rows of capacitors, which ain't easy. The rectifiers at the narrow end of the PCB are fairly close together — whether they will all lie flat against the board or not depends on the manufacturer of the particular rectifiers you buy. The diameter of 1N4006/7s varies from one make to another. The best way to proceed to to put in every second diode (which will all point in the same direction so it's easy to check for one pointing the wrong way) and then fill in the gaps with the rectifiers pointing in the opposite direction, letting them sit a little above the PCB if necessary.

When you come to solder the diodes (and all the other components for that matter) it's a good idea to cut the leads to size first and solder afterwards. The bugbear of any EHT circuit is power loss through corona discharge from sharp points or edges which encourage discharge. If your soldering iron is too hot, you can also get spikes of solder when you remove the iron from the joint. Soldering along a row of leads one after another should keep the iron cool enough.

After the rectifiers, put in the capacitors. With encapsulated types it usually happens that the leads are not exactly central when they emerge from the case. The PCB allows for a slim gap between adjacent capacitors, but if one seems to be a tight fit, turning it around should cure the problem. Finally, solder in the resistors and a few inches of insulated wire to join the 'hot' end of the board to the emitter board.

At this stage, clean the board thoroughly with isopropyl alcohol or a proprietary board cleaner of some kind, then spray on a few coats of anti-corona compound. This isn't absolutely essential but if you want to prevent unnecessary losses in the circuit it's a good idea. Spray both sides of the PCB and give it at least fifteen minutes to dry between coats. It will try your patience but it's well worth the bother.

While you're waiting for the anti-corona spray to dry, you can assemble the emitter and ion counter board (Fig. 3b). Leave a little slack in the neon bulb leads to allow it to be positioned under the lens later on. Once again, cut the component leads before soldering. After soldering the components, push a 20mm M3 bolt through the hole in the large, square pad, with the head on the copper side of the board (Fig. 4a), put on a nut to hold it in place, then solder the bolt head to the PCB pad. Solder the wire from the main PCB to the small PCB, then clean the small board and give it a few layers of anti-corona compound too. Before you spray, put two or three nuts onto the end of the bolt (which will later act as a support and contact for the emitter) to keep it clear of the compound.

While both boards are drying, you can drill out the case. The emitter will need a 1/8in hole in the top of the box, half way between the two sides and about 1in (not critical) from the end. Half an inch away from the emitter, towards the left-hand side of the case (looking at it from the front panel end) comes the neon lens hole (Fig. 4b).

If you can't get hold of a separate lens or a suitable piece of translucent plastic, you can saw the end off a panel neon lamp and use that. It's a shame to waste a lamp but you can at least salvage the bulb (and if you're really miserly, the resistor too!).

The box specified for the project has aluminium front and rear panels and a steel chassis. The only metal part allowable on the ioniser is the front panel — the chassis and the rear panel will have to go. The chassis is not needed at all, but the rear panel will have to be replaced with a plastic one. You can cut one from the plastic case of a retired project, using the metal panel as a template or you may use some other suitable material.

The front panel has to be drilled for the mains lead (which must be fitted with a strain relief bush), the neon lamp and the pot RV1. If you use a separate resistor R1, neon bulb and lens (wired as in Fig. 3a), the 'mains on' indicator can go in any convenient position. If you use a panel neon assembly (wired as in Fig. 4c — note that R1 is no longer required) the hole must be mid-way across the panel and fairly high up so that the neon body is well clear of the components on the PCB. The pot and mains inlet positions you can arrange according to taste but wiring is a darn sight easier if you put the inlet to the left and the pot to the right. It also helps if you bolt the pot to the panel with its tags facing upwards.

Now that the boards are dry you can solder the fuse holder clips to the PCB (if you'd soldered them earlier they'd be covered in goo by now!) Also solder three 3in lengths of insulated wire for the pot connections and a similar length for the neon lamp connection. Push the mains wire through the strain relief bush, then push the bush through the panel hole, squeezing the bush with pliers to clamp the wire firmly. There should be about 4in of mains lead on the inward side of the panel. Strip off all but 1/4in of the outer insulation and cut the live and neutral wires back to about 1 1/2in length. Strip the ends and solder them to the PCB.

By this time you will feel more like a snake handler than an electronics enthusiast, with several feet of mains wire connected to the large PCB connected to the small PCB and a metal panel dangling somewhere along the way. To tidy everything up, screw the main PCB into the case (using four no.4 6.4mm self tapping screws), slot the front panel into the lower section of the case and tape the small PCB temporarily to the main PCB to prevent the link wire from flexing and maybe breaking.

Now the front panel has to be earthed. In the prototype I used a neon lamp with a metal body which fixed to the front panel with a nut and shakeproof washer. A OBA solder tag fitted neatly over the body and was held between the washer and the panel. The earth wire was soldered to the tag.

Now solder the neon lamp wires and the pot wires (makes it much easier with the terminals facing upwards, doesn't it?) and check out your wiring carefully with Fig. 4c. There is provision on the PCB for an on/off switch if you want to fit one. I didn't — the ioniser is left on day and night and I've never wanted to turn it off! There is also provision for fitting a separate neon bulb and resistor if you prefer this to using a complete lamp assembly. Connections are shown in Fig. 3a.

Remove the tape holding the small PCB to the large one. Twist another nut onto the emitter bolt and rest a shakeproof washer on top of it. Push the end of the bolt through the hole in the case lid and adjust the position of the nut so that when it is pushed against the lid the PCB will be level with the neon bulb just underneath the lens. Above the case top, drop another washer onto the bolt, put on another nut and, holding the PCB so that it doesn't twist around, tighten up the nut to hold the PCB firmly in place (Fig. 4d). Just to make sure the nuts don't work loose, you can apply a little Loctite or Superglue or some similar preparation.

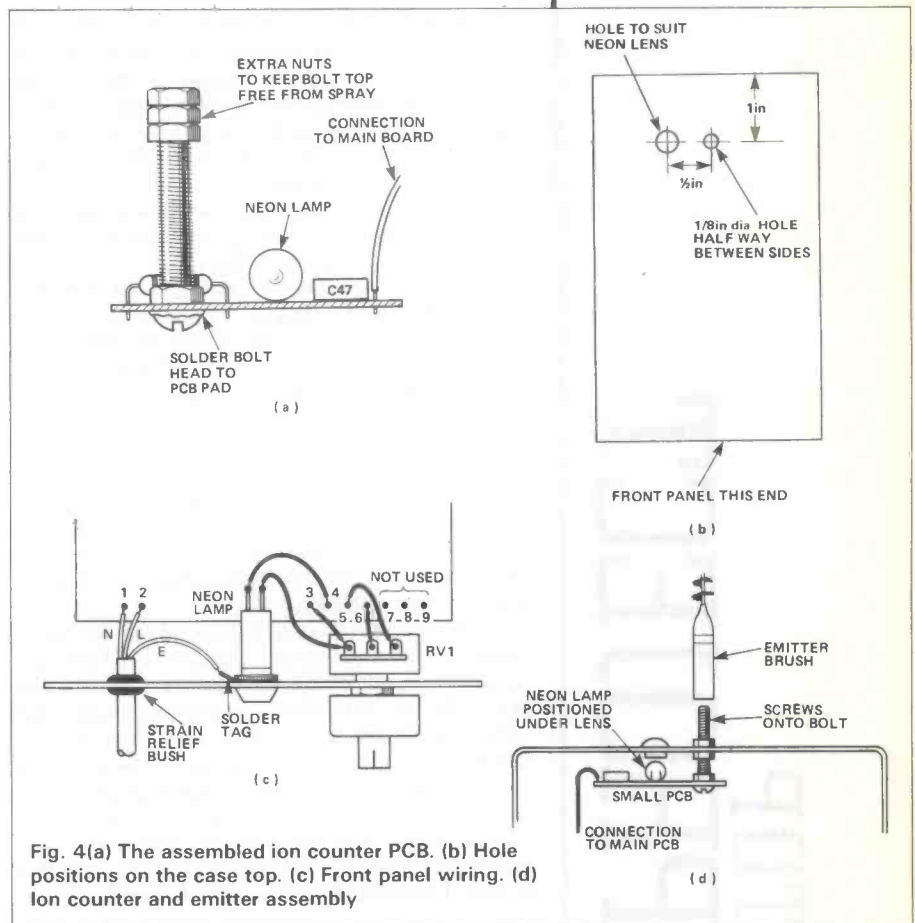
Push the back panel into the bottom case section and bring the two halves of the case together. Put in the case screws, tighten them up, push on the plastic feet and you're done. Apart from the emitter, that's it.

is better, and a brush with 'V' shaped wire soldered to the top is best of all (Fig. 6a). The wire is sharpened by cutting it with a pair of flush-cutting wire cutters used 'upside down' — that is, with the flat side of the cutters pointing away from the brush and the bevelled side towards it. The brush simply screws onto the emitter bolt — the chances are that the thread won't quite match (I took my brush along to the local hardware shop and they couldn't find any thread to match it!) but it should screw down far enough to be held firmly. As a last resort you could solder an M3 nut to the bottom of the brush, but it shouldn't be necessary.

If you fancy experimenting with different emitters (and since the effectiveness of the ioniser depends very much on the quality of the emitter it's certainly worth doing) there are all kinds of things you can try. A very effective emitter, although it doesn't look very pretty, is a length of stranded connecting wire with about 1/2in of insulation removed and the strands separated out so that they point upwards, sideways, all directions. If you remove 2in or so of insulation, you'll find the strands will be attracted to your finger. With 6in of bared wire, you've got an electric forest that will wave about if you pass your hand above it!

I have been told that carbon fibres make a very effective emitter. Rumour has it that it's possible to buy reels of the stuff in a kind of carbon rope from which the individual strands can be separated out. So far I've been unable to track down a source so I can't give a first hand report. If you find any — try it!

Sewing needles can make fairly good emitters, especially if you use several of them. Outside the case they would be a menace — imagine having a restless night and impaling your hand on one — but inside the case they'd be fine. The way to arrange it is to get hold of an offcut of copper clad board, solder the needles along one edge (stainless steel doesn't solder too well, so you may need to fix the needles in place



Emitters

The emitter used on the prototype was an airgun cleaning brush. It works well, but a rifle cleaning brush

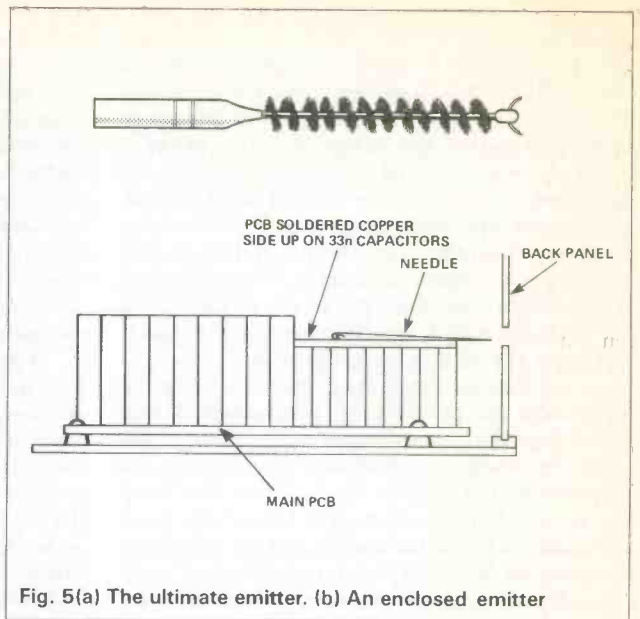
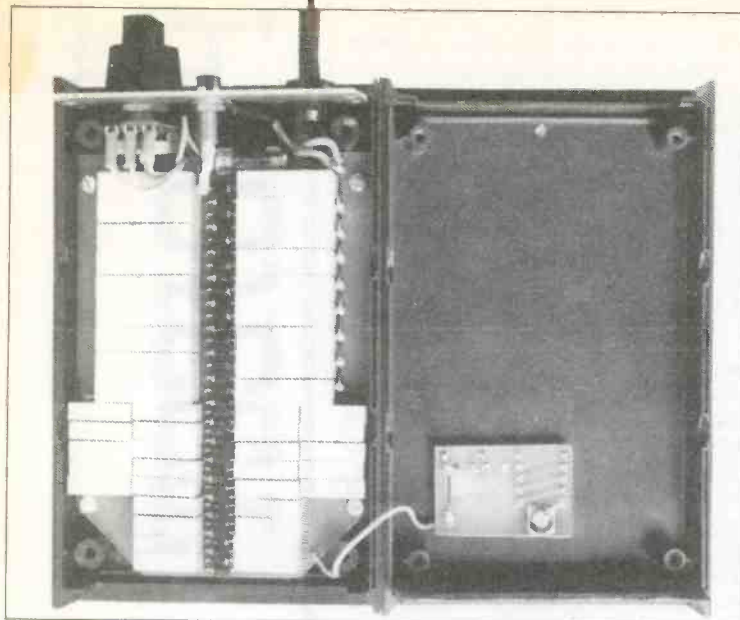


Fig. 5(a) The ultimate emitter. (b) An enclosed emitter

some other way) then glue the board copper side up onto the 33n caps at the end of the main PCB. Drill a 3/16in hole for each needle in the plastic end panel of the case and you have a completely enclosed ioniser (the needle tips should be about 1/4in behind the holes). This won't give you a better ioniser but if it is to be used by children it may be preferable to having an exposed emitter. (Fig. 5b).

The general rule is that anything with sharp points or edges will make a good emitter. Come to think of it, a razor blade would probably work well, although comments about pins outside the case should be multiplied by a factor of 99 billion where razor blades are concerned. Inside the case — why not?

Certain types of houseplant make excellent ion emitters. I remember hearing once that somebody was actually making plant pots with an ioniser built into the base, although I've never actually seen one. Have to be a bit careful watering the plants with a 5kV ion generator in the vicinity, I should think. If you want to try it out, choose a plant with sharp, pointy leaves, stand it on a polythene bag, run a wire from the ioniser's output bolt to the soil in the plant pot and you've got your very own truffid.

If you put your hand close to one of the leaves, it will be drawn towards you. Let the leaf touch you and it will spring back again. A very shy truffid. The reason is, of course, that the leaf discharges as soon as it touches your hand. Plants don't seem to mind being ionisers and some say they grow better when treated in this way.

The Variat-Ion is quite powerful enough to run several emitters — you can spread empty plastic boxes with gun brushes attached all round the room and run them all from the one ioniser. The best scheme is to give each brush a separate series resistor so that it can select its own operating voltage.

The ionisation potential control can be left at maximum for most types of emitter. The time you need a lower potential is if the emitter has very fine points, like the carbon fibres, needles or (possibly) the razor blade! If you use too high a potential, all that happens is that the current density in the point will melt it, round it off and make the ion emission less efficient. The best thing is to bring the control up from minimum until you feel a distinct breeze from the points and leave it on the setting where that first occurs. If you can afford to waste a few emitters, you can try setting the control higher, then check an hour

later to make sure that the ionisation rate is just as strong. If the ion counter is flashing less frequently, you've got the control set too high, so start again. Keep the windows open while you're doing this to keep the ion density in the room fairly low, since the rate of emission will drop off in any case as the room becomes saturated with delicious neg-ions.

Safety

The Variat-Ion works by raising a piece of metal to several thousand volts above its surroundings. In the version with the external emitter it is possible to touch both the high voltage part and an earthed object (such as the front panel of the ioniser itself) simultaneously. For any healthy adult this experience is not in the least dangerous, or even shocking, if you'll excuse the pun, since the current available is very small. The circumstances where I would advise caution are either if you have any reason to suppose your heart is dodgy, if you (or anyone else who may come into contact with the ioniser) have a pacemaker or if young children are likely to have access to it. In any of these cases, the safest thing would be to make the fully enclosed version where the ionising points cannot be touched.

The current available from the ioniser will depend to some extent on the quality of the mains earth in your house. In mine, I measured 75 μ A on the prototype. The maximum current from the ionising tip to mains neutral (which is the maximum current available no matter how good your earth) was 110 μ A. The current needed to have any effect on a healthy adult is well over 100 times as great so there's a good safety margin.

The main problem with young children is not that the current itself may harm them but that the surprise of a sudden tingle (which they will feel more keenly through sensitive skin than you will through your tough fingertips) might cause them to drop the ioniser or knock it onto the floor, with who knows what results? If in doubt, enclose the points, OK?

If you have to dismantle the ioniser for testing or any other reason after it has been turned on, be sure to discharge it thoroughly by touching the neutral prong of the mains plug to the emitter. There are resistors to bleed away the charge on the larger caps but with any EHT circuit you can't be too careful.

Living With Ions

When you try out the ioniser the first thing you might notice in a quiet room is a gentle hiss from the emitter.

If you don't — put it a bit closer to your ear! The gentle breath you feel on your hands or face a few inches from the emitter is the ion breeze I spoke of earlier.

It's quite understandable if you feel a little wary of the ioniser at first. The best thing is to approach it boldly. Touch the emitter with the back of your hand. You'll hear a little squeak as you make contact but you shouldn't feel anything at all. The only way you can get a tingle from the ioniser is to touch some earthed surface (like the front panel of the ioniser itself) and to hold a finger about 1/8in from a flat part of the emitter — the shaft of the gun brush. Alternatively, you can touch the emitter and hold a finger close to the front panel. The sensation comes about because conduction in your finger takes place in a series of quick pulses as your body charges and discharges. Touch the emitter and earth without leaving a gap and you'll feel nothing again. So now you know, and there'll be no surprises!

The Variat-Ion is designed to run continuously, day and night. If you don't want the bother of moving it around the house, the best place for it is by your bedside where you will have the benefit of ionised air for eight hours or so at a time. Because its strong action in precipitating dirt and dust from the air, it's a good idea to stand the ioniser on a washable surface a few feet away from the nearest wall. The dust will then fall in the carpet and be swept up during normal household cleaning. Too close to a wall and it may taint the paint or wallpaper, which will not be too popular with the Mizz.

The lightest and most active ions are found close to the emitter, so the nearer the ioniser is to your bed, the better. This is particularly important when it is being used to treat respiratory complaints, which seem

to need the small, highly mobile ions. If you're just looking for a general improvement in mood and brain function, put it anywhere in the room.

Some people like to hold the ioniser quite close to their face and breathe deeply for minutes at a time. This, they say, makes them feel fresh and alert. Others just like to know there's an ioniser around the place and may not touch it for weeks at a stretch. Some move it from room to room during the day, and even take it to work with them. Others prefer to let the ions build up in one single room. Some say their ioniser has changed their life. Others say they can't be sure but look uncomfortable if you suggest turning it off!

There are as many ways to live with an ioniser as there are individuals, but one thing's for sure: anybody who's ever owned an ioniser would never again want to be without one.



BUYLINES

The Retex case for the project is available from West Hyde Developments (standard version) or Specialist Semiconductors (with plastic rear panel). Suitable resistors can be obtained from a number of suppliers but the rule is to check before ordering since most 1/4W types are only rated for 300V. Half watt resistors are a better bet. Gun cleaning brushes can be obtained from any huntin', shootin' and fishin' shop (look under 'Arms and Ammunition' in Yellow Pages). Class X capacitors will be available from any large component catalogue, as will board cleaning preparations and anti-corona compound.

A complete parts set for the project can be obtained for £29.32, inclusive of postage and VAT from Specialist Semiconductors, Founders House, Redbrook, Monmouth, Gwent NP5 4LU. Components are available individually from the same source.

Points Controller

Some model railway points are purely mechanical but electric points are now a standard accessory. These are mostly very basic and are really just a manual point with the addition of a couple of solenoid mechanisms giving the option of manual operation or electric remote control using a form of changeover switch plus a 12V DC supply.

The points have three terminals, one of which is a common terminal wired to one supply rail. The other terminals are wired to the other supply rail via the changeover switch which selects the desired solenoid. By alternating this switch the points can be repeatedly set and reset.

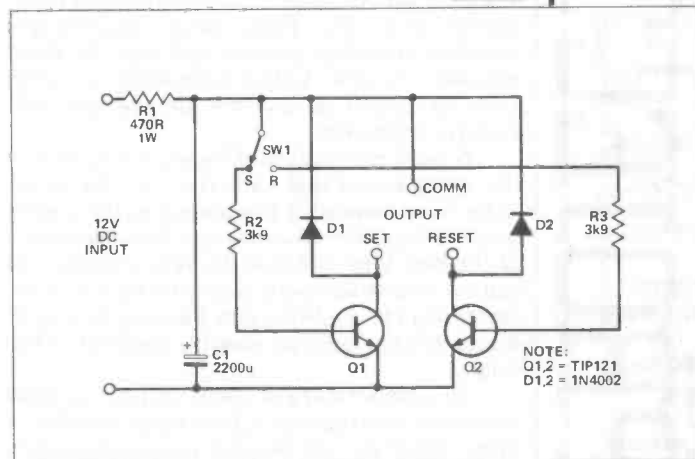
The changeover switch is slightly non-standard in that it is spring-loaded to a central off position, so that ordinarily it does not supply power to either solenoid. This is an important point, as the solenoid currents are quite high. Applying power for more than a second or two risks burning the solenoid out. These points are not always totally reliable in operation and the addition of a simple capacitive discharge circuit improves this and totally removes the risk of applying excessive power to the solenoids in an attempt to force operation.

In this points controller circuit the input supply is fed to a high value capacitor C1 by way of current limiting resistor R1. R1 keeps the current at no more than about 25mA, which should be well short of the current needed to cause over-heating. It is also well short of the current need to drive the point from one setting to the other! This does not matter though, because C1 will charge to virtually the full input supply voltage, and can supply a large enough burst of current to reliably operate the points. The extremely

low source impedance of a capacitor means that the large pulse of current normally removes any tendency for the points to stick.

The solenoids can simply be driven from across C1 by way of the changeover switch. However, things can be refined a bit further, as in this circuit. The switch selects one of two Darlington power devices (Q1 or Q2) which control the solenoids. R2 and R3 limit the base currents and result in the switch only handling very small currents. This eliminates any problems with contact sparking reducing the operating life of the switch. A miniature toggle type which is spring-loaded to a central off position is perfectly suitable for SW1.

D1 and D2 protect Q1 and Q2 against any high reverse voltage spikes generated across the solenoids as they are switched off. Q1 and Q2 do not require heatsinks. Also note that it takes a second or so for C1 to recharge after the unit has been used and that the controller cannot function until C1 has almost fully recharged.



BAR CODE LOCK

Paul Wilson looks
high and low for
the bar



How would you like to impress your friends and confuse your burglars by unlocking your front door with a can of beans? Or a bottle of shampoo? Or a shrinkwrapped piece of Lymeswold blue? Or more sensibly with a small coded plastic key that you wipe over an innocent-looking sensor beside the door.

The ETI bar code switch is programmable to recognise a 14-bar key which is read by a reflective optical sensor. Verification of the code produces a short 'code accepted' pulse which can be used to open an electrically operated bolt or to trigger a relay for any purpose you may desire.

Attempts to operate the switch using the wrong key (or the wrong brand of beans) will sound an on-board alarm for a preset period — or until the correct key is used.

The barcode switch consists of two boards. The main decoder board contains the mains transformer and 12V PSU, code programming switches, decoding circuitry and also the piezo sounder. A 12V CMOS-compatible or open collector output is available to interface with external equipment.

A small pre-amp board fits in a small box with the optical sensor that scans the key. This sensor is the most important component in the system because its resolution determines the convenience of the key. If for instance the sensor could only resolve bars which were 5mm wide then a 14-bar key would end up being over 5in long. A key this long would not look very elegant attached to a key ring!

To produce a key of credit card size we need to resolve a narrow bar of 1mm and a thick bar of 2mm. There are two possible sensors depending on how rich you are.

If money is no object then the Hewlett Packard HBSC1100 reflective sensor with its resolution down to 0.19mm and its £27.00 + VAT price tag may be used. This device is designed to be used in bar code wands such as those used in many shops.

If this is too expensive then an RS sensor (see *Buylines*) may be used with the simple modification of partially covering its two sensing windows with a light proof material. Although the Hewlett Packard sensor wins hands down for performance and resolution, the RS price of about four quid is likely to persuade most constructors, myself included.

The key itself is a bar code such as that in Fig. 1 printed on paper and encapsulated in a plastic enclosure called a Pronta-pouch (honest!). This forms a flexible, waterproof and cheap key, somewhat like a credit card.

A program in BBC Basic is provided to



The correct wiping action to operate the lock.

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PROJECT

produce the bar code on an Epson or compatible printer. The program should be easy to alter for other home micros.

As can be seen from Fig. 1 the code begins with a 3mm black border. No white can show before this. Following this is the 1mm black reference bar (this must always be a thin bar as the decoder uses it as a reference to determine the length of the bars of the actual code).

Then comes the actual bar code which is a simple binary code of up to 14 bars, in any combination of thin 1mm and thick 2mm black bars — a possible 16384 combinations.

Eight bars are used for the code in the key shown, giving the binary code 01101100 where 0 = thin and 1 = thick. A 3mm black border at the finish ends the code. All the white inter-bar spaces are 1mm wide.

Note that the key shown in Fig. 1 is symmetrical so it does not matter which way it is wiped across the sensor (this should help when getting used to using the switch).

The operation of the bar code switch can best be understood by looking at the block diagram in Fig. 2. The optical sensor consists of a LED which emits light onto the surface being scanned. Light will be reflected back to its receiver from white spaces. The output from this is amplified and filtered before being compared with a reference voltage (by the *bar comparator*) to determine whether a bar or space is present. Its output will be low (0) for a space and high (1) for a bar.

The *bar counter* is incremented by this comparator as the leading edge of each bar passes over the sensor so that each of the counter's outputs 1 to 14 become active when the corresponding bar in the code is over the sensor.

Two integrators are used to measure the time taken for the bars to pass over the sensor (see Fig. 3). As the thin reference bar is over the sensor, the reference integrator ramps negative (from its normally positive condition), ideally reaching about half the supply voltage and remaining there for the rest of the sweep.

The timing integrator is reset during each white space of the code. Its time constant is $\frac{2}{3}$ that of the reference integrator so that its output goes

(ideally) to 8V during a thin bar, and 4V during a thick bar. This is compared to the (ideal) 6V of the reference by the bar length comparator producing a zero output for a thin bar and a one for a thick bar.

There is a fair tolerance regarding the speed the key can be swept across the sensor. So long as the speed is constant the timing integrator should still cross the voltage set by the reference integrator at the correct points — the only difference being the voltage at which this reference voltage is set.

More important is the effect of changes in speed as the key is swept. An increasing speed could prevent thick bars reaching the reference voltage and a decreasing speed could push ramps from thin lines over the reference threshold, either effect giving a false decoding.

This circuit allows for an increase or decrease of almost 25%, which should cause few problems,

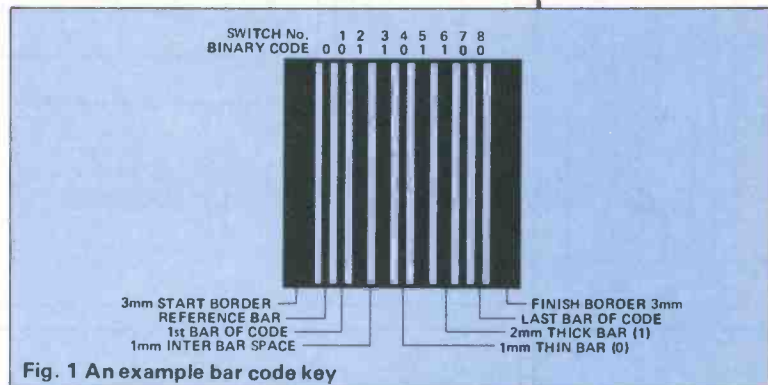


Fig. 1 An example bar code key

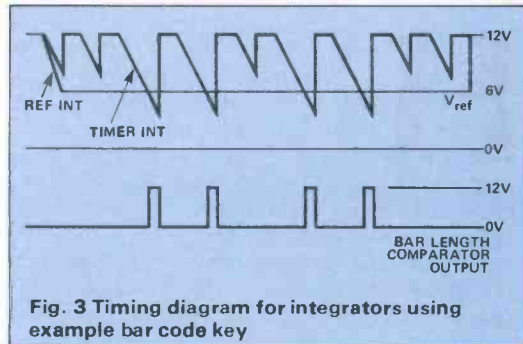


Fig. 3 Timing diagram for integrators using example bar code key

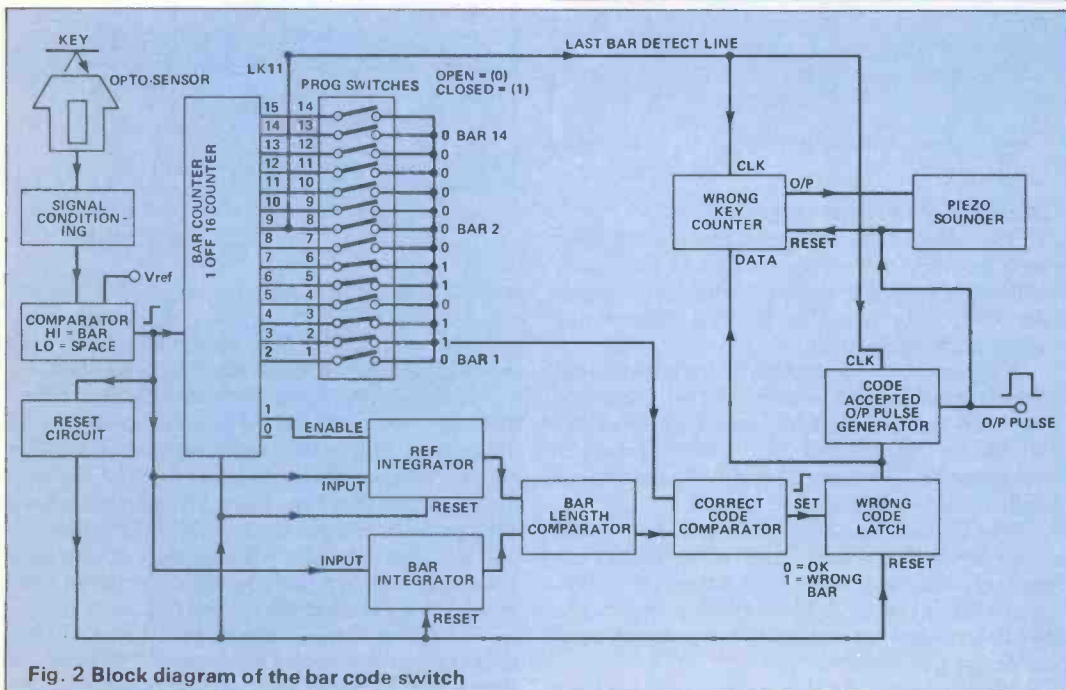


Fig. 2 Block diagram of the bar code switch

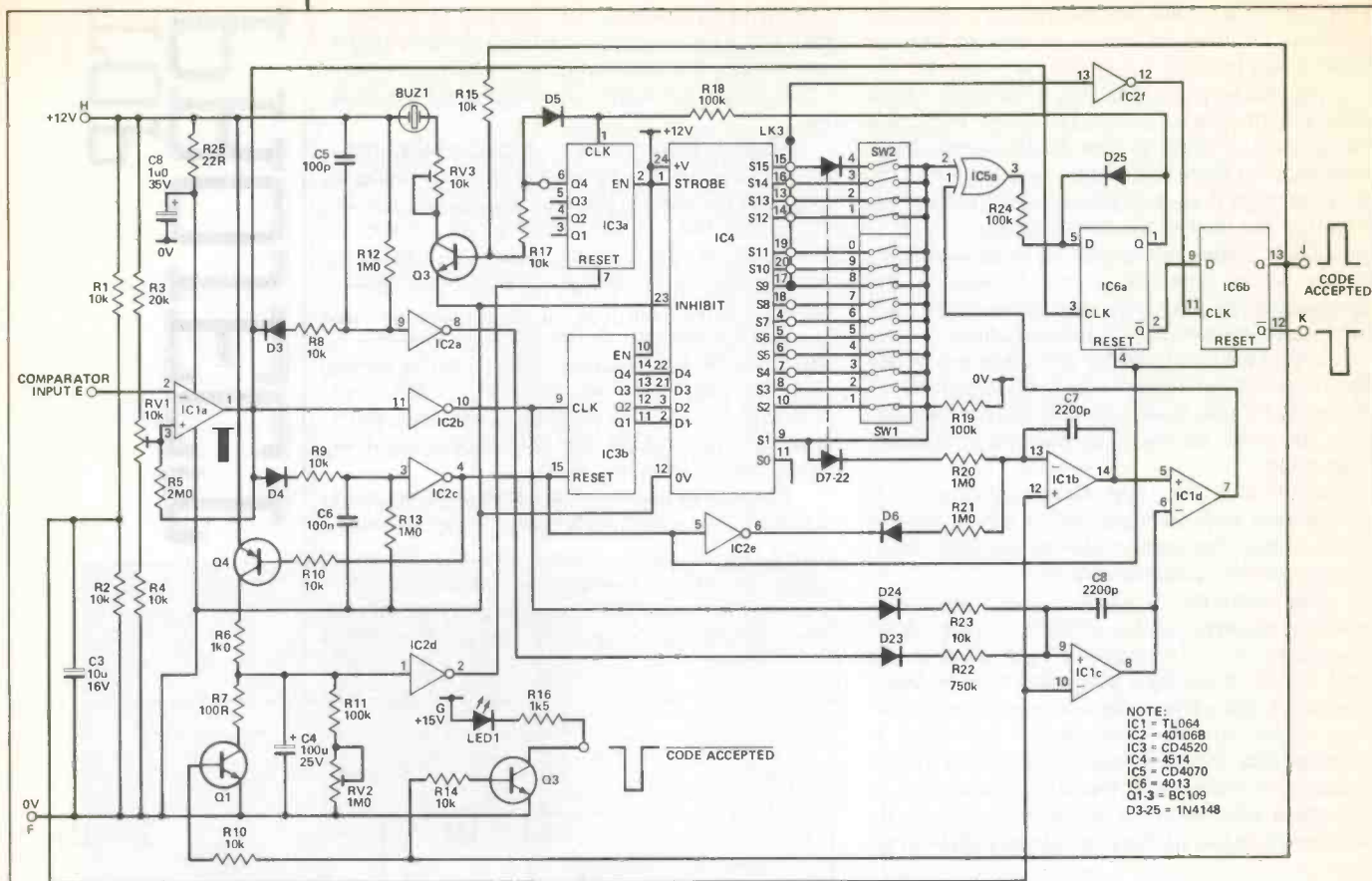


Fig. 4 (a) Main circuit diagram for the bar code switch

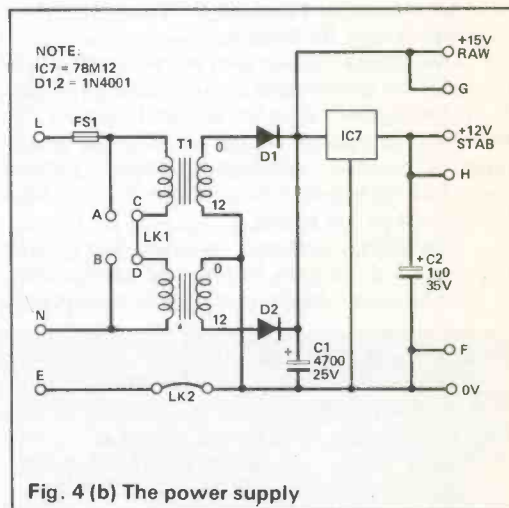
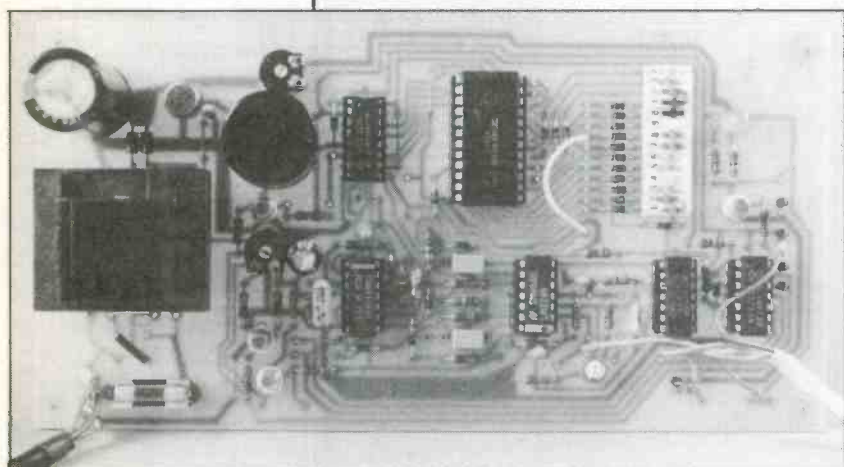


Fig. 4 (b) The power supply

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particularly after a little practice.

The output of the bar length comparator (0 for thin, 1 for thick) is then compared with the output for the code programming switch for that bar (also 0 for thin, 1 for thick) by XORing them in the correct code comparator.

If they match, the output will be low. If they are different it will be high and this will set the wrong code latch high (where it will remain for the rest of the sweep regardless of later successful comparisons). The state of this latch determines whether the key is accepted or not.

The last bar detect line is connected to the last output of the bar counter that is needed for the length of code used. In the case of the code in Figs. 1 and 3 this is output 8. On the falling edge of this line (after the last bar on the key has been scanned) two things can happen.

If the wrong code latch has not been set high,

the pulse generator will produce a short 100ms pulse which will in turn reset the wrong code counter and beep the piezo sounder. This indicates that the correct key has been used.

If the wrong code latch has been set high then the code accepted pulse will be inhibited and the wrong code counter will be incremented. If this counter reaches an internally set number, say five, then it means that five consecutive attempts have been made to operate the switch with a wrong key and the piezo sounder will run continuously for a preset period to warn of the fact. If the correct key is used the sounder will be deactivated.

The reset circuit resets the system 100ms after the last bar passes the sensor. The bar code switch is then ready to decode another key.

HOW IT WORKS

The circuit diagram is shown in Fig. 4. The output of mains transformer T1 is rectified by D1 and D2 (Fig. 4b), then filtered by the reservoir capacitor C1 to provide +16V raw DC. Series regulator IC7 is used to provide the +12V regulated supply for the circuit.

R100 (Fig. 4c) provides about 35mA of current from the raw supply to illuminate the LED emitter in SENS1, keeping the dissipation in IC7 down. The varying current in the receiver phototransistor is converted into a voltage by IC100 and rises as more light is reflected. The sensitivity of this stage is adjusted by RV100. The output of IC100a is AC coupled in a $\times 47$ inverting gain stage consisting of IC100b, R105 and R106.

The output from the preamp goes into the inverting input of IC1 (Fig. 4a). Its output is high for a space and low for a bar — IC2b inverts this and the low to high transitions clock IC3b, a 4-bit binary counter.

The counter drives IC4 to form a 1 to 6 sequential enabler. The active high output is incremented as the start of each bar passes over the sensor.

As soon as the leading edge of the first bar passes the sensor output SW1 becomes active. This is fed into the integrator formed by components D7, R20, C7 and IC1b. The output of IC1b will ramp negative until the leading edge of the next bar passes the sensor, ideally reaching 6V — this is the reference integrator's output (see main text). As each of the remaining 14 bars passes over the sensor they are timed by the timer integrator (D23, R23, C8 and IC1c).

IC2b provides a high level on the timer integrator's input for as long as the bar is over the sensor. A slightly stretched version of this is produced by D3, R8, C5, R12 and IC2a, and is used to reset the timer integrator during each space on the key.

The outputs of the integrators are compared by IC1d, producing a high for a thin bar (the timer integrator doesn't have time to ramp down as far as the reference) or a low for a thick bar (the timer ramps below the reference).

As the key is passed over the sensor each one of the bank of switches is selected sequentially by IC4's outputs S2 to S15.

These switches have been programmed for the correct key — a closed switch requires a thick bar, an open switch for a thin bar. The state of each switch is compared with the relevant bar by IC5a, producing a low if they match.

As long as all the bars match the switches then IC5a's output to the D input of flip-flop IC6a will remain low.

IC1a clocks the data through to the flip flop output and if all the codes match then the \bar{Q} output of IC6a will remain high. The negative going edge of the last counter output clocks the data at \bar{Q} to the D input of IC6B. If the correct key was used, the output Q of IC6b will be high and will turn on transistors Q1, Q2 and Q3. Q2 turns the sounder on and Q3 illuminates LED1.

The output of IC6b remains high until reset by IC2c going high when C6 is discharged by R13 (100ms). C6 gets charged by D4 and R9 during white spaces.

If at any bar the key failed to match the set switches, the Q output of IC6a will be high and is latched high by D25. R24 prevents this state being altered by any subsequent matches. So at the end of the sweep, the Q of IC6b is low and no code accept pulse is generated.

In addition, as IC6a goes high, the positive edge clocks binary counter IC3a to count the number of times the wrong key has been used.

After either five or nine attempts (link selectable) the piezo sounder is switched on as a warning, cleared either by using the correct key or automatically after a time set by C4, R11, RV2 and IC2d.

Construction

The sensor may be mounted in any suitable box, or even behind a window. The box should be at least 3in long to allow the key to be wiped smoothly across the sensor window.

The prototype used a standard 29mm deep surface mounting box and a standard blanking plate to match the mains and lighting boxes in my home.

A hole is required in the blanking plate for the opto sensor, about 10mm by 15mm as shown in Fig. 5a. On the prototype the sensor was mounted behind this using a bracket of aluminium (or tin plate) cut to the dimensions shown in Fig. 5b and folded to a 90° angle along line XY.

The unit was put together as shown in Fig. 6. Note how the bracket should overhang one of the 15mm edges by about 1mm.

The red filter for the front of the blanking plate should be about 85mm \times 35mm, fixed into place with Bostic, Evostick or some other suitable brand name. When you've done that, you'll realise that you've just covered the mounting screws with the filter and you can't screw it to the wall. You'll need

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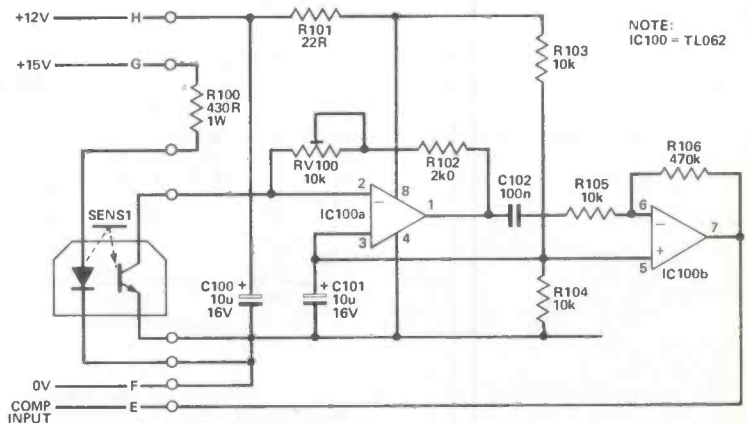


Fig. 4 (c) The sensor pre-amp

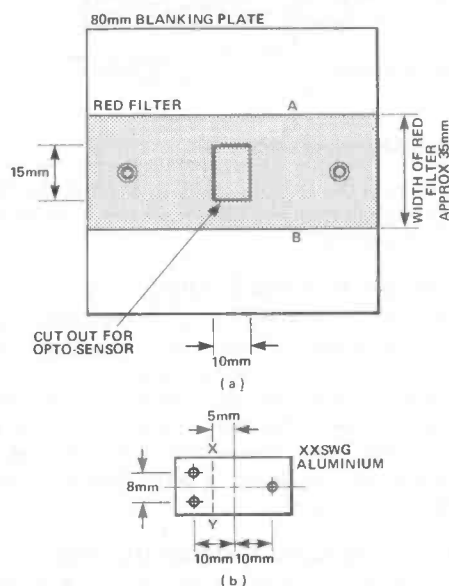


Fig. 5(a) Marking out details for blanking plate.
(b) Dimensions of sensor mounting bracket

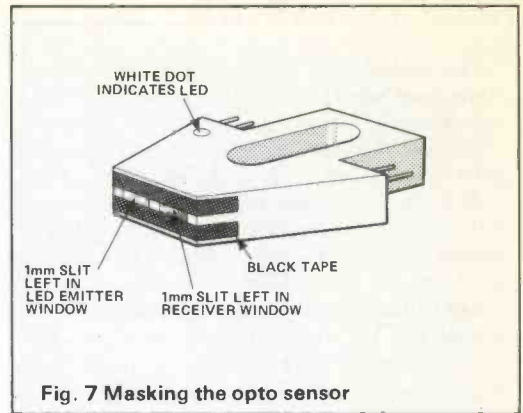
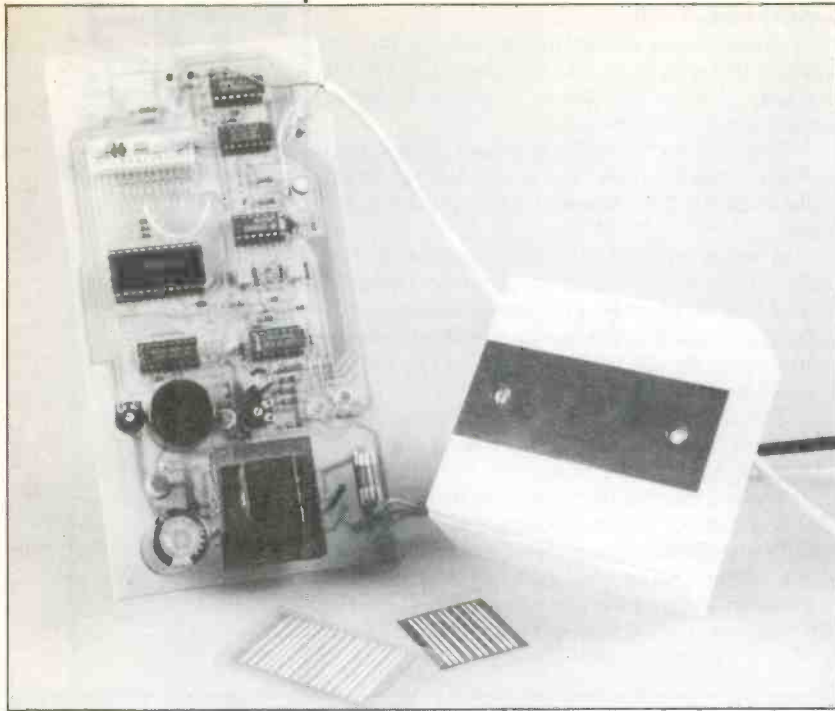


Fig. 7 Masking the opto sensor

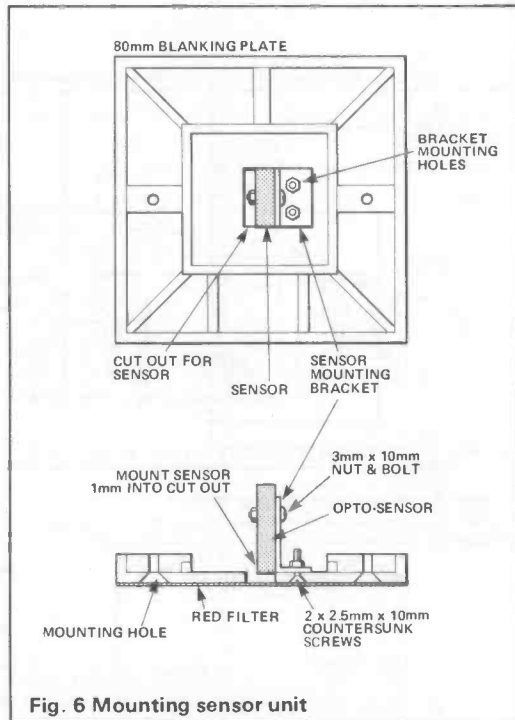


Fig. 6 Mounting sensor unit

to drill from the back of the box through the filter using a small drill bit, then from the front with a larger (5mm) bit.

Increasing Resolution

Figure 7 shows how the two windows of the sensor should be blanked off with tape leaving only a 1mm slit — necessary if the sensor is to resolve a 1mm bar code. Crepe tape (as used in PCB design) is better than insulating tape which may 'creep' if it gets warm. Take some time over this, as an accurate slit can avoid a good deal of fiddling compensation later.

Circuit Board Construction

The component overlay for the small preamp board is shown in Fig. 8.

Construction is very straightforward, beginning with the resistors and working through to the cermet trimmer RV100 and IC100. Check the

polarity of the IC and the tantalum capacitors. Any type of 4-core cable can be used to connect to pads E, F, G & H.

Mount the sensor and put the PCB in the box.

The main board Fig. 9 is slightly more complicated but should cause no problems.

Start by fitting the ten PCB links.

LK1 is as shown for 240V mains. If 110V is to be used, replace LK1 with two links — one across AD and one across BC. LK2 joins the secondary 0V to mains earth.

Next fit the diodes (noting their orientation), then resistors and IC sockets. Take care with the orientation of electrolytic capacitors — especially the tantalums which short circuit very quickly if reverse biased. If using the recommended DIL switches, these should be fitted with identification numbers facing the transformer.

When fitting the mains transformer ensure the primary is facing the fuseholder, its pins should then fit into one of the two holes provided on the PCB.

With all components connected, make a final check of polarity and any possible splashes or shorts, then set all the presets to the centre and set the programming switches as shown in Fig. 8. Fit a mains cable to the three pads provided and connect the cable from the sensor to pads E, F, G and H.

Setting Up And Test

Most of the testing can be done with a voltmeter, though a scope is pretty handy when setting up the optical sensor.

Once mains is connected to the main PCB you must be extremely careful to avoid any part of your anatomy coming into contact with live tracks — at best such contact will produce a string of four letter words, at worst a prolonged silence.

First (with CMOS devices removed) check the PSU functions. The raw voltage at the junction of D1 and D2 should be about 16V DC with about 0.5V of 100Hz ripple on it. The stabilised line on the output of IC7 should be at 12V DC (with about 10mV of wideband noise on it).

Check that these voltages appear at the correct points on the preamp board then switch off and let C1 discharge before inserting the CMOS devices. Switch on again and check that the 12V line is still OK.

Make sure that LK11 goes only to the pad next to D16, corresponding to the eight bars used in the test key (Fig. 1). Place the blanking plate loosely on top of the box and make sure that the sensor is pointing away from any sources of electric light.

If you have a scope look at the output of the preamp IC100b, with your timebase set to 10ms/div and sensitivity at 2V/div (AC coupled).

PARTS LIST

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RESISTORS (all resistors 1/4W 2% metal film except where stated)

R1,4,8,9,10,14,15,17,21,22,103,104,105	10k
R3	20k
R5	2MΩ
R6	1kΩ
R7	100R
R11,18,19,24	100k
R12,13,20,105	1MΩ
R16	1kΩ
R23	750k
R25,101	22R
R100	430R
R102	2kΩ
RV1,4	10k 1/4in cermet preset
RV2	1MΩ sub min preset
RV3	10k sub min preset

CAPACITORS

C1	4700μF 25V radial
C2,9	1μF 35V tantalum
C3,100,101	10μF 16V tantalum
C4	100μF 25V radial
C5	100pF 10V polystyrene
C6,102	100nF 250V polyester
C7,8	2200pF polyester 5%

SEMICONDUCTORS

IC1	TL064
IC2	40106B
IC3	4520B
IC4	4514B
IC5	4070B
IC6	4013B
IC7	78M12
IC100	TL062
Q1,2,3	BC109
Q4	BCY70
D1,2	1N4001
D3-25	1N914, 1N4148 etc.
LED1	Red LED

MISCELLANEOUS

BUZZ1	piezo sounder (see Buylines)
FS1	100mA 20mm
T1	15-0 15-0 1VA per winding
SENS1	opto sensor OPB7030
SW1	10-way DIL
SW2	4-way DIL

IC sockets. 20mm fuseholder. Red filter. Sensor housing (80mm box and blanking plate, 22 SWG aluminium for bracket). Nuts and bolts.

When you've made a test key to the design in Fig. 1 (you could wipe your copy of ETI across the sensor but it's hardly elegant) hold it as shown in the photograph with the key on the red filter. Only the 3mm thick boarder should be actually on the box, the rest should hang over the edge. Wipe the key smoothly across the filter lengthways.

The easiest way to get the correct speed is to count like you do between lightning and thunder '1 and 2 and 3 and' sweeping from left to right on the numbers and returning the key to its start position on each 'and'.

The preamp output should resemble a burst of sine waves (with quite some distortion) each

time the key is wiped. If this doesn't happen, adjust the height of the sensor until it does. If instead of sine waves the output just goes high then the slit in

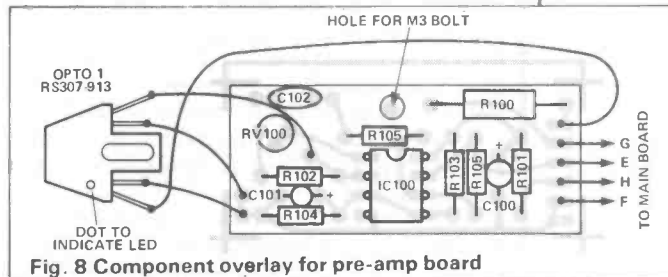


Fig. 8 Component overlay for pre-amp board

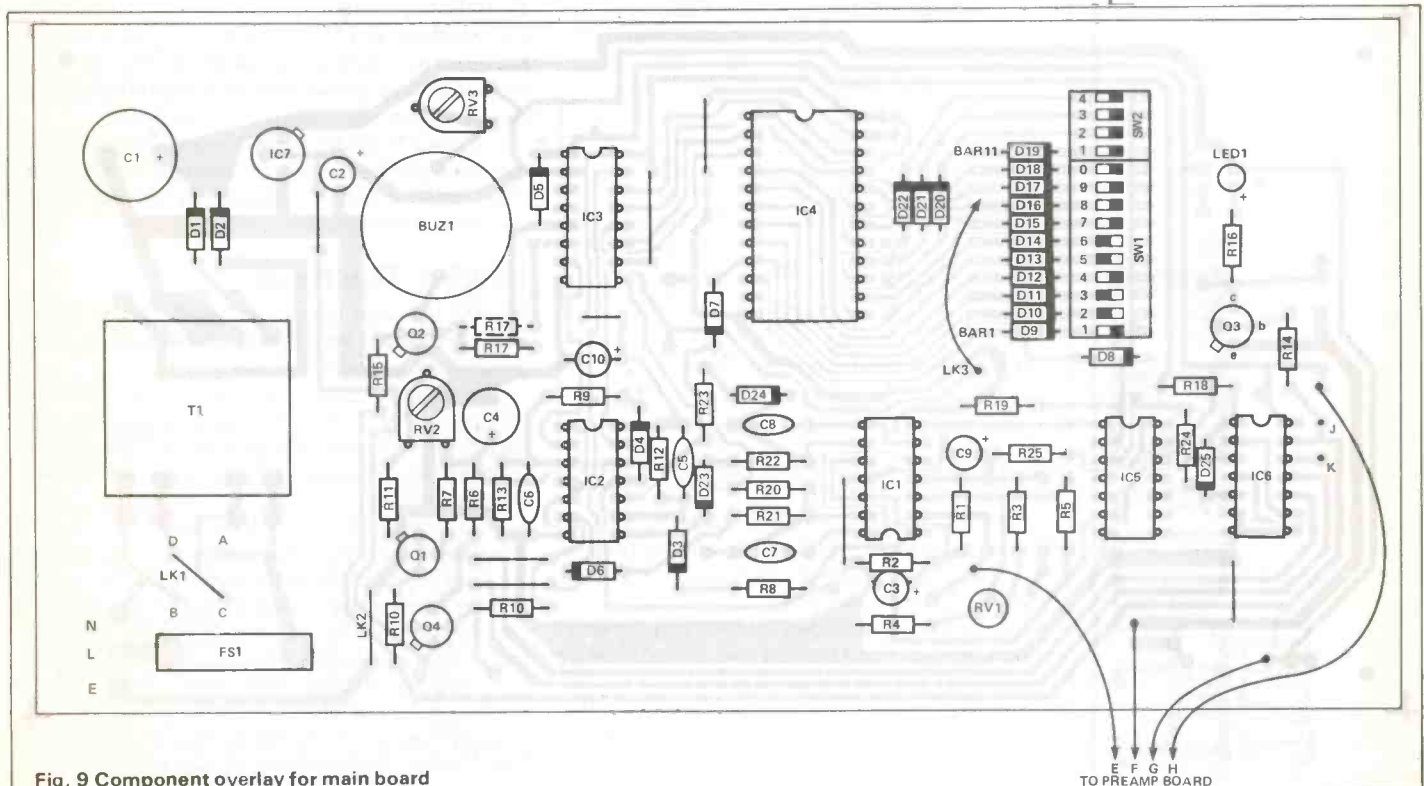


Fig. 9 Component overlay for main board

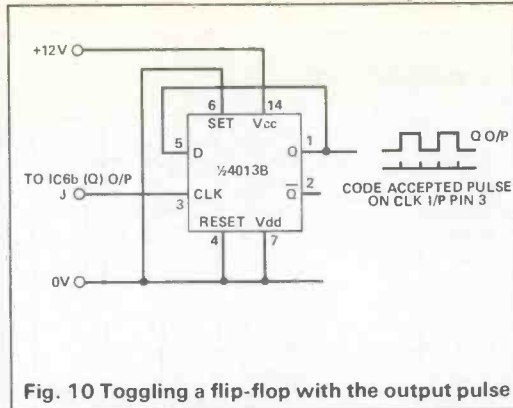
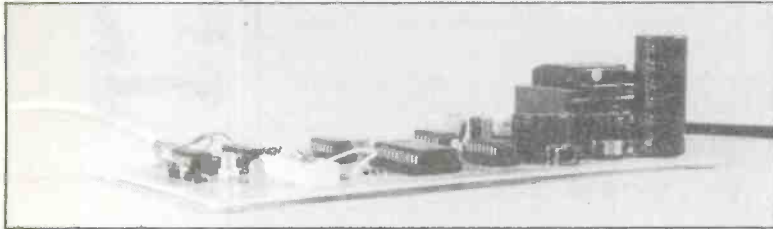


Fig. 10 Toggling a flip-flop with the output pulse



the sensing window is too wide.

Then adjust the sensor height to minimise the amplitude difference between the two different sine wave frequencies. Adjust RV100 to bring these amplitudes to about 8V peak-to-peak. Sweeping the key should now beep the piezo sander to show a correct code (otherwise either you're not sweeping properly or you've set the wrong code in the switches).

Using the scope to look at the output of the reference integrator IC1b, you can get some sweeping training by getting the voltage to drop from its normal 12V to as close to 6V as you are able. If you have a two beam scope you can look at IC1c to produce a display similar to Fig. 3.

Finally, fine tune the system by adjusting RV100 to give the best performance at varying sweep speeds.

Then tighten the sensor to the bracket, mount the preamp board by fitting a 3M x 10mm spacer to the sensor mounting bolt and attaching the PCB to the spacer with a 3M x 5mm bolt. Then close the box. With the box closed, make sure everything still works.

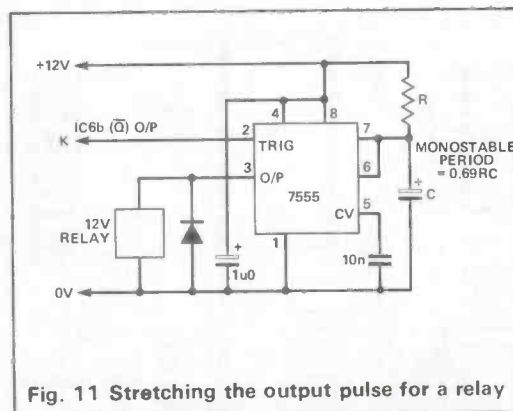


Fig. 11 Stretching the output pulse for a relay

Now change the required code by setting SW1 on the bank of switches 'on' and try the key again. After five attempts the piezo sander should sound for about 90 seconds.

The volume is adjusted by RV3 and the time constant by RV2. For a much longer period change R11 but don't exceed about 10M. By moving both D5 and R17 to their alternative positions the number of failed sweeps required to sound the alarm is increased to nine. To identify longer codes

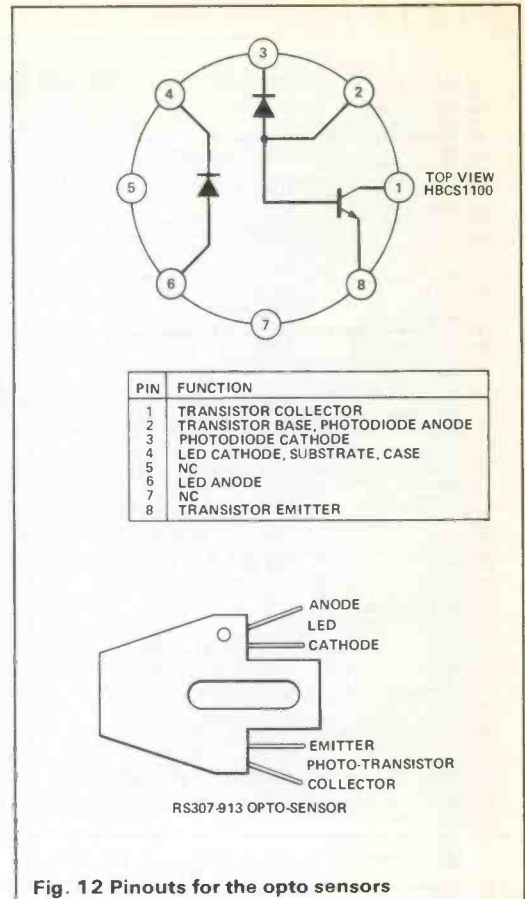


Fig. 12 Pinouts for the opto sensors

up to 14 bars, link 11 should be moved to the relevant diode.

When mounting the completed sensor housing, make sure that the sensor doesn't face an electric light as this will toggle the comparator at 50Hz and eventually trigger the alarm.

For mounting outside, a sealed watertight box should be used and a bag of silica gel (as found in camera cases and so on) in the box would stop any condensation forming.

Applications

Figure 10 shows how the code accepted pulse can be used to toggle an external flip-flop for each correct sweep of the key. This could be used to deactivate an alarm system for instance.

Figure 11 shows how the code accepted pulse can be stretched using an external monostable. This could drive a solenoid in an electrically operated doorlock.

Making The Keys

Making the keys is easy, especially if you have a BBC computer and Epson printer, for which a program is provided in Listing 1.

The program prints the selected bar code twice with a 6mm bar in the middle so the printout can be folded in half and slipped into a Prontapouch (hooray for Prontapouches!). This produces a doublesided key.

The black bars obviously need to be as dark as possible so if your printer has been producing light grey listings recently, now might be a good time to replace the ribbon. Note that the program can compensate for an ailing ribbon by overprinting several times (line 90).

Anyone familiar with BBC Basic should understand most of the program with a few side-long glances at the printer manual to sort out the VDU codes. It should run on the model B, B+ or


```

10 REM ETI BAR CODE PRINTER
20 MODE 3
30 DIM bardata(15)
40 VDU1:REM Enable Printer
50 VDU1,27,1,64:REM Initialise Printer
60 VDU1,27,1,65,1,B:REM Set Line spacing
70 RESTORE BOO
80 code=0:height=0:dots=70
90 dark=3:REM Number of overprints.
100 Nbar=0:REPEAT
110 READ code:REM Count dots in barcode
120 bardata(Nbar)=code:REM PUT DATA into Array
130 IF code=0 THEN dots=dots+20:REM Thin Bar
140 IF code=1 THEN dots=dots+30:REM Thick Bar
150 Nbar=Nbar+1:REM Count Bars used in Barcode
160 UNTIL code=9
170 dots=dots*2:REM Double Length code
180 Nbar=Nbar-1
190 Ldots=dots MOD 256:REM n1 Bit Image Data
200 Hdots=dots DIV 256:REM n2 Bit Image Data
210 PROCtop:REM Print top Border
220 REPEAT
230 FOR D=1 TO dark
240 VDU1,27,1,90,1,Ldots,1,Hdots:
250 REM LPRINT CHR$(27);"2";CHR$(Ldots);CHR$(Hdots);
260 REM ESC Z sets Quadruple=density Bit Image Mode
270 Dots/Inch
270 PROCbar(30,255):REM Print 3mm Black Border
280 PROCbar(10,0):REM Print 1mm White Space
290 FOR A=0 TO Nbar:REM Print Barcode Forwards
300 bar=bardata(A)
310 IF bar=0 PROCshort
320 IF bar=1 PROClong
330 NEXT
340 PROCbar(60,255):REM Print 6mm Centre Bar
350 PROCbar(10,0):REM Print 1mm White Space
360 FOR B=Nbar TO 0 STEP-1:REM Print Barcode Backwards
370 bar=bardata(B)
380 IF bar=0 PROCshort
390 IF bar=1 PROClong
400 NEXT
410 PROCbar(30,255):REM Print 3mm Black Border
420 VDU1,&OD
430 NEXT
440 VDU1,&OA,1,&OD:REM Print LF and CR
450 height=height+1
460 UNTIL height=10:REM height=30mm
470 PROCbottom:REM Print Bottom Border
480 VDU1,27,1,64:
490 VDU1,&END
500 DEFPROCbar(length,data):REM Print 1mm Bar, 2mm
Bar or Space
510 FORN=1 TO length
520 VDU1,data:
530 NEXT
540 ENDPROC
550 DEFPROCshort
560 PROCbar(10,255):REM Print 1mm Black Bar
570 PROCbar(10,0):REM Print 1mm White Space
580 ENDPROC
590 DEFPROClong
600 PROCbar(20,255):REM Print 2mm Black Bar
610 PROCbar(10,0):REM Print 1mm White Space
620 ENDPROC
630 DEFPROCtop:REM Print top border
640 FORA=1 TO dark
650 VDU1,27,1,90,1,Ldots,1,Hdots:
660 PROCbar(dots,7)
670 VDU1,&OD
680 NEXT
690 VDU1,&OD,1,&OA
700 ENDPROC
710 DEFPROCbottom:REM print bottom border
720 FOR A=1 TO dark
730 VDU1,27,1,90,1,Ldots,1,Hdots:
740 PROCbar(dots,224)
750 VDU1,&OD
760 NEXT
770 ENDPROC
780 REM 0=Thin Bar
790 REM 1=Thick Bar
800 DATA 0:REM Reference Bar
810 DATA 0,1,1,0,1,1,0,0:REM Bar Code Data, Max 14
820 DATA 9:REM Bar Code Data Delimiter

```

Listing 1 BBC Basic program to print bar codes

Master and (if you're lucky) on the Archimedes as well. It has been written to work with any Epson or compatible printer with quad density bit image mode such as the RX80, FX80 and LQ100.

The REM statements need not be typed in but are included to help anyone convert the program

THE PROGRAM

VDU1 is the command to send the next character or number to the printer only. The equivalent to line 240 (VDU1, 27, 1, 90, L dots, 1, Hdots;) in Microsoft Basic shown in Line 250 (LPRINT CHR\$(27); CHR\$(90); CHR\$(Ldots); CHR\$(Hdots);).

When a procedure is called as in line 270 (PROCbar(30,255)), the two values in brackets are assigned to the variables identified in that procedure's definition — line 500 (DEFPROCbar (length, data)). So length = 30 and data = 255.

The DATA statements starting at line 800 hold the binary data for the bar code. Line 800 holds the data for the Reference Bar, line 820 holds the value 9 which informs the program when all the data has been read. Both these values should not be altered. Line 810 holds the actual data for the code as set up on the programing switches, and produce your personal bar code.

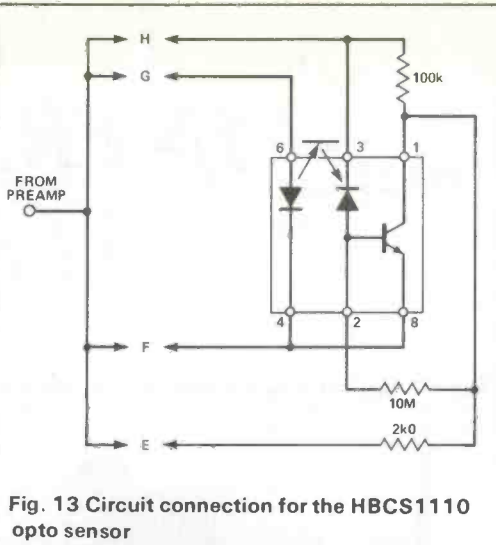


Fig. 13 Circuit connection for the HBCS1110 opto sensor

USING THE HBCS1110 OPTO-SENSOR

For anybody wishing to use the more expensive Hewlett Packard sensor, the pin connections are shown in Fig. 13. The circuit in Fig. 13 shows how to connect the device to the pre-amp using three extra resistors — note that R106 should also be changed to 100k.

To make use of the improved resolution, the integrator time constants will have to be changed. If the bar thickness is halved then C7 and C8 must be halved (from 2200p to 1000p) and use polystyrene or monolithic ceramic rather than normal ceramics (which may cause the reference integrator to drift through leakage).

Obviously the barcode printing program will require altering to produce narrower bars.

to run on something else. See also the program notes in *The Program*.

If you can't print out your own codes, then a draughting pen and white paper can be used. But make sure the bar widths are accurate — the white spaces between are less critical except for the one between the reference bar and the first code bar.

Easier still use Letraset or the crepe tracks for PCB layouts.

Whatever you use, the only way of encapsulating the code is the legendary Prontapouch plastic pouches. This produces a small waterproof flexible key that is very easy to lose, so you had better make a couple of spares now you've got the hang of it!



BUYLINES

Most of the components used in this project should be available from your usual supplier.

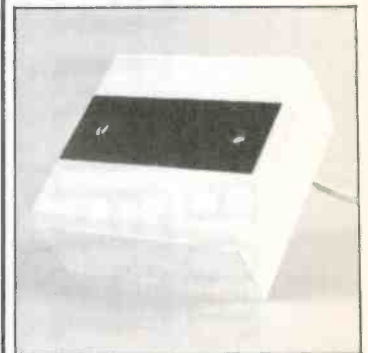
In the prototype the following components were obtained from Electromail: BUZZ1 (order code 249-794), SW1 (336-680), SW2 (337-548), the red filter (307-913), SENS1 (307-913). Electromail, PO Box 33, Corby, Northants NN17 9EL. Tel: (0536) 204555.

The sensor type is OPB7030 and is also available from other suppliers.

Note that the red filter should not be more than 1mm thick.

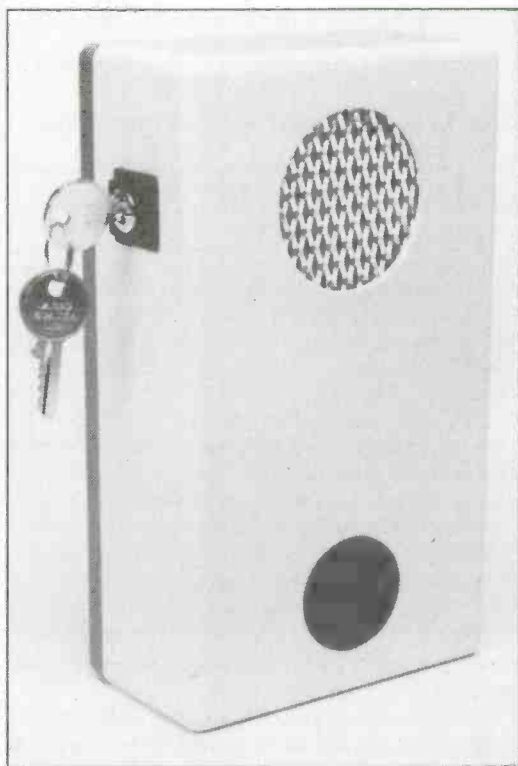
The more expensive HBCS1100 opto sensor is available from Farnell (Tel: (0532) 636311) or from Trilogic (Tel: (0274) 684289).

The Prontapouches are available at any Prontaprint shop — check your Yellow Pages or Thomson Local Directory.



PASSIVE INFRA-RED ALARM

Protect your home and valuables with this simple but effective alarm from Robert Penfold



Burglar alarms which rely on an infra-red beam being broken by any intruder are not new and devices of this type must have been in existence for at least 20 years. The same principle has been applied to automatic doors and similar applications and it is now a standard form of 'presence' detection.

Although this unit could be described as an infra-red broken beam detector, it is not of the normal active variety. Those generally have a transmitter which sends a narrow beam of infra-red pulses to a receiver unit. Anyone passing between the two units momentarily cuts the signal to the receiver and triggers the system.

The system described here is a single-ended type which is based on passive infra-red detection techniques. In other words, it detects the body heat of anyone passing through the 'beam' of high sensitivity.

Most passive infra-red detection systems are designed to cover a wide area, generally with the aid of a Fresnel lens which give zones of high and low sensitivity. A different approach has been taken with this design which has an ordinary convex lens ahead of the pyro sensor. It therefore has a very narrow corridor of high sensitivity and in use is more directly comparable to a broken beam type alarm than a normal passive infra-red detector.

There are both advantages and disadvantages to this approach. It offers what is generally a much better range than a wide angle passive detection system but has substantially lower performance in this

respect when compared to an active beam system. However, with a maximum range of around 30m it is perfectly adequate for most likely applications and does not require the difficult alignment procedures

HOW IT WORKS

IC1 is the pyro sensor and this is a single element type. In common with other pyro sensors it has a built-in source follower buffer amplifier which gives a low output impedance of the sensing element. R1 is the load resistor for the buffer stage. IC9 provides IC1 with a highly stable 5V supply. The supply voltage range for the SSC10 pyro sensor is 2.2-10V, incidentally.

The amplifier stages use the two sections of IC2 with the first operating in the non-inverting mode and the second one functioning as an inverting amplifier. The configurations used here are very similar to standard operational amplifier audio types but the coupling and decoupling capacitors are much higher in value as it is only infra-audio signals that must be amplified.

C6 and C8 severely attenuate the high frequency response of the circuit, with 'high' in this context meaning frequencies of a few Hz or more!

With passive infra-red detectors, the limiting factor on the degree of sensitivity that can be obtained is the noise level of the pyro sensor itself. The gain of the amplifier could easily be increased but it would be unlikely to give any improvement in performance.

IC3 acts as the basis of the trigger circuit, and this is really just an op-amp voltage comparator circuit. RV1 is adjusted to provide a voltage which is slightly below the minimum level achieved by the output of IC2b under standby conditions. The output of IC3 is therefore normally at the high state. When the unit is activated, the output from IC2 briefly goes below the reference voltage, the output of IC3 goes low and the 555 monostable based on IC4 is triggered.

The switch-on delay is provided by a second 555 monostable (IC5). This is triggered at switch-on by the pulse generated by R15 and C10 and via Q1 it holds the reset input of IC4 in the low state. When the pulse from IC5 ceases, the reset input of IC4 goes to the high state and IC4 will then respond to any subsequent triggering.

IC6 provides the alarm activation delay and this is a Schmitt trigger preceded by a basic C-R timing circuit. About 25 seconds from the start of the pulse from IC4 the charge on C12 reaches the trigger voltage and the output of IC6 switches to the low state.

This gates on the VCO which is part of the 4046BE (IC7). The 4046BE is actually a CMOS micro-power phase locked loop but in this circuit only the oscillator section is utilised and the other stages of this component are just ignored.

The modulation is provided by IC8 - a standard 555 astable circuit having an operating frequency of just under 2Hz. Its almost squarewave output is attenuated slightly by R22 and R23 and filtered by C14. This gives an almost triangular modulation signal of a few volts peak-to-peak, which sweeps the audio tone from the VCO over a wide frequency range. This gives a very effective alarm signal. Q2 is a VMOS power FET which is used to drive the loudspeaker and provides an output power of a few watts.

The power supply is a basic stabilised type having a fullwave (bridge) rectifier and stabilisation provided by monolithic voltage regulator IC10. Under standby conditions the current consumption of the circuit is around 35mA but when the alarm generator is activated, the current drain rises to well over 600mA.

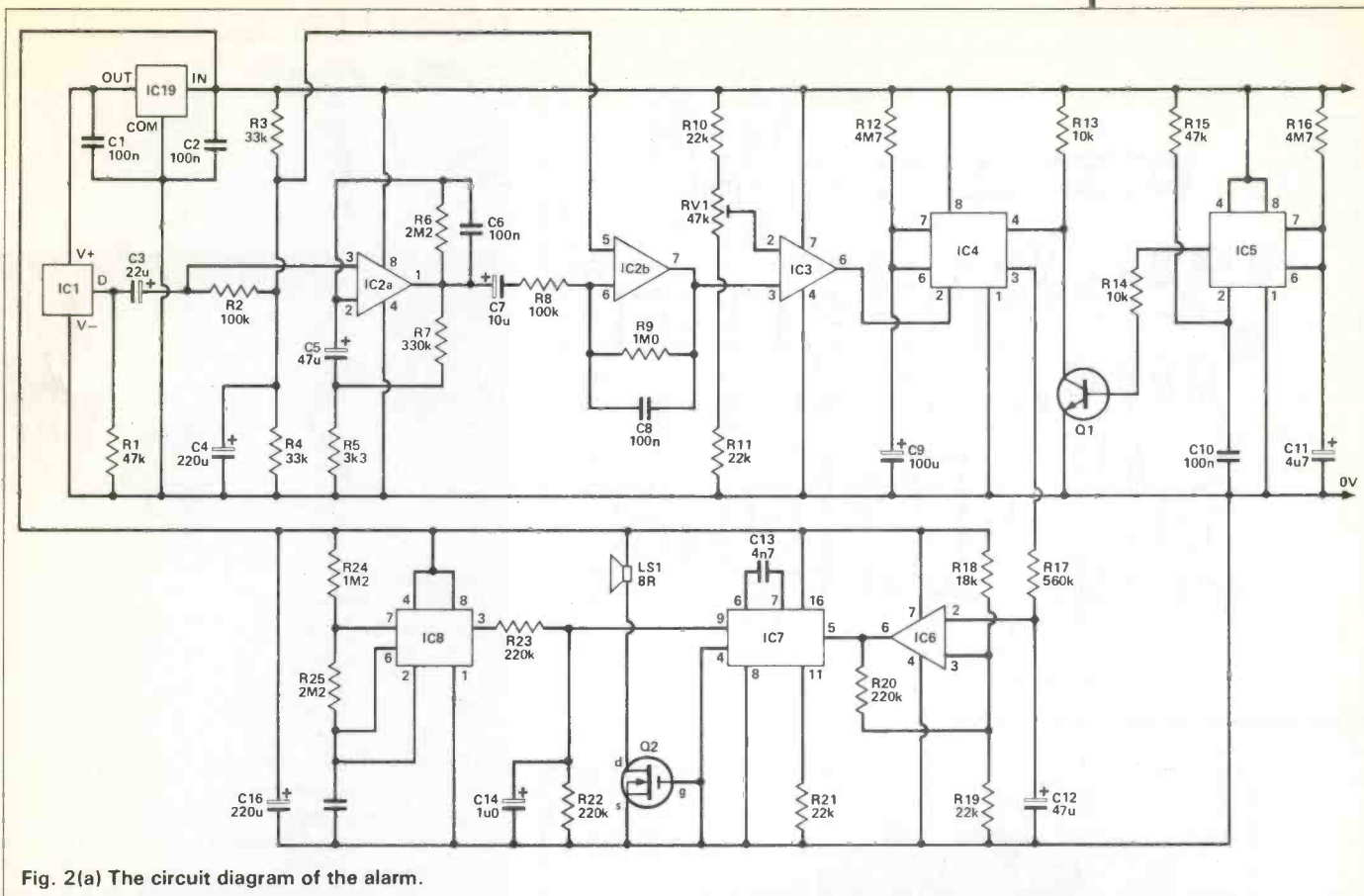


Fig. 2(a) The circuit diagram of the alarm.

associated with active systems. A passive beam system is also less prone to problems with spurious triggering as there are no problems with the system slipping slightly out of alignment or moths flying through and breaking the beam!

Compared with an active system there is also the advantage that only a single unit is required. This can greatly ease installation.

As described here the unit is a burglar alarm, complete with switch-on and activation delays, automatic alarm switch-off, and a built-in modulated alarm generator. However, the detector section of the unit can easily be extracted from the design and used as the basis of automatic doors, or whatever.

The System

The block diagram of Fig. 1 helps to explain the way in which the unit functions. Obviously some means of detecting the infra-red energy radiated by someone passing through the beam is required. Ordinary photo-transistors and the like are completely useless in this application.

Although many semiconductor photo-sensitive devices have peak performance in the infra-red part of the spectrum, this is normally at wavelengths quite close to the visible red part of the spectrum. The actual wavelengths involved are in the region of 0.7-1.0 μ m. For effective detection of body heat it is at much longer wavelengths (around 7-15 μ m) that good sensitivity is required.

This requires the use of special sensors based on ceramic crystal materials which produce a small charge when a change in the infra-red level is detected. An important point to realise when dealing with these devices is that it is a *change* in the infra-red level that is detected and not the absolute level.

An increase in the strength of the received signal produces a larger output voltage but this voltage soon starts to subside, even if the intensity of the signal is

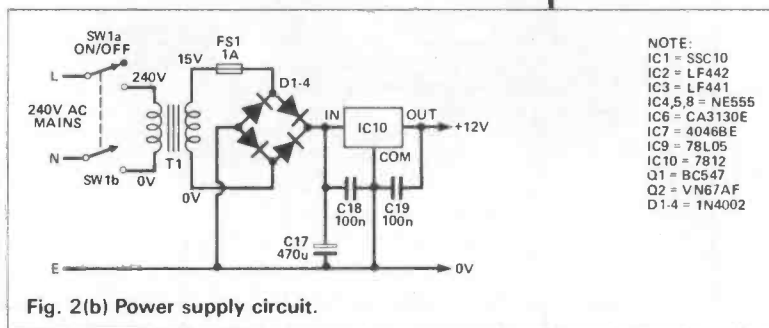


Fig. 2(b) Power supply circuit.

NOTE:
 IC1 = SSC10
 IC2 = LF442
 IC3 = LF441
 IC4,5,8 = NE555
 IC6 = CA3130E
 IC7 = 40468E
 IC9 = 78L05
 IC10 = 7812
 Q1 = BC547
 Q2 = VNG7AF
 D1-4 = 1N4002

maintained. The bandwidth of pyro sensors is usually very restricted, with 0.3-3Hz being typical. However, this is adequate for intruder alarms and similar applications.

To achieve a really good maximum operating range a convex lens must be added ahead of the sensor. This gathers up infra-red radiation over a relatively large area and concentrates it onto the sensing element. This gives an effective boost in gain

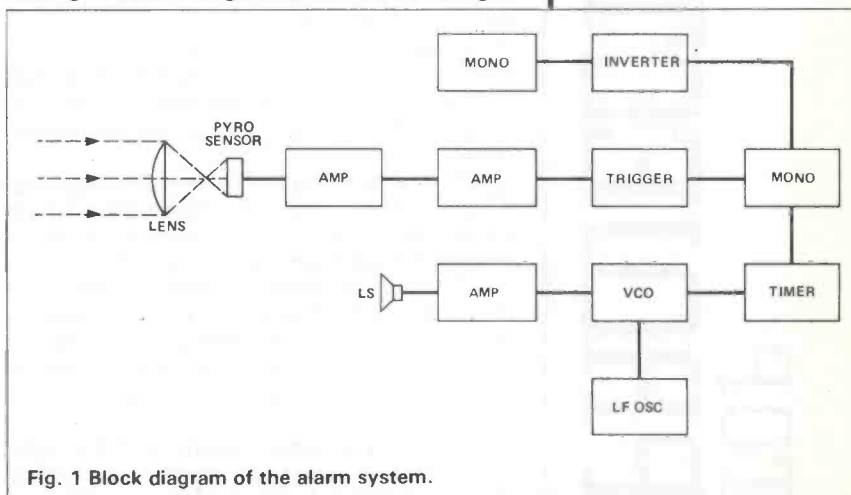


Fig. 1 Block diagram of the alarm system.

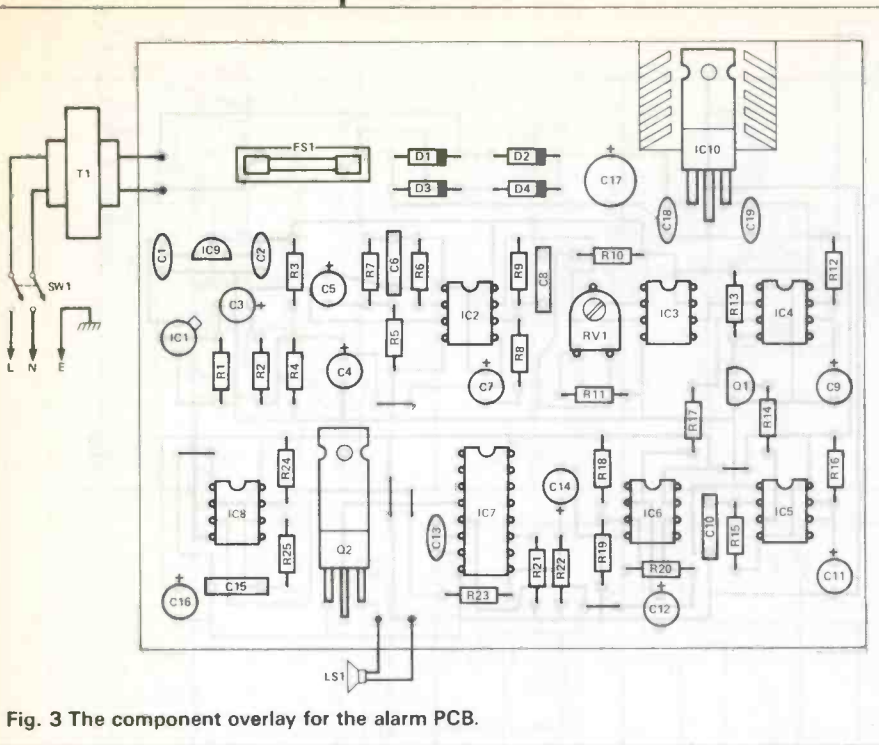
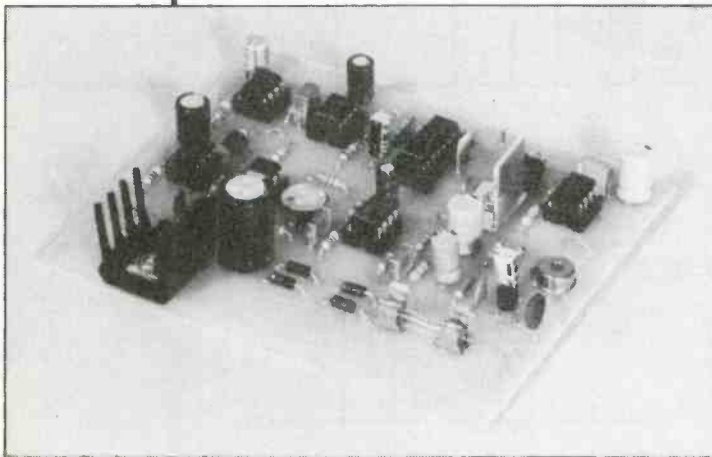


Fig. 3 The component overlay for the alarm PCB.



but makes the system highly directional. This is analogous to a high gain radio aerial, where increased signal strength but also greater directivity are obtained.

The output from the sensor is still quite low — often under 1mV peak-to-peak. A great deal of amplification is needed in order to bring the signal up to a usable level and in this case a two stage amplifier is used. This is followed by a trigger circuit which is activated when the output voltage from the second amplifier stage goes below its quiescent level by more than a preset amount.

Anyone passing through the 'beam' of high sensitivity will produce a signal from the sensor that results in the output of the second amplifier varying widely either side if its quiescent level, activating the trigger circuit.

The negative output pulse from the trigger stage is used to activate a monostable multivibrator. This has a long output pulse duration of about ten minutes. It activates the alarm generator via a delay circuit.

The point of driving the alarm generator via a monostable rather than a latch is that an automatic switch-off is obtained after about ten minutes. This ensures that once the alarm has served its purpose it does not cause unnecessary annoyance to your neighbours.

The delay circuit prevents the alarm from being sounded as soon as the unit is activated but only about 25 seconds elapses before the alarm is switched on.

PARTS LIST

RESISTORS (all 1/4W 5% carbon)

R1,15	47k
R2	100k
R3,4	33k
R5	3k3
R6,25	2M2
R7	330k
R8	180k
R9	1M0
R10,11,19,21	22k
R12,16	4M7
R13,14	10k
R17	560k
R18	18k
R20,22,23	220k
R24	1M2
RV1	47k sub-min horiz preset

CAPACITORS

C1,2,18,19	100n ceramic
C3	22µ 16V radial electrolytic
C4,C16	220µ 16V radial electrolytic
C5,12	47µ 16V radial electrolytic
C6,8,10,15	100n polyester
C7	10µ 25V radial electrolyte
C9	100µ 16V radial electrolytic
C11	4µ 7 63V radial electrolytic
C13	4n7 mylar or ceramic
C14	1µ 63V radial electrolytic
C17	470µ 25V radial electrolytic

SEMICONDUCTORS

IC1	SSC10 pyro sensor
IC2	LF442
IC3	LF441
IC4,5,8	NE555P
IC6	CA3130E
IC7	4046BE
IC9	78L05
IC10	7812
Q1	BC549
Q2	VN67AF or similar
D1,2,3,4	1N4002

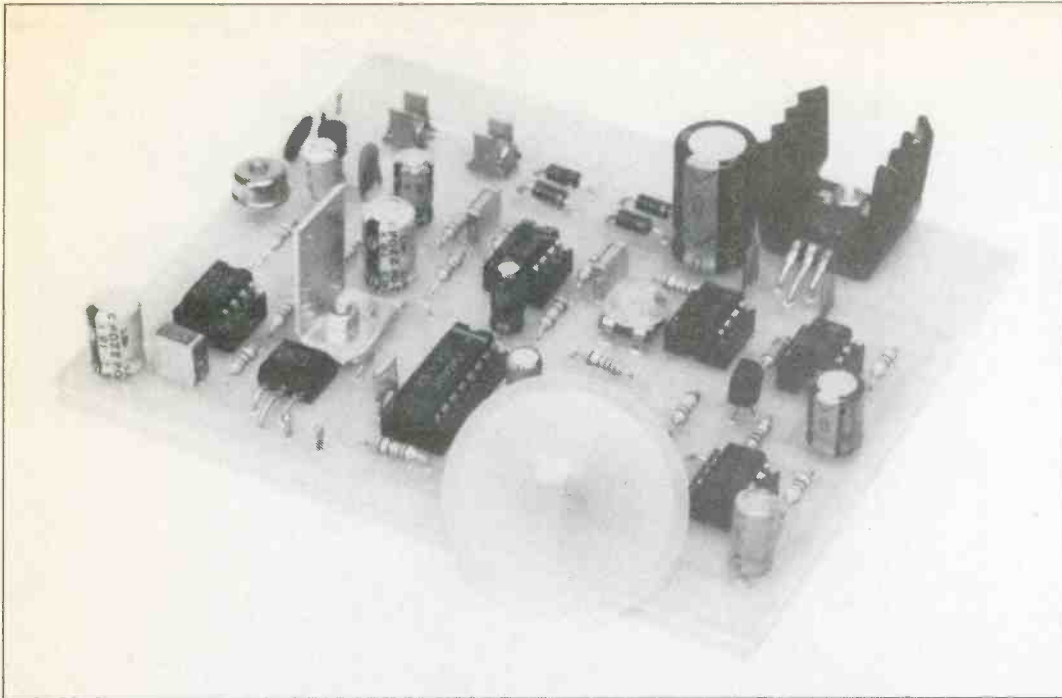
MISCELLANEOUS

FS1	20mm 1A anti-surge fuse and holder
LS1	8R, 8W loudspeaker
SW1	Mains switch
T1	15v, 1A mains transformer

PCB. Case. CE01 lens. Small finned heatsink. IC socket. Wire. Nuts and bolts.

This gives someone legitimately entering the premises an opportunity to switch off the unit before the alarm generator is activated.

Although the alarm generator is a fairly simple type, it is nevertheless quite effective. It is based on a VCO (voltage controlled oscillator) that is frequency modulated over a wide range by a low frequency oscillator. A power amplifier stage provides the unit



with an output of several watts, which gives a very loud alarm sound when used with any reasonably efficient loudspeaker.

A second monostable controls the first one via an inverter stage. This second monostable is automatically triggered at switch-on and it has an output pulse duration of about 25 seconds. Its purpose is to prevent the unit from being triggered until the person who switches on the alarm has had time to move out of the monitored zone.

Construction

Most of the components fit onto a single printed circuit board, including the power supply components apart from SW1 and T1. The component overlay is shown in Fig. 3.

IC6 and IC7 are MOS devices and the usual anti-static handling precautions should be taken when dealing with these components. Q2 is a MOS device but it has an integral zener protection diode that makes special handling precautions unnecessary.

I used a VN67AF for Q2 but similar devices such as the VN46AF and VN66AF are equally suitable.

As Q2 is operated as a switch in this circuit it does not have to dissipate much power but it is advisable to fit it with a small heatsink to ensure safe operation. A small fin made from an odd scrap of aluminium is all that is needed here.

In the power supply circuit IC10 has to dissipate a few watts of power when the unit is activated and it should also be fitted with a small heatsink. It has to dissipate somewhat more power than Q2 and the use of a ready-made finned heatsink is recommended.

It is advisable to use an anti-surge fuse for FS1, as a quick-blow type might be blown by the initial surge of current at switch on as C17 charges up.

If the three timer circuits in the unit are to function properly it is essential that the timing capacitors are good quality types. Superior grade electrolytics are usually satisfactory but tantalum types probably offer the best reliability. Even using good quality components it is not possible to set the various times particularly accurately and they will generally be somewhat longer than the calculated times. This does not really matter here as timing accuracy is obviously of little importance.

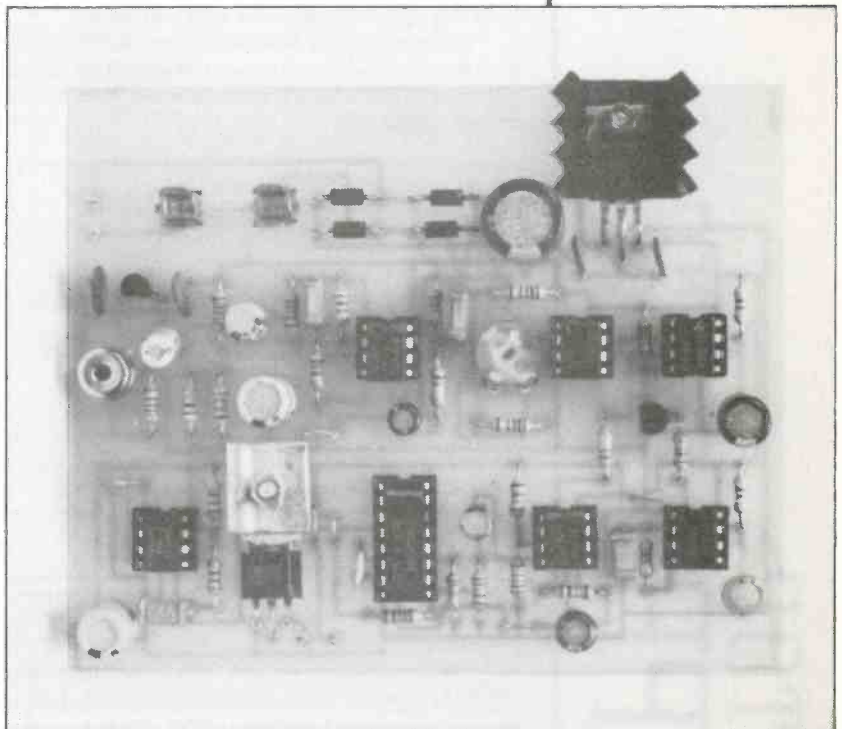
The ideal delay times will depend on the exact

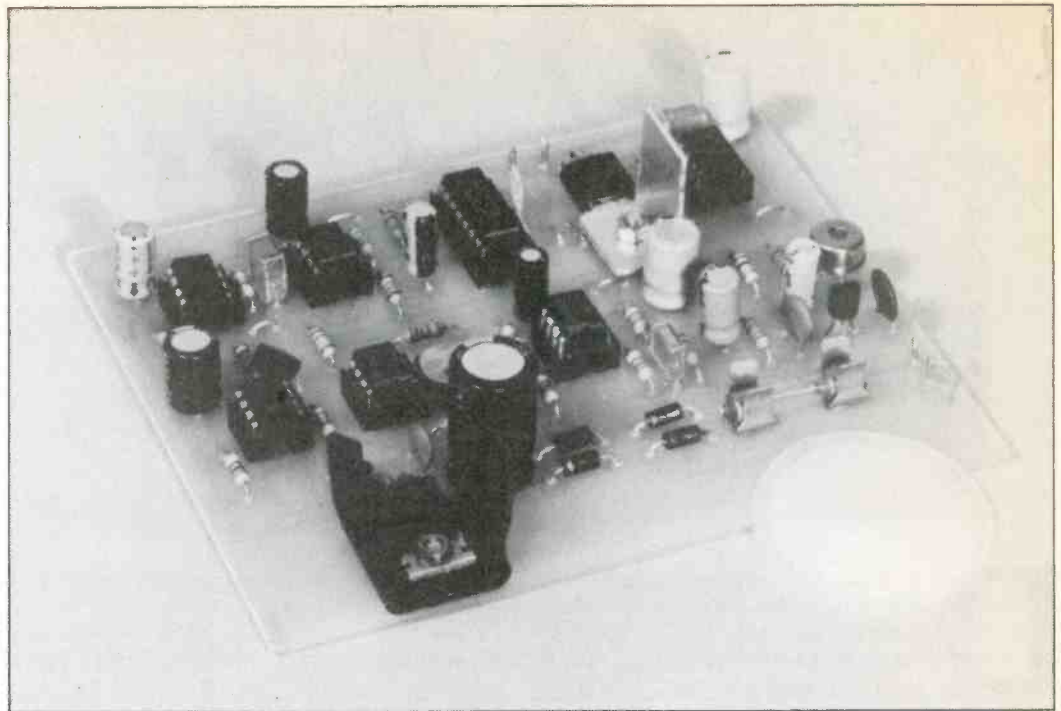
circumstances under which the unit is used but they can be altered by changing the value of the relevant timing resistor and/or capacitor. The delay times are proportional to the values of both components.

Mechanical construction must be varied to suit the conditions under which the unit will operate. As the unit is mains powered it is essential that safety precautions are observed. The unit must be fitted in a case that has a screw fixing lid or cover, so that there is no easy means of gaining access to the dangerous mains wiring. It is a good idea to insulate any exposed mains wiring anyway and any exposed metalwork must be earthed to the mains earth lead.

For security reasons the unit could be fitted in a really tough case and the on/off switch SW1 should be a key type. The alternative which is preferred by many is to disguise the unit so that the alarm goes off before the unit is discovered.

The only slightly awkward aspect of construction is the mounting of the lens. Assuming the recom-





mended lens is used, the photocell and lens must be in the relative positions shown in Fig. 4.

In some cases things can be easier if the pyro sensor is mounted off-board but in most instances the unit can be arranged so the lens is fixed behind a cut-out in the front panel and the printed circuit board is mounted with ICI in the correct position behind the lens.

It is important that the 30mm distance from the lens to the window in the pyro sensor is reasonably accurate, although a millimetre either way does not seem to greatly reduce the range of the unit.

Getting the window well centred behind the lens is also important. If the pyro sensor is slightly off centre this will not prevent the unit from working but there will be a slight loss of range and the beam will not run perpendicular to the lens. This will make it difficult to aim the finished unit correctly.

If you require some window material to give a neat finish to your cell, suitable material is available from the same source as the lens and sensor.

In theory it is not essential to use the CE01 lens and any convex lens having a diameter of about 30mm or so and a focal length of around 25 to 30mm should suffice.

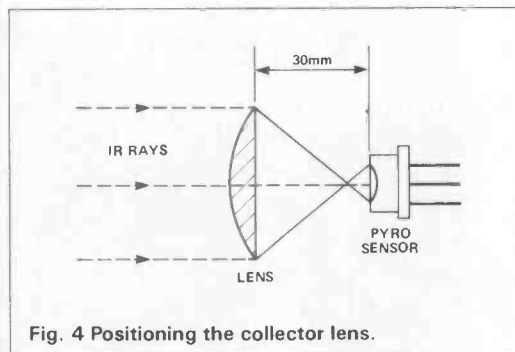


Fig. 4 Positioning the collector lens.

BUYLINES

The majority of the components used in this project are easily available from the usual sources. The pyro detector and the infra-red lens are available from Chartland Electronics, PO Box 83, Chobham, Surrey, KT11 2QB.

The lens to sensor distance should be equal to the focal length of the lens. In practice use of the CE01 lens is advisable, since this is guaranteed to operate properly in this application.

Most other lenses are designed to operate in the visible light part of the spectrum and their performance at long infra-red wavelengths is something of an unknown quantity. At best the focal length is likely to be significantly shifted and at worst there will be little transmission of long infra-red radiation.

I tried a few other lenses in the unit but they all failed to work properly and did in fact seem to be opaque at the wavelengths involved in this application!

Adjustment

The only adjustment needed before the unit is ready for use is to give RV1 the optimum setting. With this set fully anti-clockwise the unit will probably function reasonably well but with a relatively low maximum range. Advancing RV1 should improve sensitivity but adjusting it too far in a clockwise direction will result in frequent spurious triggering of the unit.

Finding the best setting is really a matter of experimenting a little with various settings. When making these adjustments it is probably best to disconnect the loudspeaker and to use a voltmeter to monitor the output of IC3. This saves your ears from the alarm generator and it also circumvents the delays which would otherwise make adjustment of RV1 a very slow and difficult business.

Remember that the output voltage from IC3 is normally high and goes low momentarily when the unit is activated.

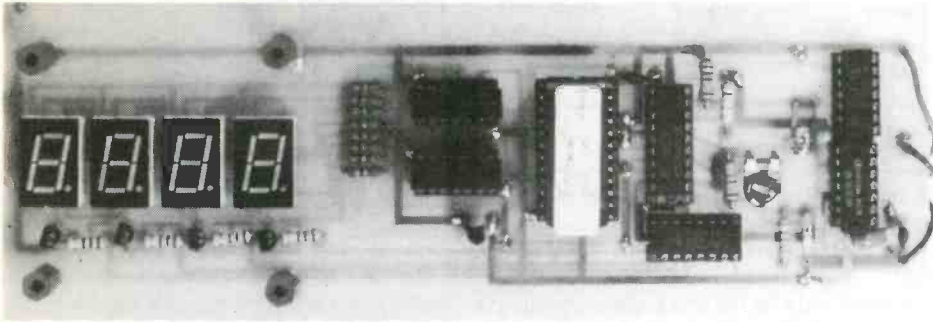
Alarms of this type have reasonable immunity from false alarms but be careful not to position the unit where there are any obvious sources of infra-red that could trigger it. In particular, when used out of doors avoid aiming the unit in the direction of passing cars. These can trigger the unit at more than its 30 metre 'human' range.

Bear in mind that the unit responds most readily to someone passing through the 'beam' at a right angle to it and that the sensitivity is relatively low for someone moving along the beam.



UNIVERSAL DIGITAL PANEL METER

TOP PROJECT



Digital panel meter ICs have been out and about for some time. The chances are that if you pull the front off that budget digital multi-meter you were given last Christmas you'll find an ICL7106 doing all the work.

The problem with commercial DPM ICs is their inflexibility. They couldn't, for example display on a logarithmic or exponential scale, and any specialised display signals are out of the question. Normally you would need to build a mass of logic around your LEDs to switch segments and digits as the conditions dictated or else abandon hope and submit to the industry standards.

This design enables you to overcome these limitations using programmable logic. There are two digital panel meters featured here — one displaying on LED segment bar graphs, the other on LED 7-segment digits. Both follow identical design patterns and are universally programmable for 'one-off' user requirements.

Fig. 1 shows the block diagram for the system. The heart of the system is the EPROM. This stores the patterns to be displayed by the LED digits or bars for each possible 8-bit output from the ADC. The ADC output addresses the EPROM and each

bit of its 'data' output controls one segment of a display.

Two higher address bits (A8 and A9) are used to select the image data from the EPROM for each digit. These bits cycle through the four combinations in response to a decade counter clocked by the ADC. These two address lines are also used to direct power to each of the four digits in turn.

In this way the four digit display is multiplexed, with each digit's display independently determined by the contents of the EPROM for each possible output from the ADC.

Richard Grodzik presents a panel meter that uses programmable logic to display the way you say

Lighting The Lights

Obviously the way the display operates depends on how you program your EPROM. The EPROM has enough memory for two complete sets of image data (two completely different ways of displaying the input — say on a linear or log scale). You switch between the two using SW1 to control the MSB (A10) of the EPROM address, switching between $\&0000-\&3FFF$ and $\&4000-\&7FFF$.

We'll look at the bargraph board first — once you've grasped that, the digit display is very straightforward.

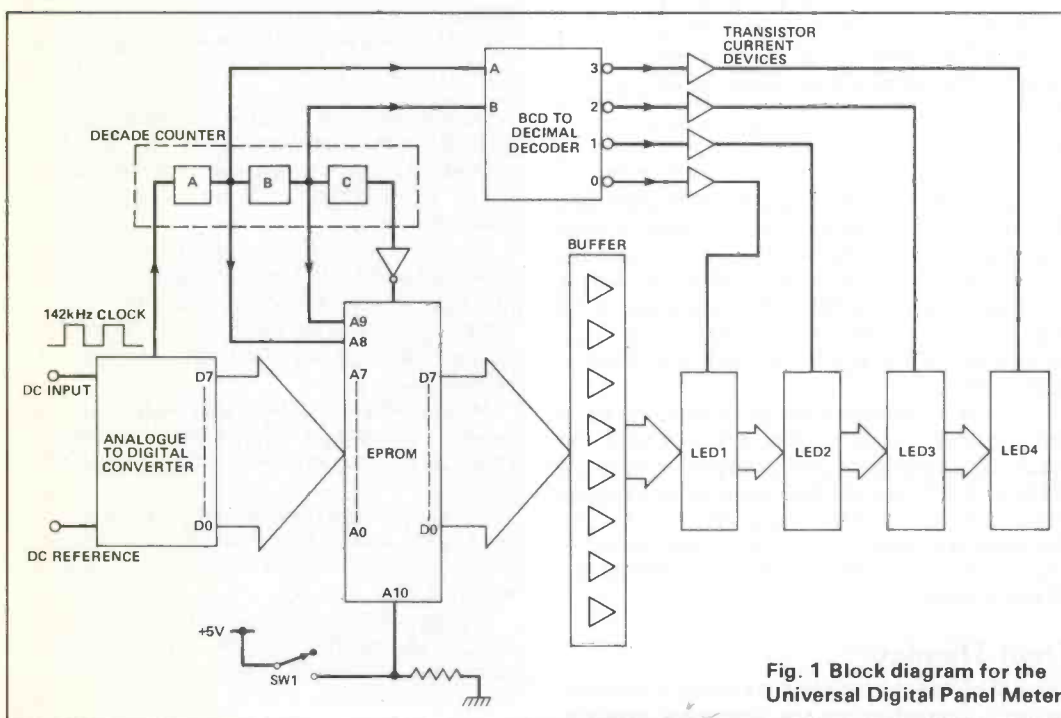


Fig. 1 Block diagram for the Universal Digital Panel Meter

1	2	3	4	COLUMN				
38-3F	6.4V	178-17F	12.8V	2B8-2BF	19.2V	3FB-3FF	25.5V	ROW 8
30-37	5.6V	170-177		2B0-2B7		3F0-3F7		ROW 7
28-2F	4.8V	168-16F		2A8-2AF		3E8-3EF		ROW 6
20-27	4.0V	160-167		2A0-2A7		3E0-3E7		ROW 5
18-1F	3.2V	158-15F		298-29F		3D8-3DF		ROW 4
10-17	2.4V	150-157		290-297		3D0-3D7		ROW 3
08-0F	1.6V	148-14F		288-28F		3C8-3CF		ROW 2
00-07	0.8V	140-147	7.2V	280-287	13.6V	3C0-3C7	20.0V	ROW 1

Fig. 2 Bar graph segment addresses

TOP	
D7	7F
D6	BF
D5	DF
D4	EF
D3	F7
D2	FB
D1	FD
D0	FE

Fig. 3 LED dot segment data

An input voltage range of 0V to 25.5V to the panel meter will (after attenuation and conversion) give an addressing range of &00 to &FF for the EPROM.

The image data for the first segment column is stored between &00 and &FF, the image data for the second column between &100 and &1FF, for the third column between &200 and &2FF, for the fourth column between &300 and &3FF.

The segment addresses for a linear scale display are shown in Fig. 2. You can see that for a display range of 0V-25.5V each segment represents 0.8V and is lit from any one of eight consecutive addresses.

The data coding required to enable any individual segment is shown in Fig. 3.

So an input voltage of 19.2V (for example) would address the EPROM at &0BF, then &1BF, &2BF and &3BF in turn (as the decade counter increments). The data is sent to columns 1, 2, 3 and 4 respectively.

In order to light only the 19.2V segment, Fig. 3 tells us that the data in these addresses should be &FF, &FF, &7F and &FF.

The complete hex dump for this scale display is shown in Listing 1. Remember that this will use

Address	D7	D6	D5	D4	D3	D2	D1	D0
FF								
FE								
FC								
FB								
F0								
E0								
C0								
80								
00-DATA								

Fig. 4 LED segment data

only half of the EPROM. The other half (addresses &400 to &7FF) can be used for a bar graph display where all LEDs up to the input voltage segment are lit. To use the second half of the EPROM, SW1 is switched making the MSB of the address (A10) high so that column 1 now takes data from addresses &400 to &4FF, column 2 from &500 to &5FF and so on.

The data needed to enable all segments up to the required one is shown in Fig. 4 with the resulting hex dump in Listing 2. All addresses from &438 to &4FF contain &00 since for any voltage above 5.6V all column 1 segments should be lit. Similarly for column 2 all addresses between &578 and 5FF contain &00, and for column 3 between 6B8 and &6FF.

Digit Display

Figure 5 shows the required hex codes to produce numeric characters on the 7-segment displays.

D7	D0	HEX	Display
11000000		C0	0
11111001		F9	1
10100100		A4	2
10110000		80	3
10011001		99	4
10010010		92	5
10000011		83	6
11111000		F8	7
10000000		80	8
10011000		98	9
01111111		F7	—

Fig. 5 LED digit display data

Decoding from the ADC is straightforward since 1 bit has a loading of 0.1V so a maximum input voltage of 25.5V will output &FF from the ADC. The hex dump of Listing 3 displays the input voltage in a standard numeric fashion. If we take an example of the decoding for an input voltage of 12.8V, the following addresses will be generated:

Addresses	&380	&280	&180	&080
Data	&F9	&A4	&F7	&80
Display	1	2	—	8

Construction

The overlay diagrams for the two boards are shown in Figs. 8 and 9. Construction of the PCBs should be straightforward.

IC sockets are recommended for all ICs and should certainly be used for the EPROM and ADC (IC6 and IC1). The ADC is a CMOS device so static handling precautions should be taken.

The main difference between the two boards is that the LED digit panel meter is a double sided PCB and has some 19 through-hole pins. These should be soldered in at the start of construction.

The LED bargraph board has several wire links which must also be fitted early on since some of them sit under resistors. Then proceed in the

HOW IT WORKS

Basically the meter consists of an ADC to convert the input voltage to a digital equivalent, and an EPROM which contains the code conversion required by the LED display.

The block diagram (Fig. 1) is the same for both panel meters and the circuit diagrams are shown in Figs. 6 and 7.

The analogue input voltage is first attenuated by a potential divider formed by R1, R3 and RV1. This attenuates by a factor of 10 to give a maximum voltage of 2.5V for the ADC (IC1). RV1 can be used to set full scale deflection.

The ADC is in free-running mode, continuously converting and providing an 8-bit digital output. Pin 5 of the ADC toggles after each conversion providing a clock signal to the decade counter IC4. When IC4 reaches 100₂, pin 8 goes high, is inverted by IC5 and enables the EPROM.

At the same time the two LSBs of IC4s output are driving IC7 and send pin 1 of IC7 low switching on transistor 1. LED1 is thus powered and driven by the EPROM contents.

Further ADC conversions clock IC4 and select LED2, 3 and 4 in turn, sending EPROM data from the addresses formed by the ADC conversion plus MSBs from pins 9 and 12 of IC4.

Switching SW1 to the 'on' position will enable EPROM addresses &400 to &7FF, thus providing an alternative code conversion for the display.

TOP PROJECT

TOP PROJECT

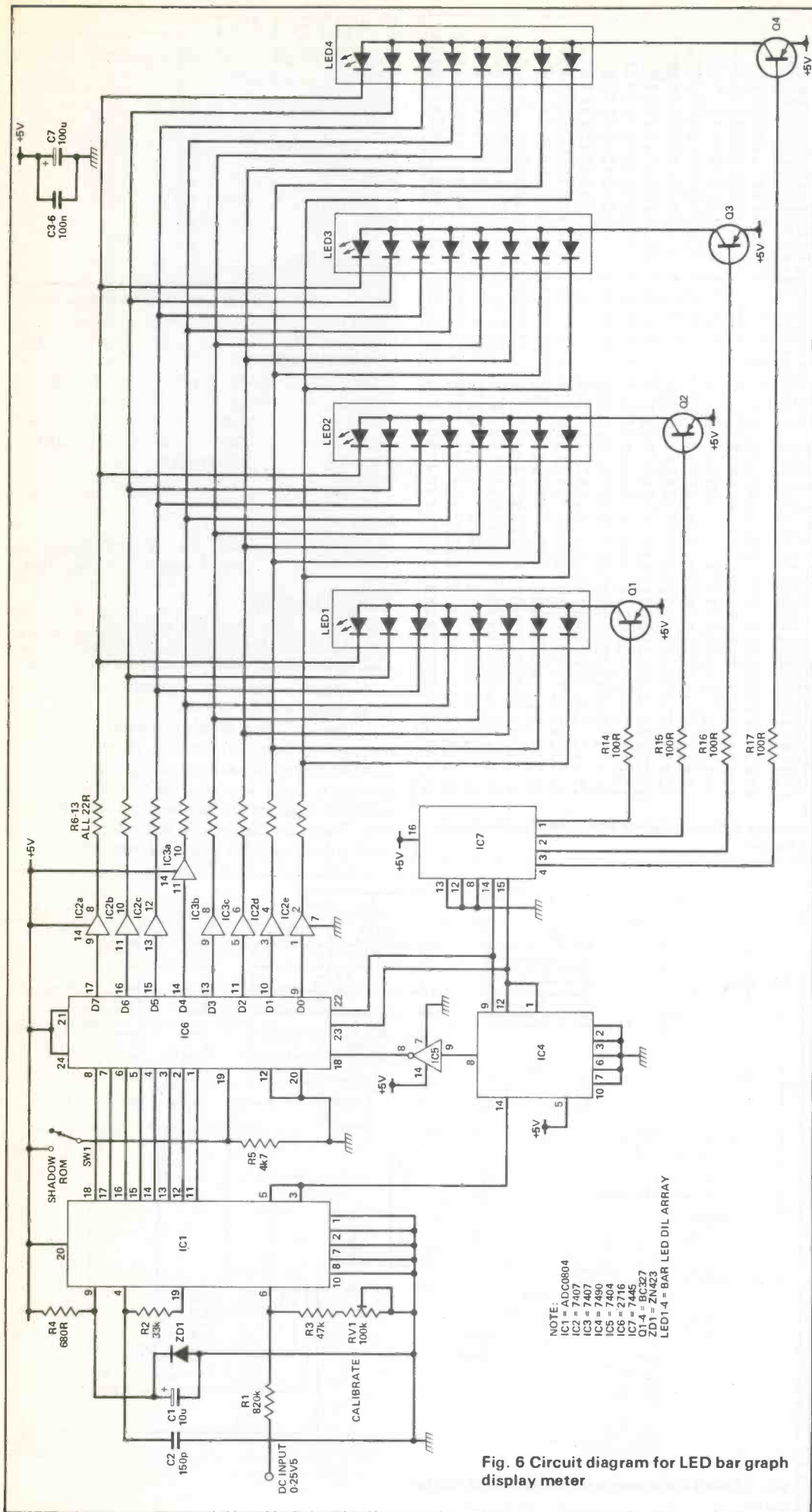
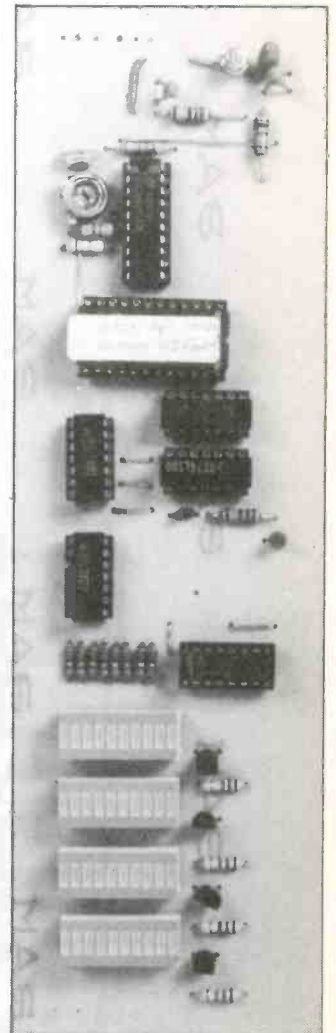


Fig. 6 Circuit diagram for LED bar graph display meter



Address	Data
&0000-&0007	&FE
&0008-&000F	&FD
&0010-&0017	&FB
&0018-&001F	&F7
&0020-&0027	&EF
&0028-&002F	&DF
&0030-&0037	&BF
&0038-&003F	&7F
&0040-&013F	&FF
&0140-&0147	&FE
&0148-&014F	&FD
&0150-&0157	&FB
&0158-&015F	&F7
&0160-&0167	&EF
&0168-&016F	&DF
&0170-&0177	&BF
&0178-&017F	&7E
&0180-&027F	&FF
&0280-&0287	&FE
&0288-&028F	&FD
&0290-&0297	&FB
&0298-&029F	&F7
&02A0-&02A7	&EF
&02A8-&02AF	&DF
&02B0-&02B7	&BF
&02B8-&02BF	&7F
&02C0-&03BF	&FF
&03C0-&03CF	&FE
&03CB-&03CF	&FD
&03D0-&03DF	&FB
&03DB-&03DF	&F7
&03E0-&03EF	&EF
&03EB-&03EF	&DF
&03F0-&03FF	&BF
&03FB-&03FF	&7F

Listing 1 Hex data for scale display

0000	C0	F9	A4	B0	99	92	83	F8	B0	98	C0	F9	A4	B0	99	92
0010	B3	F8	B0	98	C0	F9	A4	B0	99	92	83	F8	B0	98	C0	F9
0020	A4	B0	99	92	83	F8	B0	98	C0	F9	A4	B0	99	92	83	F8
0030	B0	98	C0	F9	A4	B0	99	92	83	F8	B0	98	C0	F9	A4	B0
0040	99	92	83	F8	B0	98	C0	F9	A4	B0	99	92	83	F8	B0	98
0050	C0	F9	A4	B0	99	92	83	F8	B0	98	C0	F9	A4	B0	99	92
0060	83	F8	B0	98	C0	F9	A4	B0	99	92	83	F8	B0	98	C0	F9
0070	A4	B0	99	92	83	F8	B0	98	C0	F9	A4	B0	99	92	83	F8
0080	B0	98	C0	F9	A4	B0	99	92	83	F8	B0	98	C0	F9	A4	B0
0090	99	92	83	F8	B0	98	C0	F9	A4	B0	99	92	83	F8	B0	98
00A0	C0	F9	A4	B0	99	92	83	F8	B0	98	C0	F9	A4	B0	99	92
00B0	83	F8	B0	98	C0	F9	A4	B0	99	92	83	F8	B0	98	C0	F9
00C0	A4	B0	99	92	83	F8	B0	98	C0	F9	A4	B0	99	92	83	F8
00D0	B0	98	C0	F9	A4	B0	99	92	83	F8	B0	98	C0	F9	A4	B0
00E0	99	92	83	F8	B0	98	C0	F9	A4	B0	99	92	83	F8	B0	98
00F0	C0	F9	A4	B0	99	92	83	F8	B0	98	C0	F9	A4	B0	99	92
0100	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7
0110	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7
0120	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7
0130	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7
0140	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7
0150	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7
0160	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7
0170	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7
0180	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7
0190	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7
01A0	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7
01B0	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7
01C0	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7
01D0	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7
01E0	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7
01F0	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7
0200	C0	C0	C0	C0	C0	C0	C0	C0	C0	C0	C0	F9	F9	F9	F9	F9
0210	F9	F9	F9	F9	A4	A4	A4	A4	A4	A4	A4	A4	A4	A4	A4	B0
0220	B0	B0	B0	B0	B0	B0	B0	B0	B0	B0	B0	B0	B0	B0	B0	B0
0230	99	99	92	92	92	92	92	92	92	92	92	83	83	83	83	83
0240	83	83	83	83	83	F8	F8	F8	F8	F8	F8	F8	F8	F8	F8	F8
0250	B0	B0	B0	B0	B0	B0	B0	B0	B0	B0	B0	B0	B0	B0	B0	B0
0260	98	98	98	98	C0	C0	C0	C0	C0	C0	C0	C0	C0	C0	C0	F9
0270	F9	F9	F9	F9	F9	F9	F9	F9	A4	A4	A4	A4	A4	A4	A4	A4
0280	A4	A4	B0	B0	B0	B0	B0	B0	B0	B0	B0	B0	B0	B0	B0	B0
0290	99	99	99	99	99	92	92	92	92	92	92	92	92	92	92	92
02A0	83	83	83	83	83	83	83	83	83	F8	F8	F8	F8	F8	F8	F8
02B0	F8	F8	F8	F8	B0	B0	B0	B0	B0	B0	B0	B0	B0	B0	B0	B0
02C0	98	98	98	98	98	98	98	98	C0	C0	C0	C0	C0	C0	C0	C0
02D0	C0	C0	F9	F9	F9	F9	F9	F9	F9	F9	F9	F9	A4	A4	A4	A4
02E0	A4	A4	A4	A4	A4	A4	B0	B0	B0	B0	B0	B0	B0	B0	B0	B0
02F0	99	99	99	99	99	99	99	99	99	99	99	92	92	92	92	92
0300	C0	C0	C0	C0	C0	C0	C0	C0	C0	C0	C0	C0	C0	C0	C0	C0
0310	C0	C0	C0	C0	C0	C0	C0	C0	C0	C0	C0	C0	C0	C0	C0	C0
0320	C0	C0	C0	C0	C0	C0	C0	C0	C0	C0	C0	C0	C0	C0	C0	C0
0330	C0	C0	C0	C0	C0	C0	C0	C0	C0	C0	C0	C0	C0	C0	C0	C0
0340	C0	C0	C0	C0	C0	C0	C0	C0	C0	C0	C0	C0	C0	C0	C0	C0
0350	C0	C0	C0	C0	C0	C0	C0	C0	C0	C0	C0	C0	C0	C0	C0	C0
0360	C0	C0	C0	C0	F9	F9	F9	F9	F9	F9	F9	F9	F9	F9	F9	F9
0370	F9	F9	F9	F9	F9	F9	F9	F9	F9	F9	F9	F9	F9	F9	F9	F9
0380	F9	F9	F9	F9	F9	F9	F9	F9	F9	F9	F9	F9	F9	F9	F9	F9
0390	F9	F9	F9	F9	F9	F9	F9	F9	F9	F9	F9	F9	F9	F9	F9	F9
03A0	F9	F9	F9	F9	F9	F9	F9	F9	F9	F9	F9	F9	F9	F9	F9	F9
03B0	F9	F9	F9	F9	F9	F9	F9	F9	F9	F9	F9	F9	F9	F9	F9	F9
03C0	F9	F9	F9	F9	F9	F9	F9	A4	A4	A4	A4	A4	A4	A4	A4	A4
03D0	A4	A4	A4	A4	A4	A4	A4	A4	A4	A4	A4	A4	A4	A4	A4	A4
03E0	A4	A4	A4	A4	A4	A4	A4	A4	A4	A4	A4	A4	A4	A4	A4	A4
03F0	A4	A4	A4	A4	A4	A4	A4	A4	A4	A4	A4	A4	A4	A4	A4	A4
03FO	A4	A4	A4	A4	A4	A4	A4	A4	A4	A4	A4	A4	A4	A4	A4	A4

Listing 2 The complete hex dump for the digital display

PARTS LIST

RESISTORS (all 1/4W 5% unless specified)

R1	820k
R2	33k
R3	47k
R4	680R
R5	4k7
R6-13	22R DIL
R14-17	100R
RV1	100k preset

CAPACITORS

C1, 7	10µ 16V tantalum
C2	150µ polystyrene
C3-6	100n ceramic

SEMICONDUCTORS

IC1	ADC0804
IC2, 3	7407
IC4	7490
IC5	7404
IC6	2716 EPROM
IC7	7445
Q1-4	BC327
ZD1	ZN423T
LED1-4	Either 0.5in 7-segment digit common anode display or 10-bar DIL array

MISCELLANEOUS

SW1	Single pole toggle
Case. Wire. Nuts and bolts. 5V power supply.	

usual order — resistors, capacitors, IC sockets, zener diode and transistors.

The LED bar graph columns need a little preparation before mounting. Only the bottom eight segments of each column are used and the anodes of these are bent up or cut short, then soldered together in common anode configuration. These are then connected to the two unused (and unbent) anodes which fix into the PCB.

TOP PROJECT

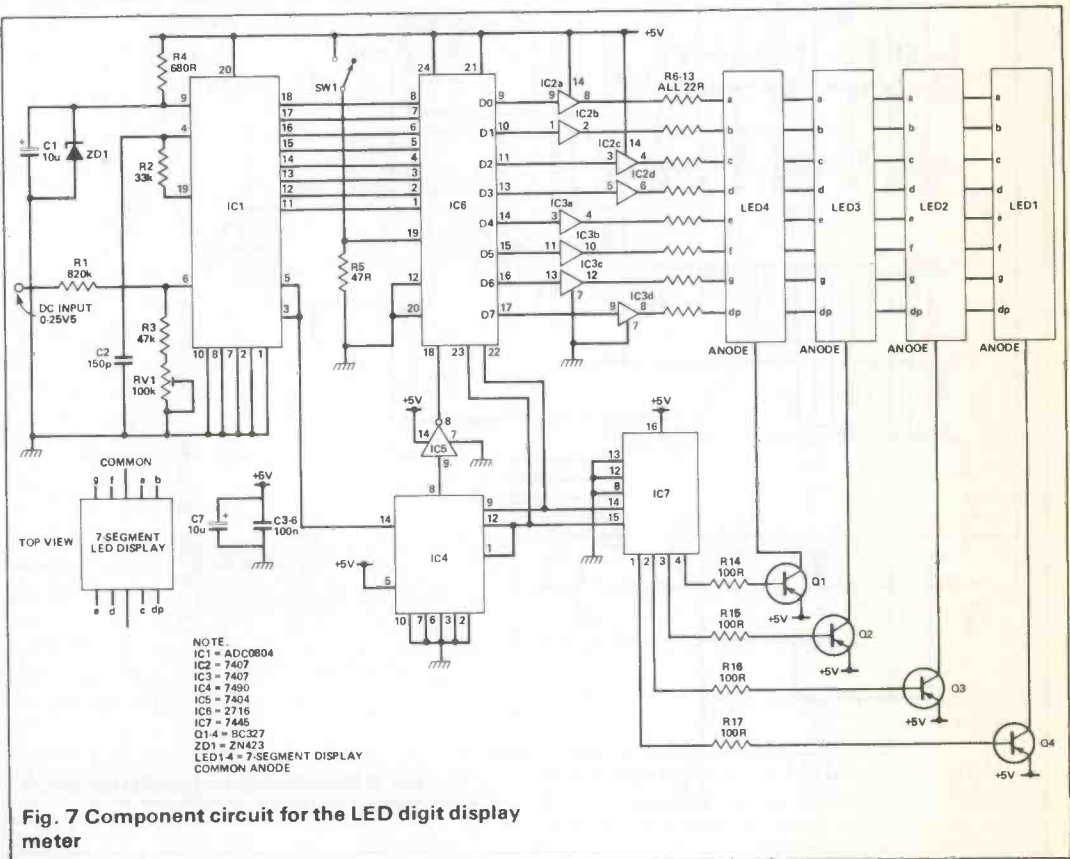


Fig. 7 Component circuit for the LED digit display meter

TOP PROJECT

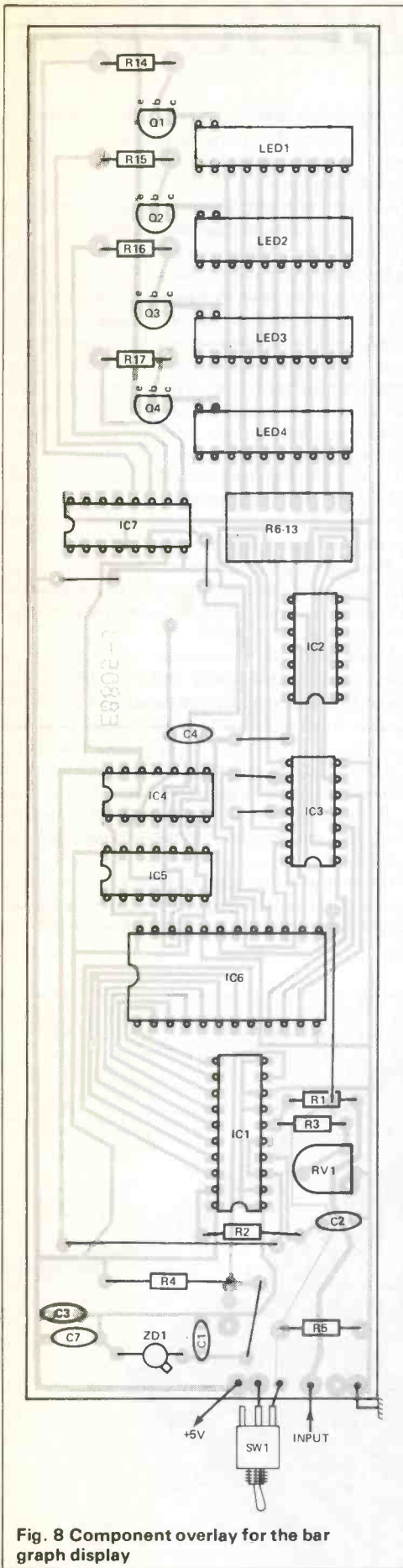


Fig. 8 Component overlay for the bar graph display

With the LEDs in place you can program your EPROM to behave as you desire, put your ICs into place and enjoy the luxury of your own uniquely personal digital panel meter.

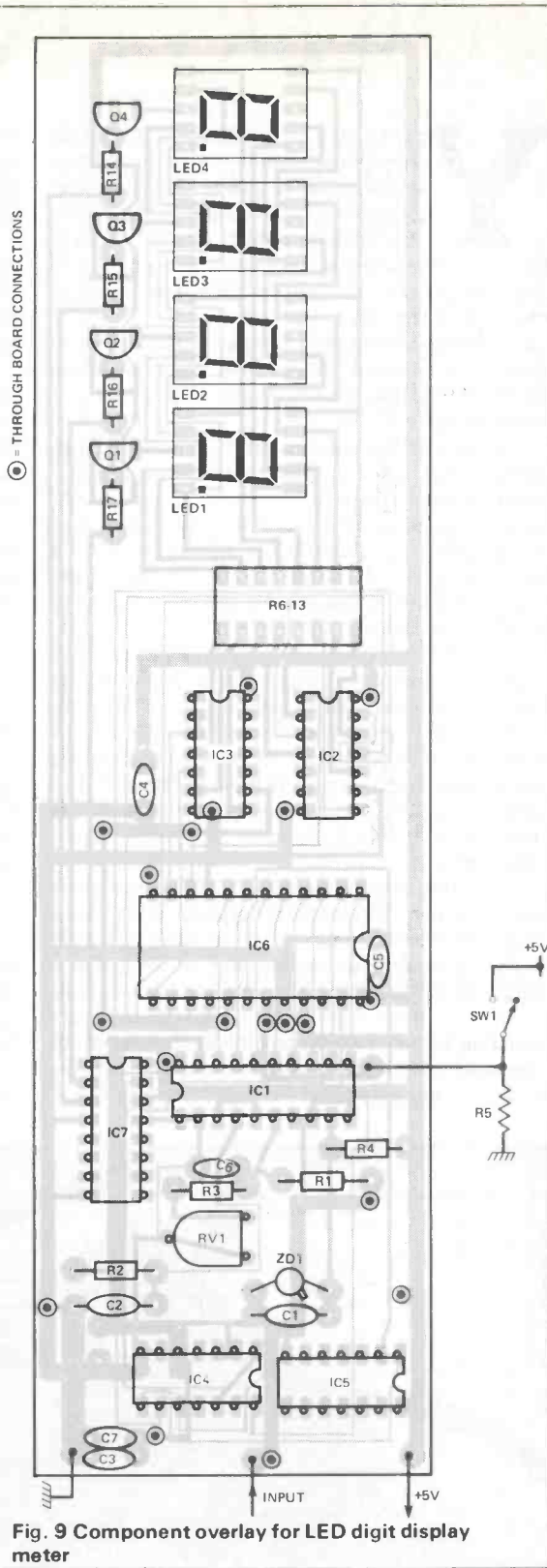


Fig. 9 Component overlay for LED digit display meter

BUYLINES

All components are available from most component suppliers except perhaps IC7 and ZD1.

IC7 is stocked by STC as either a National or TIIC (the National is cheaper — stock No 29350A). STC, Edinburgh Way, Harlow, Essex CM20 2DF. Tel: (0279) 441687.

ZD1 can be obtained from Electromail (stock number 283-233).

Address Data

&0400-&0407 &FE
&0408-&040F &FC
&0410-&0417 &FB
&0418-&041F &FO
&0420-&0427 &EO
&0428-&042F &CO
&0430-&0437 &BO
&0438-&043F &OO

&0440-&04FF &OO
&0500-&053F &FF

&0540-&0547 &FE
&0548-&054F &FC
&0550-&0557 &FB
&0558-&055F &FO
&0560-&0567 &EO
&0568-&056F &CO
&0570-&0577 &BO
&0578-&057F &OO

&0580-&05FF &OO
&0600-&067F &FF

&0680-&0687 &FE
&0688-&068F &FC
&0690-&0697 &FB
&0698-&069F &FO
&06A0-&06A7 &EO
&06A8-&06AF &CO
&06B0-&06B7 &BO
&06B8-&06BF &OO

&06C0-&06FF &OO
&0700-&07BF &FF

&07C0-&07C7 &FE
&07C8-&07CF &FC
&07D0-&07DF &FB
&07DE-&07DF &FO
&07E0-&07E7 &EO
&07E8-&07EF &CO
&07F0-&07F7 &BO
&07F8-&07FF &OO

Listing 2 Hex data for bar display



POWER CONDITIONER

Paul Chappell's mains is close-up clean thanks to this top spec and remarkably attractive power conditioner

Year by year the pollution of the mains supply grows steadily worse. In addition to the usual industrial effluents from rotating machinery, waste products from switch mode power supplies, sewage from drills, washing machines, vacuum cleaners and oven thermostats, there are now plans afoot to pollute the mains deliberately.

I hardly need to mention the consequences — streaky TV pictures, popping and crackling radios, mushy hi-fi sound. Greenpeace — where are you when we need you?

Mains borne interference is not a thing to be taken lightly. Spikes of 1kV and above are common (in some areas frequent) and this can and does damage unprotected equipment. A simple voltage dependent resistor (VDR) connected between live and neutral of the mains plug will usually forestall damage to the equipment but it doesn't prevent the annoying interference effects.

Apart from spikes and impulsive interference, there is a constant background of more regular interference which gets steadily worse as time goes on. RF interference has become more of an annoyance since the CB boom and the increasing use of switch mode power supplies adds its own contribution. The latter are supposed to be suppressed at source but this only serves to reduce the interference and doesn't eliminate it.

Another development has been the increasing use of the mains for signalling purposes. At its lowest level this can be equipment such as cordless intercoms but the problems associated with sending digital signals through the mains are rapidly being overcome.

Some years ago National Semiconductors introduced the Bi-Line system, the front end of which was an IC (the LM1893) which puts data through the mains by means of an FSK modulation system. It was,

by its nature, for localised use but this and similar systems — even the home computer add-ons for through-the-mains control — are all adding to mains borne interference.

A system to eliminate gas and electricity meter readers has now reached the stage of field trials. The idea is that meter readings are sent via the mains as far as the nearest sub-station, from where they will be transferred to telephone lines by means of a modem.

This long distance use of mains signalling obviously can't be suppressed, so a band has already been set aside for it. One can envisage a time when the 'mains waves' will be just as strictly regulated (and just as crowded) as the air waves. The effects on hi-fi and audio equipment have yet to be seen.

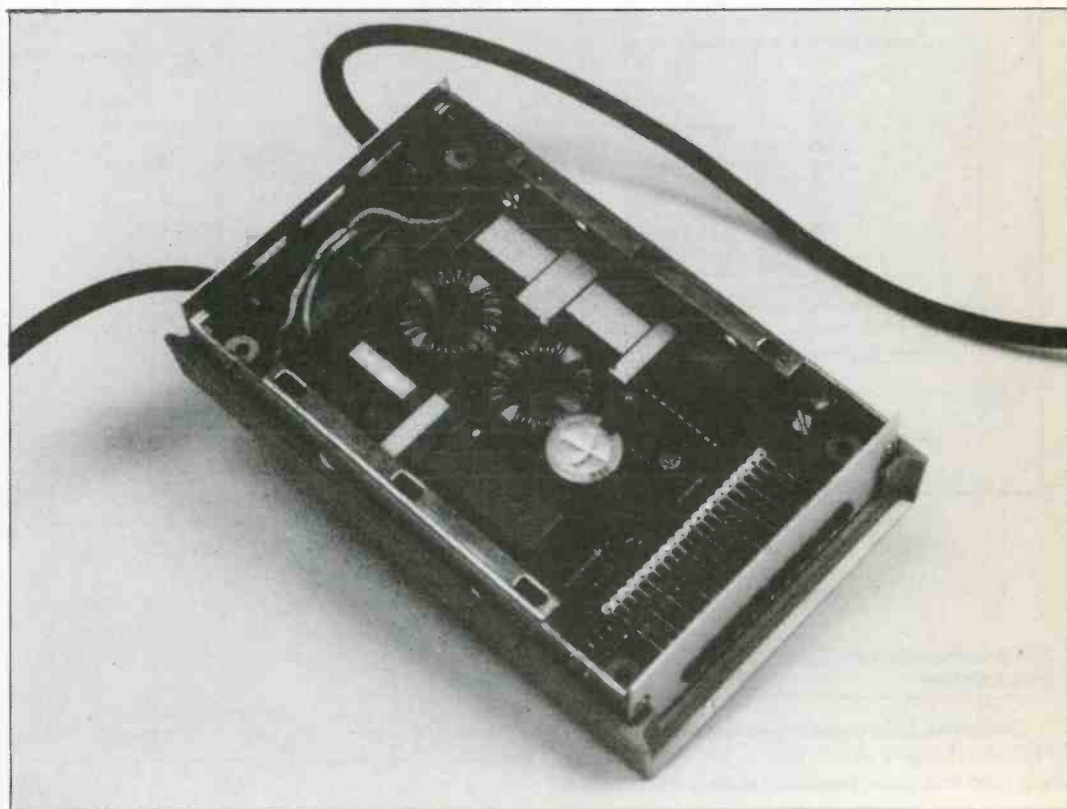
In addition to all this man-made interference, there is another source which will always be beyond any kind of legal regulation and control — the weather. Electric storms and even lightning strikes make their presence felt through the mains.

The only way to be sure of an unpolluted power supply for your audio equipment, TV or computer is to clean it up yourself. The ETI power conditioner is the tool you need for the job.

Inside the conditioner the mains supply is purified, transients are cleared and RF interference is blocked. The clean supply is then fed to a socket or multi-way outlet which can supply power to all your sensitive equipment.

If you find it hard to believe that the mains is really as polluted as I say, this project will certainly convince you. A unique feature is its bar graph display which actually lets you see how much interference it is removing.

As you watch the LEDs marking an occasionally flick way up towards the top of the scale, you'll be in no doubt that the power conditioner is working for its living.



TOP
PROJECT

The Dorchester Doorman

The correct way to avoid any problems with mains connections, the gospel goes, is to plate all your plugs with gold. The reasoning behind this was explained to me by the proprietor of Hi-Price Audio to be something like this:

The gold plating on the plug, he explained, acts very much like the uniform of the doorman at the Dorchester Hotel. Nice, well-bred sine waves know that they will be welcome inside, whereas interference is overawed by the golden splendour of the doorman's uniform and embarrassed by its own scruffy appearance. It knows that it will feel out of place in such magnificent equipment and wanders on in search of the electronic equivalent of a Yummy Eater fast food bar.

"Besides," he said, "if punters fink they can hear a difference am I going to argue?" I was impressed by his logic and bought a dozen.

Of course, back in the real world we have a mains filter which actually works to consider.

The circuit is shown in Fig. 1. The filter begins with six VDRs. This is partly a concession to the fringe hi-fi community who believe that if one is good, six must be six times as good. For a given spike, the clamping voltage will be reduced by an infinitesimal amount by having a number of VDRs in parallel, due to the highly non-linear voltage to current relationship of these devices.

It's rather like hoping to reduce the forward voltage drop of a diode by wiring half a dozen in parallel. It will be reduced very slightly but not so you'd notice the difference.

For more rational beings, there is another reason for having half a dozen VDRs.

A VDR will only absorb a certain amount of energy from a spike before becoming stressed beyond its limits. If these limits are exceeded, it can result in the VDR breaking open and scattering zinc oxide far and wide. After that, your equipment is no longer protected.

One of the essential figures on a VDR data sheet is the maximum energy it can absorb in a short period of time. Figures of 5-20 joules in 10µs are common for small components. To increase the energy you have the choice of buying a larger VDR or using

several in parallel.

Parallels

The parallel option has the advantage that you can choose how much protection you want to give (an

HOW IT WORKS

The filter section begins with six VDRs, which are intended to remove the damaging effects of high energy transients on the mains. To some extent they will reduce impulsive interference effects too but will not eliminate them.

The filter section will remove RF interference from the power lines. The current balanced inductors in combination with the Y-capacitors (C8, 9, 12, 13) serve to clean up common mode interference, while the X-caps (C1-6 10, 11) do the same for differential mode noise.

The current balancing in the toroids prevents the cores from saturating under the effects of the current drawn by the load.

The pick off coil from the first toroid detects any imbalance caused by interference currents flowing to ground via the Y-capacitors. The signal is amplified by IC1a and passed to the detector circuit consisting of Q1 and 2 and associated components.

This detector responds to the peak value and to the duration of the signal, so a short, high voltage pulse will give the same reading as a sustained, low amplitude burst.

IC1b feeds the detected voltage to IC2, which is a common or garden bargraph drive IC.

The LEDs are fed with current pulses from D5 to reduce the overall current consumption of the circuit and dissipation in IC2. The IC is switched to dot mode twice each cycle of the mains, (via pin 9) to reduce the current requirements still further.

If you look closely at the display, you might just discern a difference in brightness between the highest dot and the rest of the bar but the overall effect is of a continuous bar display.

The power for the low voltage circuit is derived from the mains via C14, R3 prevents damaging inrush currents if the mains happens to be close to its peak value at the time the circuit is switched on.

R2 provides a discharge path for C14 when the conditioner is disconnected from the mains or if the fuse should blow.

This kind of power supply does not isolate the low voltage circuit from the mains and is only suitable for use in completely self-contained pieces of equipment like the conditioner. The supply capacitor will be large but nowhere near as bulky or heavy as a mains transformer for circuits requiring small currents (up to 100mA or so).

A capacitor used in this way should be X-rated since it is effectively connected across the mains.

TOP PROJECT

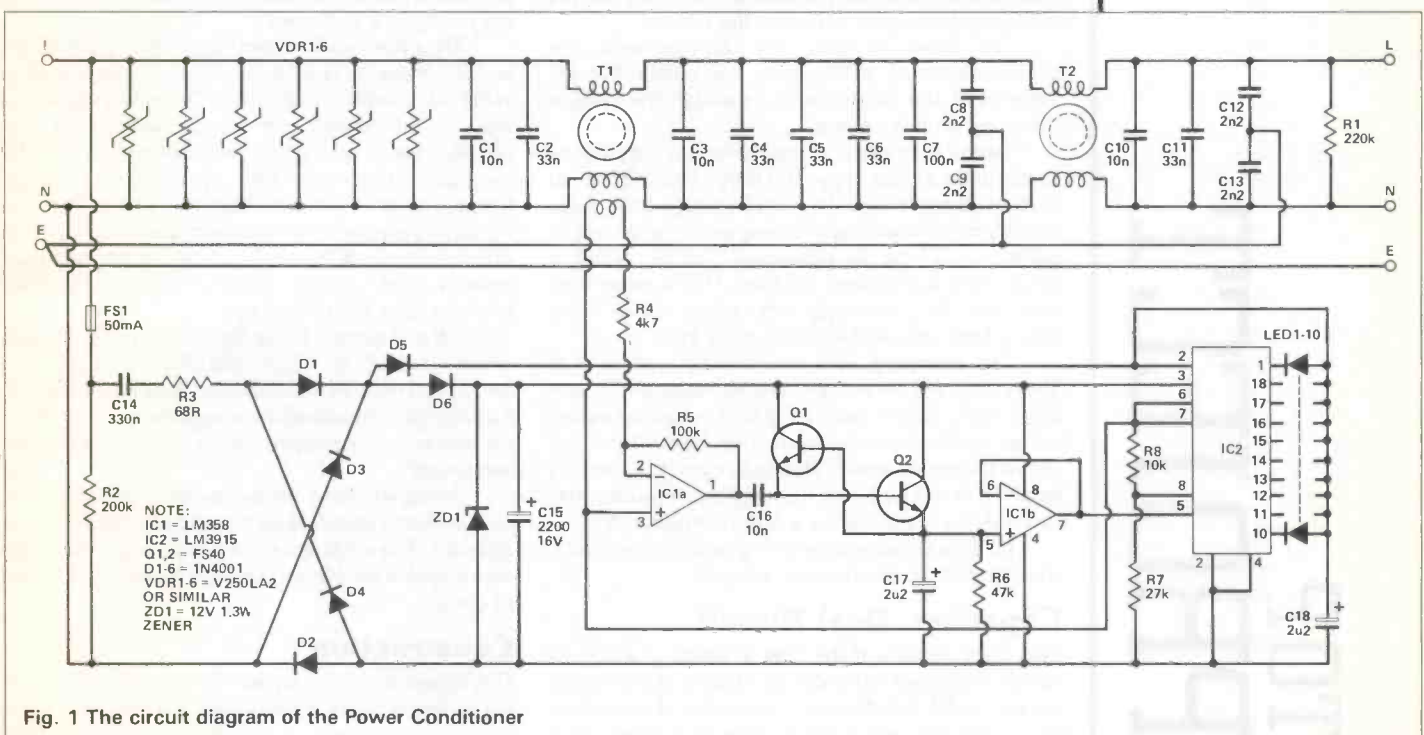


Fig. 1 The circuit diagram of the Power Conditioner

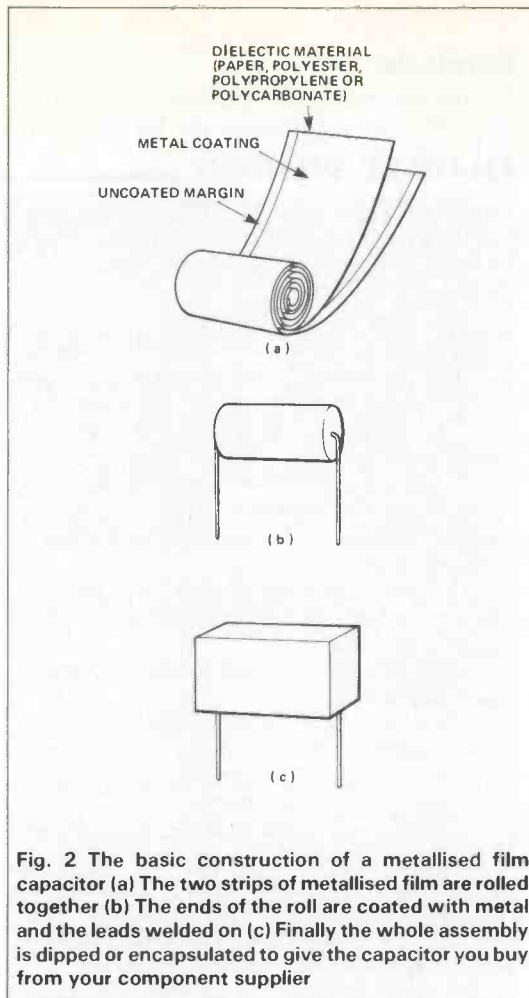


Fig. 2 The basic construction of a metallised film capacitor (a) The two strips of metallised film are rolled together (b) The ends of the roll are coated with metal and the leads welded on (c) Finally the whole assembly is dipped or encapsulated to give the capacitor you buy from your component supplier

upgradeable mains filter!) and that the average absorption over a longer period of time will be greater than for a single large VDR.

It could be that because of an electric storm you get just the conditions to pop a large VDR (and your equipment) but which would allow the parallel combination to continue giving protection. Speaking as one whose new TV set was zapped last year by a thunderstorm which exploded the plug VDR too, the more protection you can give, the better.

For those of you not familiar with the characteristics of VDRs, they are rather like AC versions of the Zener diode, although the voltage clamping is not so sharp.

Below their rated voltage they are virtually an open circuit. A little above this they begin to conduct until at about twice the rated voltage they have virtually no resistance at all. It may seem that a sharper cut-off would be an advantage but too quick a conduction would lead to blown VDRs every time there was a long term surge in the mains voltage. They are, in fact, very well suited to their job.

The clamping voltage is usually measured at 100A and will be somewhere between 600V and 800V for a device rated for 240V mains operation (which will begin to conduct at about 350V — just above the mains peak). The peak current for even a small VDR will be many hundreds of Amps but this can only be sustained for a few microseconds.

High peak currents for a very short time is exactly what impulsive interference will give.

Capacitor, Heal Thyself

The main section of the filter consists of a pair of current balanced inductors and banks of capacitors to remove RF interference. A number of capacitors in parallel are used in preference to a single large

capacitor to take advantage of the much higher self resonant frequency of the smaller caps and also because they are generally able to withstand short term thermal and voltage overload better than their larger brothers.

The value of the capacitors to earth is limited by the need to comply with earth leakage regulations — they are the maximum allowable values, taking into account their tolerance and should not be increased under any circumstances.

Connecting capacitors across the mains puts them under enormous stress and components not designed for the job can easily catch fire, short circuit or at best just quietly fail — even if the voltage rating is high enough.

Capacitors which have been designed to withstand the stresses and to comply with the appropriate standards are divided into three main categories: Class X1 are for connection between live and neutral in situations where pulses of over 1.2kV can be expected. Class X2 are for connection between live and neutral where transients will not exceed 1.2kV. Class Y are made to the highest standard of all and are used for connection between a power line and earth or any other situation where failure might expose someone to a lethal shock.

Most capacitors for mains use have the rather magical sounding property of self-healing. This is a consequence of the metallised film construction, the essentials of which are shown in Fig. 2.

The dielectric material is coated with a very thin layer of aluminium — around 300 Angstroms (3×10^{-8} metres) thick. Two dielectric strips will be coated — one with a margin on the left hand side and one with a margin on the right. The two will then be wound together so that the metal film of one 'plate' extends to one side of the roll and the other to the opposite side.

To make the connections, the two sides of the roll are sprayed with metal from a flame or arc gun and the lead attached.

You can see this kind of construction in the 'naked' metallised polyseter capacitors — the block shaped ones with metal at either end and leads that fall off at the slightest provocation. These caps are layered in long strips and then sawn up into individual capacitors rather than being individually wound, but the principle is the same.

The difference between class X and Y capacitors and the cheap 'n' cheerful metallised types is mainly in the standard of construction. The mains capacitors may be interleaved with paper (sounds an odd material but it had some excellent properties), be vacuum impregnated with epoxy to remove air pockets where ionisation may take place, be series wound to reduce electrical stresses, have several layers of bonding metal, be encapsulated in fire retardant material and so on. Construction varies from manufacturer to manufacturer.

If the dielectric is punctured by a high voltage spike, instead of short circuiting through the carbonised mess left behind when the dielectric burns, the very thin metallisation is vapourised away from the area and the capacitor carries on as if nothing had happened!

Strictly speaking, the metallisation is oxidised, the oxygen being supplied by the decomposition of the dielectric. The oxide doesn't conduct, so the damaged area is sealed off. It's not quite self-healing but almost as good!

Construction

The component overlay for the project is shown in Fig.3. Some of the components are mounted vertically to save space — the leads should be bent

carefully and not too close to the body of the component to avoid stressing the bonding.

The best way is to hold the lead just above the component body in a pair of pliers, then to bend the lead in a smooth curve with finger and thumb.

The VDR positions have two holes for the 'live' connections, allowing components with either a 0.2in or 0.3in lead pitch to be mounted. Similarly, the capacitor which supplies the low voltage circuit has two pads for one of its connections to allow two popular sizes of capacitor to be mounted. The remaining hole is left unused.

Each coil on the two toroids had 15 turns of 1mm diameter enamelled wire. Each coil is a mirror image of its counterpart on the opposite half of the core. In addition to the power windings, T1 has a further pick-off coil of 15 turns of 0.25mm diameter wire over the centre of the coil in the neutral line. This connects to points A and B on the circuit board. The direction of this winding is not important.

The 1mm diameter wire is firm enough to support the toroids on its own (in fact, you'll need quite strong fingers to wind it into a neat coil) but holes have been provided on the PCB for strapping them down with cable ties, just to be sure.

Figure 4 shows details of the inlet and outlet cables and connections. A 2BA bolt and solder tag is used to earth the metal chassis of the case and to provide a connection point for all the earth wires. Strain relief grommets must be used on the panel cable holes to clamp the leads firmly in place.

The front panel is drilled with a line of hole at

0.2in intervals for the LEDs. I used 3mm round red LEDs in the prototype but there is no reason why you should not use other shapes or colours if you wish. The usual black mounting clips can be used but they will have to be pared slightly with a sharp knife to fit the 0.2in spacing of the holes. Otherwise, you may prefer the appearance of the LEDs without clips.

Whether or not the clips are used, the LEDs should be stuck in place with epoxy resin so there is no possibility of the leads touching the panel or slipping through and becoming exposed.

The low voltage section of the circuit is not isolated from the mains, so for safety purposes must be thought of as live.

When the LEDs and the inlet and outlet cables have been attached to their respective panels, you can solder the power connections to the PCB.

The LEDs are best left unconnected until the case had been assembled. Otherwise you won't know how short to trim the leads. Screw the chassis together, with the PCB resting on the bottom flanges of the side pieces. Turn the whole assembly over and check that there is enough clearance between the metal flanges and the pads and tracks of the PCB. Check also for solder blobs, untrimmed leads or any swarf on the flanges that might cause a short between the metal and the PCB tracks.

When you are sure that all is well, fit the chassis into the bottom section of the case and screw the PCB to the support pillars. The LED leads can now be trimmed to size and soldered to the header pins on the PCB.

All that remains is to put in the fuse, screw down the lid of the case, press in the rubber feet and your Power Conditioner is complete!

PARTS LIST

RESISTORS (all 1/4W 5%)

R1, 2	220k 1/2W
R3	68 1W
R4	4k7
R5	100k
R6	47k
R7	27k
R8	10k

CAPACITORS

C1, 3, 10	10n class X2
C2, 4-6, 11	33n class X2
C7	100n class X2
C8, 9, 12, 13	2n2 class Y
C14	330n class X2
C15	2,200µ 16V radial electrolytic
C16	10n ceramic
C17	2µ2 16V electrolytic
C18	2µ2 tant or 10µ electrolytic, 16V

SEMICONDUCTORS

IC1	LM358
IC2	LM3915
Q1,2	FS40
ZD1	12V 1.3W zener
D1-6	1N4001
VDR1-6	V250LA2, Mullard 593/4 series, or equivalent
LED1-10	3mm red LED

MISCELLANEOUS

FS1	PCB mounting fuse clips and 50mA fuse
T1,2	FX4054 coated toroid cores wound with 1mm and 0.25mm enamelled wire as per the text

PCB. Case. 20-way right angle PCB header. Mains plug. Mains socket or multi-way connector. 0.75mm² mains cable. Strain relief grommets. LED clips. Nuts and bolts.

Testing

There is very little that could be wrong with the filter

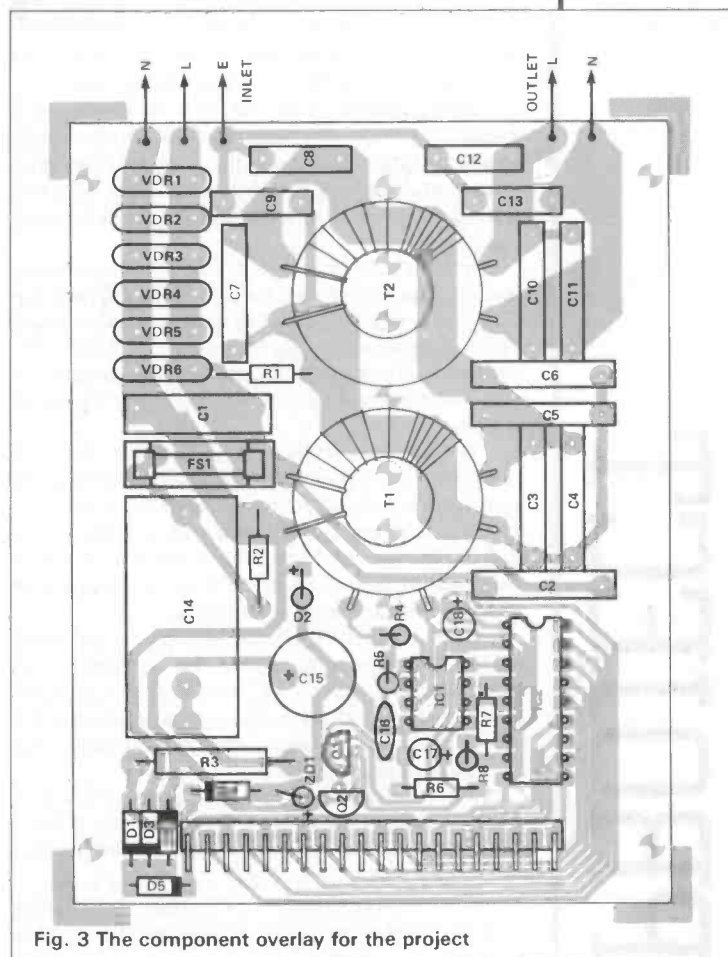
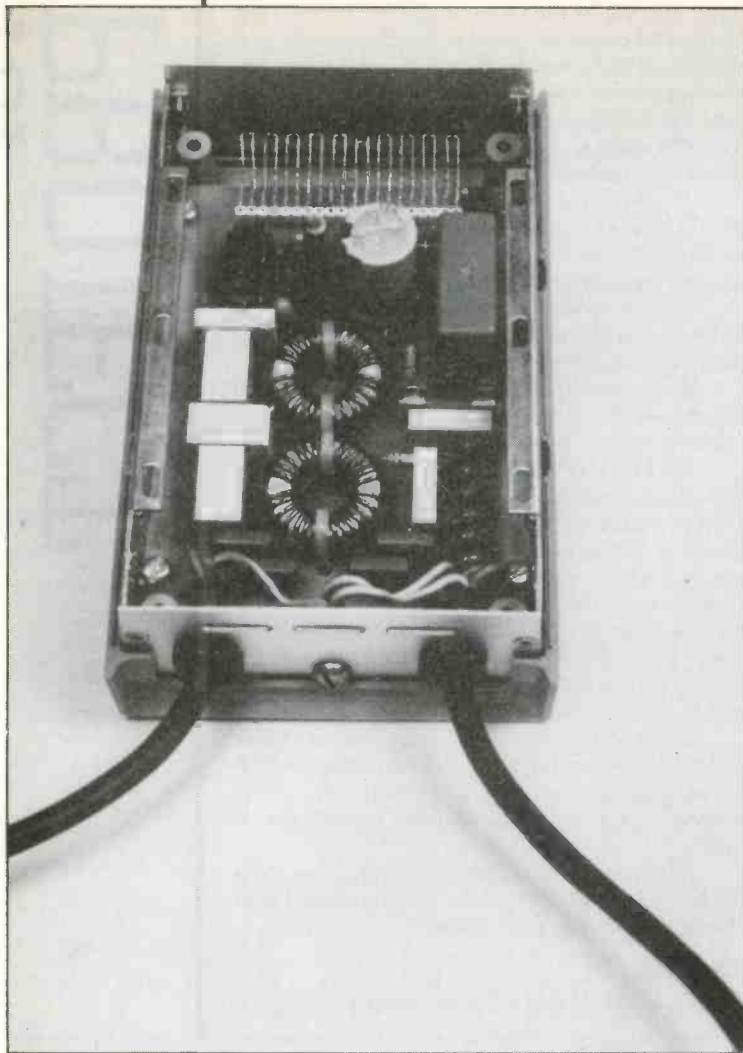


Fig. 3 The component overlay for the project



section of the circuit except for open or short circuits (you did check the PCB carefully, didn't you?)

Before plugging in, it's best to do a quick resistance check. Set your multimeter to a high resistance range and check the resistance between ground and live on the inlet lead, then between ground and neutral. Both should appear as an open circuit.

If there is any movement of the meter whatsoever, *don't attempt to use the conditioner*. Check the PCB again, check your input lead connections and if both of these seem OK, take out each Y-capacitor in turn and check its resistance. The fault can only be in one or other of these places, so you won't have far to look.

A resistance measurement between live and neutral on the inlet or outlet lead should show up as a resistance of about 220k — the discharge resistor. If it is much below this (say, below about 180k, which could just be the result of resistor tolerance and meter inaccuracies) take out the fuse to the low voltage circuit and see if this makes any difference.

If not, check the PCB carefully and as a last resort check the resistance of each of the X-capacitors. A final possibility — if you've damaged the coating of the copper wire on the toroid coils and allowed the two coils to touch (I hope not!) this will also cause problems (to say the least!)

If all is well so far, check the continuity of the live, neutral and particularly the earth connections. (Check the resistance between the input earth and output earth and make sure it's zero).

After making sure that there is a suitable fuse in the plug, apply power to the conditioner but don't plug anything into the output socket yet. You should see

the LED display flick upwards as you turn on the power, then the LEDs will go out one by one until they are all extinguished. If you keep watching the display for a while, you'll probably see it flick upwards every now and again as the conditioner catches some interference. Even with nothing connected to the output, it still removes pollution and gives an indication of how much there is around.

If all the LEDs light up and remain lit, don't instantly conclude that there's something wrong. Take a look around and see if you can find anything that might be causing a lot of interference.

When I first tested the prototype in the ETI lab, all the LEDs lit up and I spent several minutes puzzling what could be wrong — everything seemed OK. Then the photocopier in the next room stopped printing . . .

Now is the time to find out how good a job you've made of winding the coils. Plug your hi-fi, TV set or whatever into the outlet socket and take another look at the LED display. The sensing circuit will always pick up a certain amount of 50Hz signal from slight imbalances in the inductor and from slight difference in the Y-capacitor values but it should not be enough to swamp the display.

If most or all of the LEDs remain lit ten seconds or so after plugging something into the output socket, there is a good chance that you have one turn too many or too few on one of the coils.

If one or two LEDs remain constantly lit, you can improve matters by adjusting the coils (or rewinding them if they're untidy!) or as an absolute desperation measure, the value of R5 can be reduced to bring the display into line. The heavier the load, the more apparent any imbalances will be — an electric fire makes a good test load.

If the display section does not seem to be working properly, don't attempt to test it with its capacitor power supply. Remove all connections from the mains, set your bench power supply to about 16V, connect the negative lead to the negative lead of C15 and the positive lead to the junction of C14 and R3. Connect the negative lead of the multimeter to the negative terminal of your power supply.

Check the voltages on pins 9 and 3 of IC2. Both should be 12V (or within 1V either way). If both are higher, ZD1 is probably faulty. If only one is higher, check D5 or D6. If either or both are low, disconnect the power and check all the diodes (in particular, check they are the right way around). Also check C15 and C18 and the PCB for shorts.

If the readings are OK so far, check the voltage at pins 6 and 7 of IC2 and pins 1,2 and 3 of IC1. They should all be the same at about 6V. Touching a finger to pin 2 of IC1 should cause all the LEDs to light. Remove the finger and they should turn off one by one.

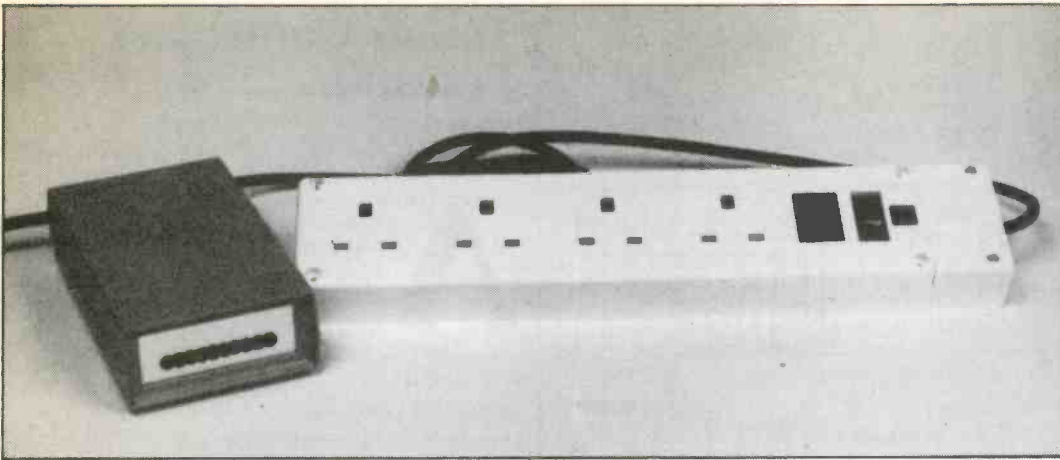
If this works but the display doesn't seem to pick up anything from the mains, check R4 and the connections to the pick-off coil.

If nothing happens at all, measure the voltage at the positive plate of C17 and see if it rises when you touch the IC pin. If not, check for a short in C17 (or a solder blob across its pads!) and the connections of Q1, Q2, and C16.

If the voltage across C17 rises, but the LEDs don't light, check the voltage at pin 5 of IC2. This should also rise. If not, IC1 is faulty. If it does rise but the LEDs don't light, check all the connections around IC2 and replace it if necessary. If the voltage across C17 remains high at all times (without the finger), suspect Q1, Q2 or C16.

Using The Conditioner

In the form presented so far, the Power Conditioner



can be used with loads of up to 1.5kW. It will, in fact, cope with load of 2kW intermittently — I tested the prototype by running it for an hour with a 2kW electric fire as a load. It didn't come to any harm but it did get rather hot!

Most domestic equipment will have a label or tag on it somewhere to say how much power it consumes. If you are using a multi-way output socket, don't forget to add the loading of all the equipment you have plugged into it.

As a very rough guide, a TV set consumes 100 to 150W, a 100W per channel hi-fi will consume about 300W with the volume turned up to full blast, a home computer may be anywhere between 10W and 250W depending on whether it had its own screen, disk drives, or whatever.

It is also important to use mains cable that is

suited to the load. To be on the safe side, you could wire the conditioner up immediately with 13A cable but it's wasted if you're only running small, sensitive devices.

the normal 0.5mm² mains flex will cope with loads of up to 750W total. The thicker 0.75mm² cable will be OK up to 1.5kW, so this is probably best compromise.

Unless you intend to load it to the limit, a 5A fuse in the inlet plug is advisable. If you are in doubt about any of this, your local electric shop will probably have an electrician who can advise you.

The conditioner will cope with all likely loads as it is (you don't really want to decontaminate the power to your electric fire, do you?) However, there are always one or two big-number enthusiasts who want to upgrade to the limit.

The way to do it is simply to use thicker wire to wind the toroids. You'll be faced with the option of using fewer turns (which is OK as long as all the coils have the same number, although low frequency performance will be impaired) or of overlapping the turns slightly. I wish you luck!

If you do have an application for the higher current version, it would be advisable to solder some thick copper wire along the main current carrying tracks (the wide ones) on the PCB.

Unless you can find a way of winding the coils evenly, or are willing to accept fewer turns, you will probably find the bargraph registering 50Hz pick up. Reducing the value of R5 will prevent it from swamping the display, which will then be less sensitive but should still give a good indication of the suppression.

There is no lower limit to the value of R5 — it's up to you to choose a suitable compromise between rejection of unwanted pick up and display sensitivity.

In areas of high RF interference, it is a good idea to keep all leads *after* the conditioner as short as possible. Use the inlet lead to give you the reach you need, then keep the outlet leads trimmed short. Most of the time this will not be critical but it's worth bearing in mind if you live next door to a CB enthusiast Twelve-ten till we do it again, good buddies!

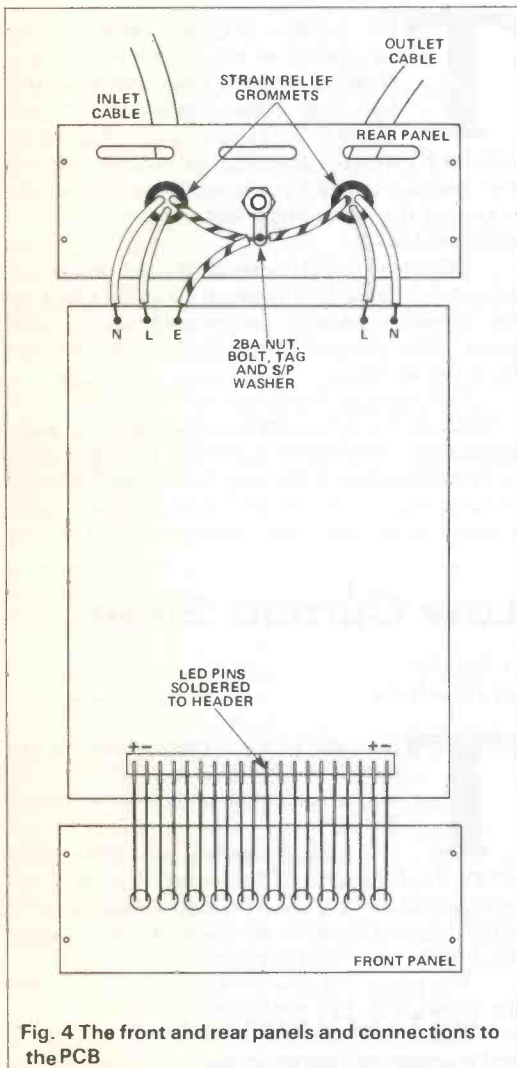


Fig. 4 The front and rear panels and connections to the PCB

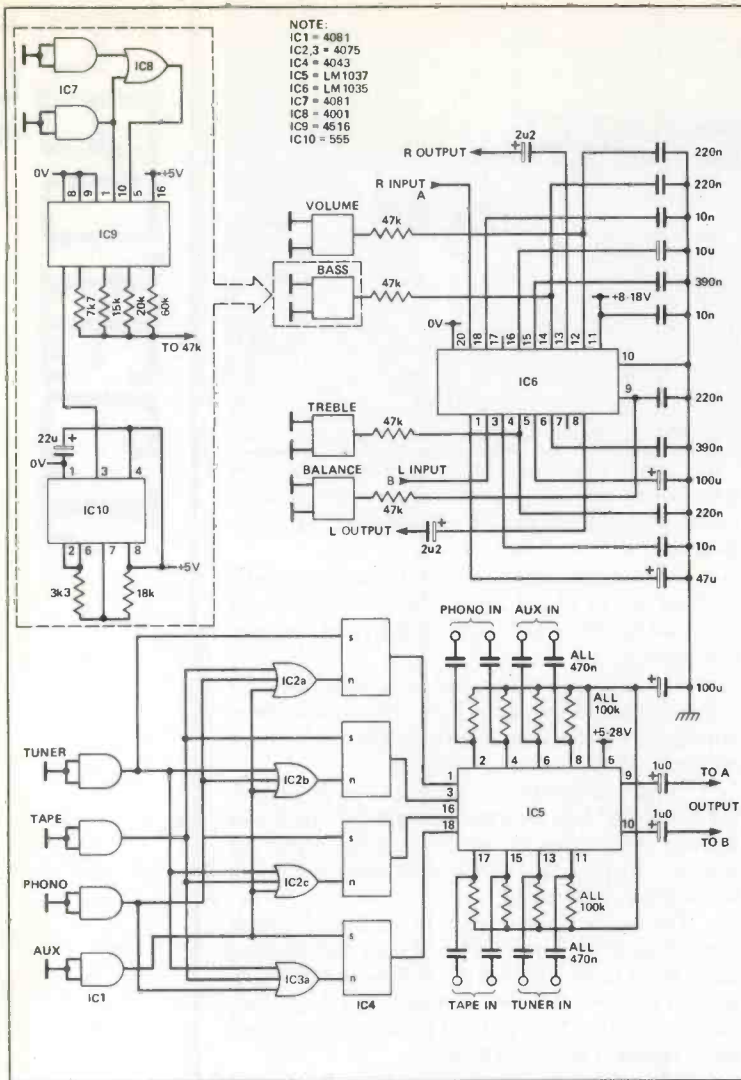
BUYLINES

The case is available from West Hyde Developments, toroids and X- and Y-rated capacitors from Farnell. The PCB can be obtained from our PCB service and other components from your usual supplier.

The plug, socket and mains cable is available from Woolies or from your local electrical shop.

A complete parts set for this project, including case, PCB, components, (but not the mains plug, socket and cable) is available for £28.50 + 60p postage + VAT from Specialist Semiconductors, Founders House, Redbrook, Monmouth, Gwent.





Touch Controlled Pre-amp

A J Bird
Walsall

A touch controlled pre-amp with touch plate selection of inputs and volume, bass, treble and balance can be easily constructed with the help of the LM1037 and 1035 audio control ICs.

The touch plate sensors rely on the tied inputs of the AND gates (IC1, 11, 21, 31, 41) floating low and being taken high by a touch on the plate.

IC2, 3 form a latching arrangement so that each touch on an input selector plate will set the relevant flip-flops and reset the others.

The four flip-flop outputs are used to switch on a pair of inputs to IC5 through to IC6. This uses the DC voltage from the four identical volume, bass, treble and balance circuits to filter and attenuate the stereo channels.

The DC control voltage is obtained by weighting the 4-bit output from up/down counter IC13 (23, 33 and 43). The counter is clocked by the 555 timer in astable mode and enabled to count up or down by IC11 and IC12.

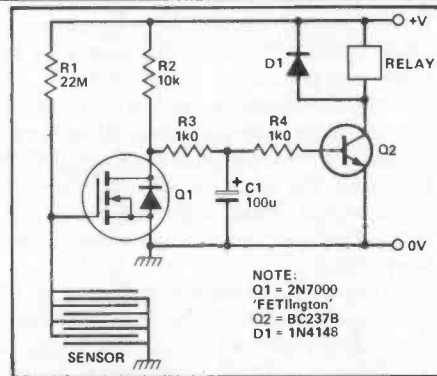
Cheap Touch Switch

R J Fletcher
Penzance

This circuit, originally designed as the switch of an alarm system for a disabled person, takes advantage of the high input impedance of the 2N7000 'FETlington.' The high value resistor R1 pulls the gate of Q1 to the positive rail. If the operator's finger is placed across the sensor contacts, the gate voltage falls close to zero. This switches Q1 off.

Q2 acts to invert the signal from Q1 and so the relay is normally de-energised. R3 and R4 provide the correct voltage at the base of Q2. C1 adds some delay to overcome any 'contact' bounce from the sensor.

The type of transistor used for Q2 is not critical and nor is the supply rail voltage. R1 may be reduced to 10M to reduce sensitivity. With a value of 22M it was found the switch could be activated by breathing on the sensor! For the prototype a small piece of stripboard was used for the sensor.



Low Current Siren

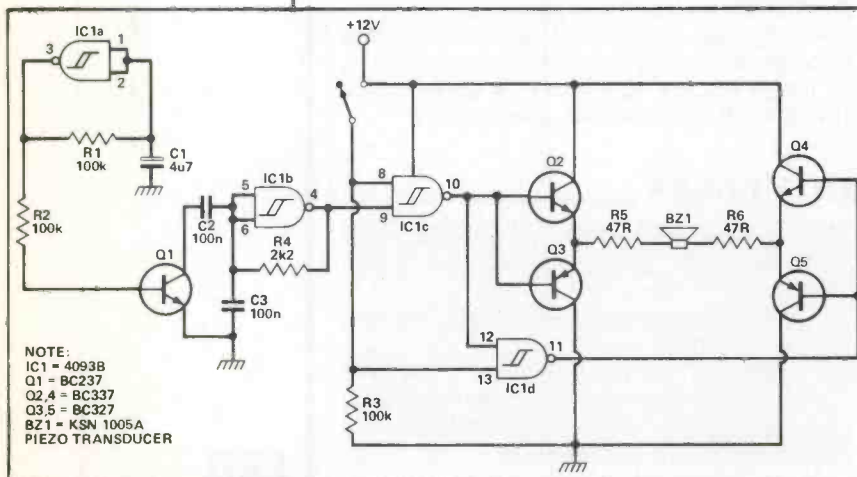
G Landry
South Africa

This efficient circuit provides an output of 10V RMS (approx 103dB at 1m) at a current consumption of only 30mA.

Low frequency oscillator IC1a varies the frequency of audio oscillator IC1b by switching in and out C2. The rapidly varying audio signal is gated by IC1c to output amplifier stage Q2,3 and an inverted signal is passed to Q4,5.

The piezo transducer is connected between the stages with 20V peak-to-peak across it.

Resistors R5 and R6 serve to limit the current and stabilise the output stages.



GAS ALERT

TOP PROJECT



Greg Thompson promises not to set the world alight with this top-spec gas detector design

Gas explosions in the home, caravans and the like are becoming virtually a daily occurrence. The ETI modular gas detection system will help to reduce these horrific accidents.

The system will detect and provide early warning of the presence of domestic gas, bottled gas based on methane and explosive vapours such as petrol fumes and other hydrocarbons.

Good Sense

Most inflammable vapour sensors are based on what is known as the 'hot-wire' principle. This involves a small heater element inside the sensor.

The sensor chosen incorporates the usual heater element which is designed to operate at 5V ($\pm 0.2V$). The sensor output is quite simply a varying resistance.

This resistance remains stable whilst the sensor is in clean air but the resistance across the sensor drops when gas or explosive vapour is detected. The heater element and resistive detector are two independent circuits within the sensor.

As with all hot-wire sensors, respect must be given to current consumption. The heater element in this sensor will draw approximately 170mA when supplied by a 5V regulator but this current drain compares favourably with other available devices.

Talking of other devices, use of the 'two dome' sensor/compensator type detector should be avoided. These detectors consume more current and are rendered useless if allowed to absorb silicone. Gas alarms that are utilised in domestic applications can easily become contaminated with the silicone used in

many household spray polishes.

It may seem strange or even absurd to incorporate a heater element in a gas sensor as such a system appears to be a source of ignition itself.

The sensor type used here has been vigorously tested in an atmosphere of 2:1 hydrogen/oxygen — a very explosive mixture. These tests were carried out under normal conditions and with an internal spark, both without causing ignition. This is due to the extremely fine stainless steel gauze used in the construction of the sensor.

The sensor itself is an internationally proven and accepted device and we stress it cannot itself be a source of ignition. However, careful consideration must be given to the circuit and system in which it is used. It's OK for your electric toaster to blow you off the face of the earth but if your gas alarm does the same, it's not on, is it?

It is worth pointing out at this stage that due to relatively high current power consumption it is neither practical nor recommended to operate such a gas detector from dry cell or NiCd batteries.

In this design we have incorporated an independent relay output in the form of a simple single pole make switch. The relay used is of the sealed reed type. This is important as relay contacts create a spark when thrown.

The relay output is included so the detector can be used to trigger existing alarm systems or any external device for that matter.

Some of the more ingenious readers may decide to develop subtle luxuries such as switching in your extractor fan to help to 'clear the air'.

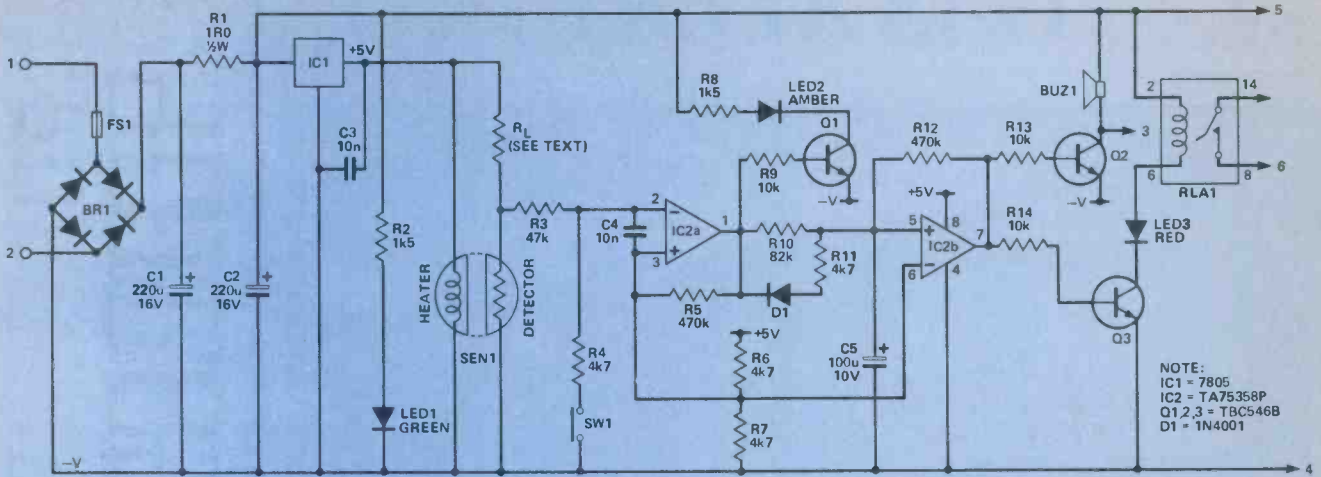


Fig. 1 The circuit diagram of the Gas Alert

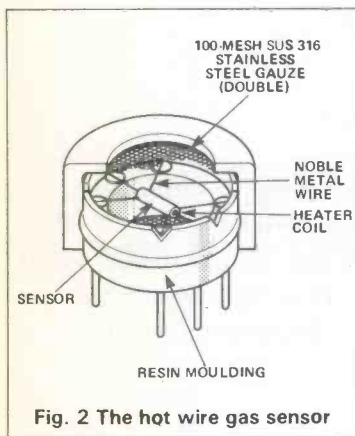


Fig. 2 The hot wire gas sensor

You may well decide to do this by using the internal reed relay to throw an external mains relay. Mains relays are usually of the open type and will without doubt cause a spark sufficient to ignite a gas filled room. It's recommended that a triac switching circuit be used for switching in any mains powered add-on.

We could also add that the electric motor inside extractor fans will also produce an arc from its commutator brushes but for the moment we'll assume most extractor fans are sufficiently sealed and in any event are normally exposed to clean air on one side.

Having scared the living daylights out of you we should now tell you that the alarm will function well before an explosive mixture is allowed to accumulate.

The point at which a mixture of air and explosive vapour or gas will ignite is known as its lower explosive limit (LEL). Such mixtures are defined in parts per million (PPM). This is the molecular count of explosive mixture per one million molecules of air. The LEL is dependent on the PPM — got it!

Our gas alarm will trigger when an atmosphere of between 10% and 40% LEL has been reached. This may seem a rather large tolerance window but it includes all explosive atmospheres — methane (natural gas), butane, propane and so on, and other vapours (petrol, methanol, ethanol, propanol, Navy Rum, etc).

Alarmingly Falsified

False alarms are a day-to-day saga in the majority of warning and detection devices of all types. Sophisticated electronic devices incorporating failsafe and fail failsafe are normally so safe that they fail to register anything or they are continually being triggered by just about everything except the gas they were designed for.

It's not a bit of good having a gas detection system triggered off by a quick squirt of hair spray or cooking deposits in the air. It's just switched off when everybody is so fed up of grabbing their wallets and



HOW IT WORKS

Power enters the circuit via a protective fuse. The specified transformer supplies about 10.5V on the +V rail.

C1, R1 and C2 form a smoothing filter which acts as a safeguard should the unit be powered from an unsmoothed supply. IC1 is a 5V regulator from which the sensor and IC2 are powered. C3 is an additional smoothing capacitor.

LED1 and its series resistor R2 are positioned across the supply rails to provide power-on indication.

The heater element of the sensor is fed directly from the 5V rails. IC2a acts as a voltage comparator biased by resistor R_L and the sensor itself. R3 and C4 raise the input impedance and also stabilise the op-amp inputs.

When the sensor detects gas its resistance drops below that of R_L causing the voltage at the inverting input (pin 2) to swing negative which in turn causes the output (pin 1) to go high. The non-inverting input (pin 3) is biased to half the supply potential by R6 and R7 enabling the op-amp to make its comparative decision against the voltage at pin 2.

R10, C5 and R11, D1 form the time delay stage. When gas is detected, pin 1 goes high which will after approximately 13 seconds take pin

5 high (the non-inverting input of IC2b).

If the gas dissipates within 13 seconds, pin one returns low (its normal state). C5 then discharges through R11 and D1. Pin 1 must remain high for the full duration of the 13 seconds before the final alarm is triggered.

Any brief encounter with gas will be shown by the illumination of amber LED2. This is turned on whenever pin 1 goes high via R9 and Q1.

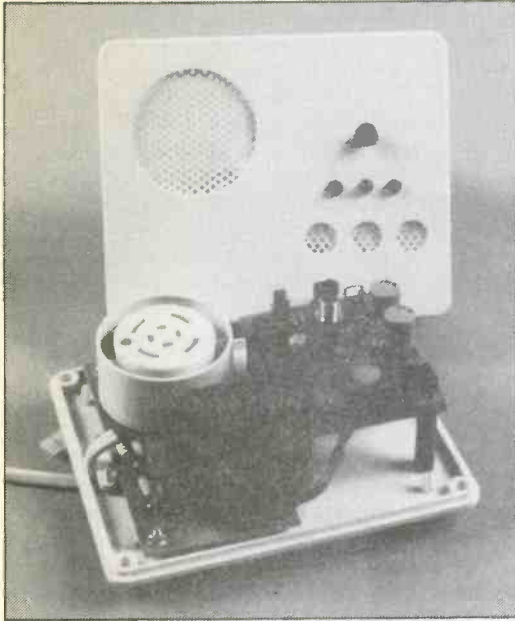
IC2b again serves as a voltage comparator also biased by R6 and R7. If gas is detected for a longer period than 13 seconds, the non-inverting input (pin 5) is held high causing the output (pin 7) to also go high. When this happens Q2 and Q3 are also turned on thus switching on the buzzer, red LED3 and reed relay RLA1 via Q3.

The coil of the reed relay also serves as a series resistance for LED3.

Pin 8 and 14 of the relay form a single pole switch. These contacts are normally open and close when the device is triggered.

Push-button SW1 when closed will test the entire circuit. This takes pin 2 low via R4 in the same way that the sensor operates when it has detected a presence of gas.

purses and running out into the street and going four or five doors down the road to use someone's phone (next door is too near, they'll go up as well!)



Now Hear This

The British Standards Institute is in the process of receiving a draft proposal from British Gas in respect of domestic gas alarms. Although the document will delve into meticulous detail of test procedures involving gas concentrations, temperature and air pressure, notwithstanding wind velocity, it would appear that some of the more important factors have been overlooked.

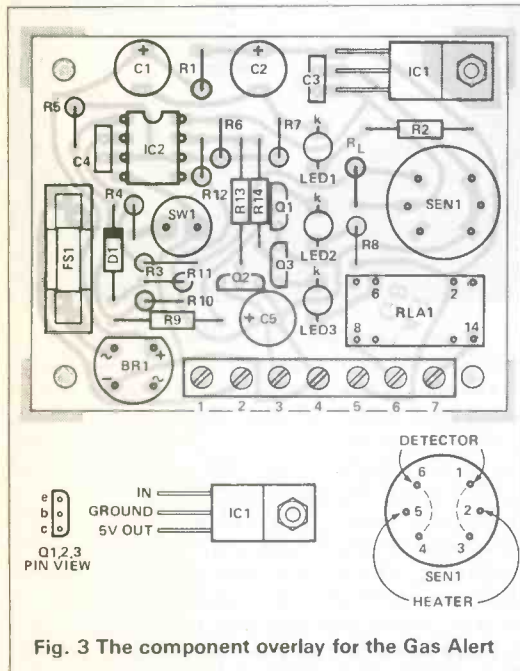


Fig. 3 The component overlay for the Gas Alert

The whole purpose of an alarm is to let someone know something is happening. Quite sensibly, the Standard had opted for an audible alarm which it stressed must have a sound level output of 85dB at 3m but it omits to specify the frequency of the sound!

It may well be that if you buy a gas alarm that has been manufactured to British Standards, your first indication of an imminent explosion is the dog going berserk or your mynah bird flat on its back in the cage pushing up the daisies.

About 400-700Hz would be suitable. However

PARTS LIST

RESISTORS (all 1/4 W 5%)

R1	1R0 1/2W
R2, 8	1k5
R3	47k
R4,6,7,11	4k7
R5, 12	470k
R9,13,14	10k
R10	82k

CAPACITORS

C1,2	220µ 16V radial electrolytic
C3,5	10n ceramic
C5	100µ 16V radial electrolytic

SEMICONDUCTORS

IC1	7805
IC2	TA75358P
Q1-3	TBC546B
D1	1N4001
BR1	W02
LED1	Green LED
LED2	Amber LED
LED3	Red LED

MISCELLANEOUS

BJZ1	Piezo buzzer
FS1	500mA, 20mm fuse
RLA1	SPST 12V 1kΩ coil DIL reed delay
SEN1	Hot wire gas sensor and matched resistor
SW1	SPST push switch 7V mains transformer
PCB	7-way terminal block. Case. Nuts and bolts.

even at the desired frequency, 85dB is certainly not over loud. In an average house you may have an alarm installed in your kitchen. If the kitchen door is closed, your bedroom door is closed, it's the middle of the night and you're asleep, it is open to interpretation as to whether you would hear an alarm operating at this sound pressure level.

The ETI system has an internal buzzer rated at 75dB at 1m but serious provision had been made for external louder audible sounders positioned wherever required. This is of particular importance in larger houses.

Sensors

In the near future British Gas may invite you (at your own cost, of course) to have a gas detection device fitting in your kitchen. That's fine if you get a gas leak in your kitchen but what about the gas meter under the stairs, the gas fire in the lounge, the central heating boiler in the garage or what have you.

In the light of that, consideration should be given to the installation of more than one sensor in order

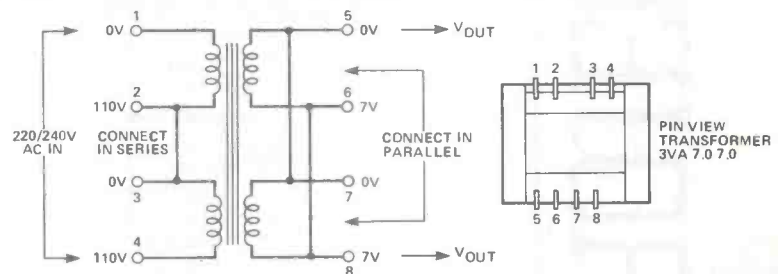


Fig. 4 The 7-0, 7-0 transformer supplied in the Live Audio Systems kit is specifically designed to power the hot wire sensor. For UK mains it must be wired up as shown

TOP PROJECT

to provide comprehensive cover.

The ETI Gas Alert is designed to operate from an AC or DC supply producing 12V. Up to now we have dealt with practical considerations for domestic installations and for this purpose a 24V mains transformer is used.

Boats and (more so) caravans are also prone to gas leaks from faulty low pressure bottled gas (LPG) systems.

This system can be powered from standard 12V lead-acid car batteries — the normal source of power for boats and caravans. The current consumption of around 200mA under normal working conditions, would not be a serious drain on such battery systems.

The consumption of the unit rises above 200mA when the alarm is triggered but the last thing you are going to worry about is a flat battery if you're about to spontaneously combust!

The Circuit

As previously mentioned, false alarms are not acceptable in any gas alarm system. The sensor supplied for this project requires no setting-up or calibration. Each individual sensor has been calibrated prior to leaving the manufacturer's factory.

During the manufacture of a complex device such as this component, material tolerances are unavoidable. The inclusion of a resistor (R_1) which is supplied with the sensor enables the device to operate within the prescribed parameters.

If you are assembling more than one detector, care must be taken to ensure each sensor and its companion resistor do not get mixed-up.

As a precaution it is worthwhile measuring the resistance of the resistor supplied and writing its value on the side of the sensor with a fine permanent marker. You will need to use an accurate digital meter if you choose to do this.

IC1 acts as two voltage comparators. As with the rest of the components, a good quality op-amp is chosen — the Toshiba TA75358. In fact this is a dual op-amp in an 8-pin DIL package — an LM358. It

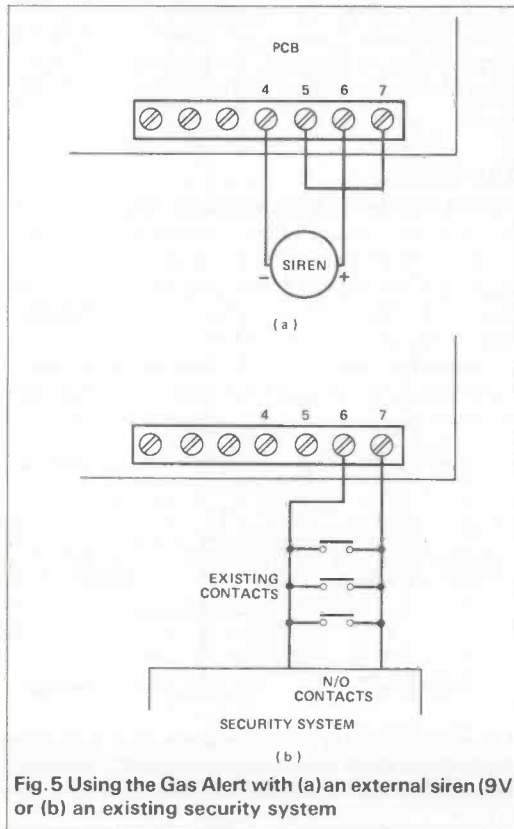


Fig. 5 Using the Gas Alert with (a) an external siren (9V) or (b) an existing security system

The Sensor

Whilst most of us are more interested in the electrical and environmental characteristics of the sensor, the physical philosophers and philosophically fit will be eager to learn how it works. You will see from Fig. 2 that the heater element passes through a small ceramic tube. This is coated with a layer of tin oxide SnO_2 .

If tin oxide is heated in a 'clean air' atmosphere, oxygen is absorbed into the surface layer. The rate of absorption remains constant at a given temperature. If, however, a contaminant combustible gas is introduced, this will also be absorbed.

The reaction of a combustible gas with the oxygen causes electrons to be released from the oxygen giving the tin oxide greater electrical conductance. This all takes place between the two electrodes at either end of the ceramic tube. The resultant factor is increased conductivity which is equal to the lowering of its electrical resistance.

features distinct advantages in a circuit of this type.

It is specifically designed to operate on single supply rails, has very low current consumption and its output will swing fully low.

Whilst on the subject of Toshiba, the TBC546B transistors were chosen, again being a quality device and are equivalent to BC546. All right Tosh!

Construction

Assembling the Gas Alert should provide no particular problems, particularly if the recommended PCB (Fig. 3) is used.

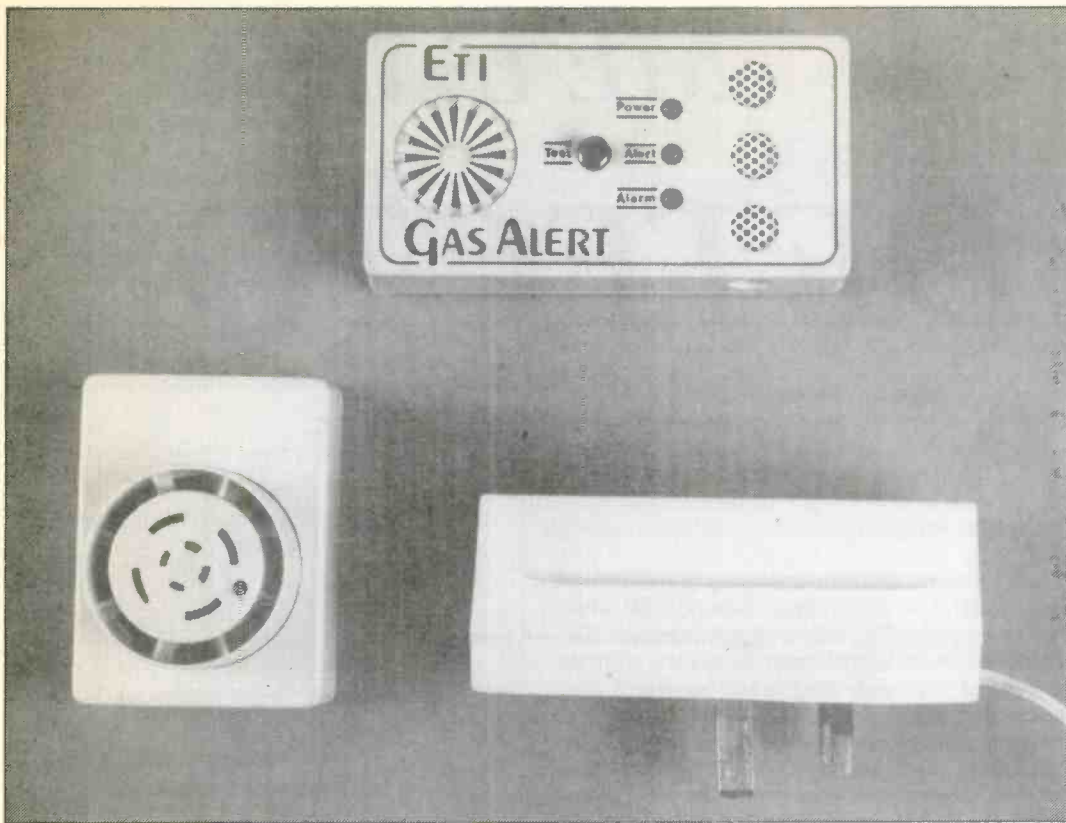


In the recommended case, the component leads should be trimmed close to the board underside to enable the backpanel to be fitted. The LEDs should be soldered in first with 8mm sleeves over the leads so that they stand proud of the board at the correct height to protrude through the case top. The test button should be soldered in next. It must be positioned exactly vertical and with careful comparison to the height of the LEDs for correct positioning. Although it is a little awkward to have this test button protruding throughout construction, it must be fitted at this stage since the amount of heat required might damage more delicate components. The nut on the test button is unused and the pins need trimming off.

The voltage regulator IC1 is bolted flat to the board with its pins at right angles. A small heatsink may be placed on top (held in place by the bolt) but this is not imperative.

The fuseholders should be installed with the fuses in place. Solder in the tags and trim. Fit the bridge rectifier and check its polarity.

The transistors and ICs can now be fitted, again with attention to their orientation. Solder the relay into place, treating it like an IC. If the relay is not required,



insert a 1k Ω resistor between pinholes 2 and 6 to load LED3.

The transformer may be mounted with an additional fuse (500mA) in the mains live input if desired. Rectification and smoothing are performed on the PCB. The transformer can either be mounted in a plug-topped box or in the complete unit with the alarm sounder.

Note that the sensor is a rugged 6-pin device which requires no special handling precautions. However, a device such as this should be treated with respect. Neither the heater element nor the internal detector are polarised — they have no positive or negative supply requirement.

The pinout configuration ensures it cannot be inserted into the PCB incorrectly (there are two possible ways and either will do). You will see from the pinout that pins 1 and 3 of the sensor are connected internally, as are 6 and 4. So, pin 1 or 3 and pin 6 or 4 are the sensor's resistive detector. Pin 2 and 5 supply the heater element.

Testing

The unit can be tested by pressing a cigarette lighter over the sensor for about 15 seconds (don't light it unless you want to melt your PCB). The 'Alert' LED (LED 2) should light almost immediately and the alarm should sound after about 20 seconds.

If this doesn't happen (and the supply voltages are known to be operational) then check polarity of components, terminal numbers on the transformer and look for soldering errors.

Installation

Some thought should be given to siting the Gas Alert module or modules. Try to place them near likely sources of leaks — the kitchen, gas meter, gas fires and so on.

If used for detecting LPG bottle gas, (butane, propane and so on) the sensor should be 6-12in from the floor (LPGs are heavier than air). For domestic or other natural gas, the sensor must be about 12 in from the ceiling as these gases are lighter than air.

The placing of the extension siren (if used) will depend on your habits. Don't put it under the stairs with the gas meter — unless you're in the habit of sleeping there!

For use in caravans, I recommend the module with sensor and 75dB sounder in a single box which simply connects to the caravan's 12V DC supply. Similarly for boats, where the unit could be installed in bilges or engine compartments to detect excess fuel vapours.

It is possible to mount the sensor away from the PCB (a case is available to do this — see *Buylines*). In this case resistor R_L should be wired across the sensor (to maintain the resistive calibration) not into the PCB. This separate unit can then be connected to the PCB using lightweight 3-core cable (do not use screening as one of the cores).

A louder extension siren can also be fitted, powered via the reed relay contacts. A suitable 85dB siren module is available (see *Buylines*).

BUYLINES

Although many of the parts used for the Gas Alert are available from usual suppliers, some components are specific to this project. These can be obtained from Live Audio Systems, Unit 52, Tafarnbach Industrial Estate, Tredegar, Gwent NP2 3AA.

The gas sensor and matching R_L resistor cost £10.95, the mains transformer £2.25 and the PCB £2.25.

A kit of the PCB, sensor and other PCB-mounting components costs £19.95.

A complete kit of the PCB, components, buzzer and screen printed case suitable for 12V caravan or boat use costs £25.75. The small extension sensor case costs £2.95. A box for the transformer incorporating a built-in mains plug is available for £2.75. The extension siren module on its own costs £4.50.

A larger kit including the PCB, components, transformer, siren and a box suitable for mains operation is available for £32.85.

All prices include VAT. Please add 50p per order for postage. Please address all orders to Live Audio Systems. Enquiries can be answered on (0496) 717462 from 3.00 to 5.00pm



Keith Brindley finds buried treasure and avoids nailing through the water pipes with this simple but effective metal detector

METAL DETECTOR

Although this metal detector is certainly small, it does require a few extras. You don't need a car battery for power, a rucksack (to put it all in) and a six-foot dipole aerial to make the project work but you do need a small transistor radio.

The metal detector works by transmitting a weak radio wave carrier signal around itself, which has to be picked up with a nearby tranny.

The carrier signal main frequency is in the vicinity of the lower end of the longwave band (around 120kHz) and is of sufficient strength to interfere with a radio within about a foot or so, tuned into the medium or long wave. The interference is heard as a whistle from the radio's loudspeaker. As the whistle changes frequency, you know the metal detector is approaching a metal or metal-like object.

Sensitivity is pretty good considering how simple the project is. With a remote pickup coil metals can be detected from a distance of six inches or so. Even when the pickup coil is mounted on the project's case (as ours is) metals can be detected from around three or four inches.

Construction

Two ways are suggested to build this project — either on PCB or stripboard. Both methods are straightforward and apart from a few points are more-or-less self-explanatory.

On PCB, construction needn't follow any particular order, although it's probably best to leave the transistor and coil till last. Whatever, go

HOW IT WORKS

The circuit is a Colpitt's oscillator, formed around transistor Q1 which is connected as a common base amplifier. Positive feedback is applied from collector to emitter via the AC potential divider formed by series connected capacitor C2 and C3.

Capacitors C2 and C3 also form one arm of a parallel LC circuit. The circuit's resonant frequency is given by the relationship:

$$f = \frac{1}{2\pi\sqrt{LC}}$$

and is around 120kHz. Conversely, we can calculate from the relationship that the coil inductance is around 0.88mH. Try it for yourself.

Coupled in this way, the transistor amplifier becomes a weak radio transmitter, transmitting a carrier wave frequency of around 120kHz. Now, this is actually slightly below the frequencies which are normally found on the dials of long and medium wave radios (long wave is typically from about 150kHz to 300kHz and medium wave is from about 500kHz to 1600kHz). This means that if the metal detector's transmitted carrier was pure, long wave and medium wave radios could not be used to

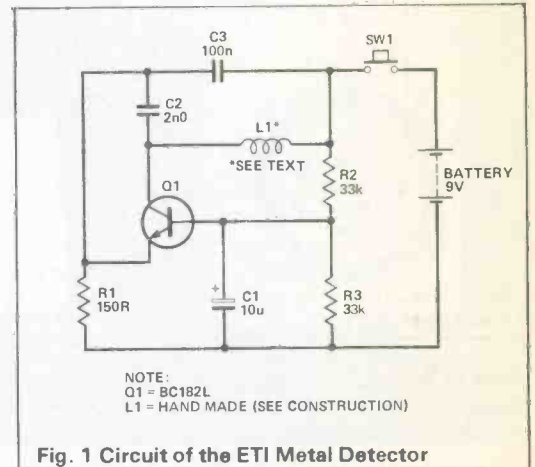


Fig. 1 Circuit of the ETI Metal Detector

easy on the heat. Solder only one leg of each component at a time then leave the component to cool before moving on to solder the next leg.

On stripboard it's probably best to stick to a conventional order, still maintaining heat precautions. Insert and solder the single wire link, followed by resistors, capacitors and the flying leads to peripheral components. Lastly insert the transistor Q1 and, when you've made it, the coil.

Whichever construction method you choose, check that no unwanted solder links or bridges are present between component leads.

The coil L1 needs to be wound. First, find a former on which to wind it — something with an external circumference of about 220mm, although this measurement is by no means critical. For reference, we used the widest part of a 250ml

pick up the oscillations. Fortunately, oscillations are not of a pure sine wave nature, so many harmonics of the resonant frequency are also formed, going right up through the long and medium wavebands and beyond.

The project functions as a metal detector simply because the actual inductance of the resonant frequency's coil varies with the proximity of local metallic bodies. Ferromagnetic bodies particularly concentrate the magnetic flux within the coil, so increasing the coil's inductance and lowering the resonant frequency of the oscillator.

A local transistor radio is used to pick up the weak carrier signals produced by the metal detector, along with a carrier wave of another radio transmission (of a more legal, broadcast nature). The two carriers heterodyne (interfere) to produce an audible beat frequency from the transistor radio's loudspeaker. The beat tone is stable, until a metal object approaches the metal detector's coil. Then the coil's inductance varies, causing the resonant oscillation frequency to vary and in turn causing the beat tone to vary. So the user hears, simply by a change of the beat tone's pitch, that the coil is somewhere near a metal object.

TOP PROJECT

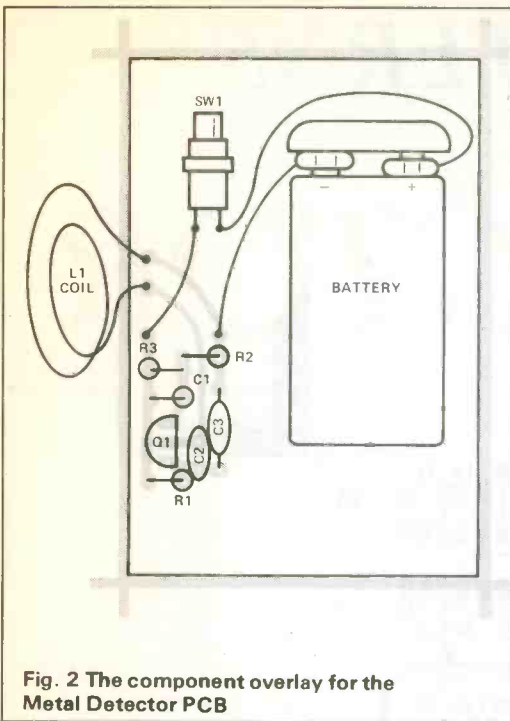


Fig. 2 The component overlay for the Metal Detector PCB

bottle of Sainsbury's Baby Lotion — no prizes or guessing who's been left holding the baby! Alternatively, a piece of thick card about 110mm long could be used to hand-wind the coil. Make 100 turns of 30swg enamel covered copper wire, leaving sufficient ends to connect between the coil's final position and the PCB.

When you've wound the coil, fasten it together in two or three places around its circumference with tape and slip it off its winding former. Adjust its shape to suit.

Before you solder the ends of the coil into the PCB, make sure you scrape off the enamel from the copper wire for about 5mm from each end, so they can be soldered. If you are using polyurethane coated insulated copper wire, there is no need to scrape off the insulation as the copper is self-fluxing on application of heat from a soldering iron.

Any suitable sized box can be used to house your project, although the PCB is exactly the right size to fit the box used (see *Buylines*). The only real

PARTS LIST

RESISTORS (all 1/4W, 5%)

R1 150R
R2, 3 33k

CAPACITORS

C1 10μ 16V axial electrolytic
C2 2n2 ceramic
C3 100n ceramic

SEMICONDUCTOR

Q1 BC182L

MISCELLANEOUS

SW1 Push-to-make
L1 Hand-made coil (see text)
PCB. Case. Type PP3 battery and clip. 30swg enamel covered copper wire for coil L1.

BUYLINES

All parts are easily obtained from component suppliers. The case used was a Type 1 general purpose Vero case. The PCB is available from the PCB Service.

precaution you need to take is to mount the coil on the outside of the case (if it's on the inside its inductance is fixed primarily by the PCB and associated components — not by metals you wish to detect!) or better still, remotely.

Setting Up

Setting up is simplicity itself. Turn on your radio and, while you press the metal detector's push-button on/off switch, adjust the radio's frequency tuning control until you hear a whistle. When you release the push-button the whistle should stop. If not, the whistle isn't caused by the metal detector and you should re-adjust the radio's frequency tuning control.

Test the metal detector by moving it closer to metal. The whistle from the radio will change frequency.

Now you're all set to find your fortune buried in the compost heap in the back garden. **ETI**

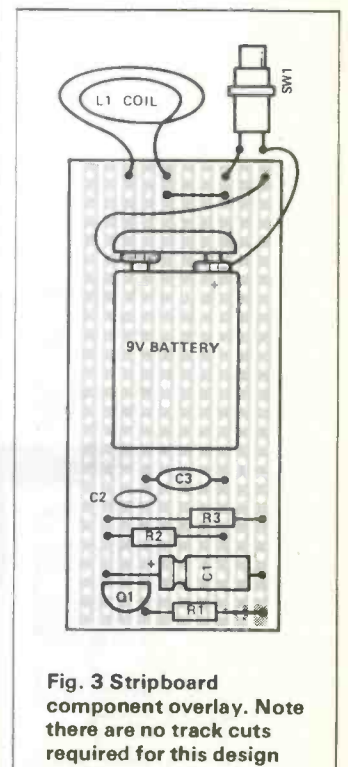
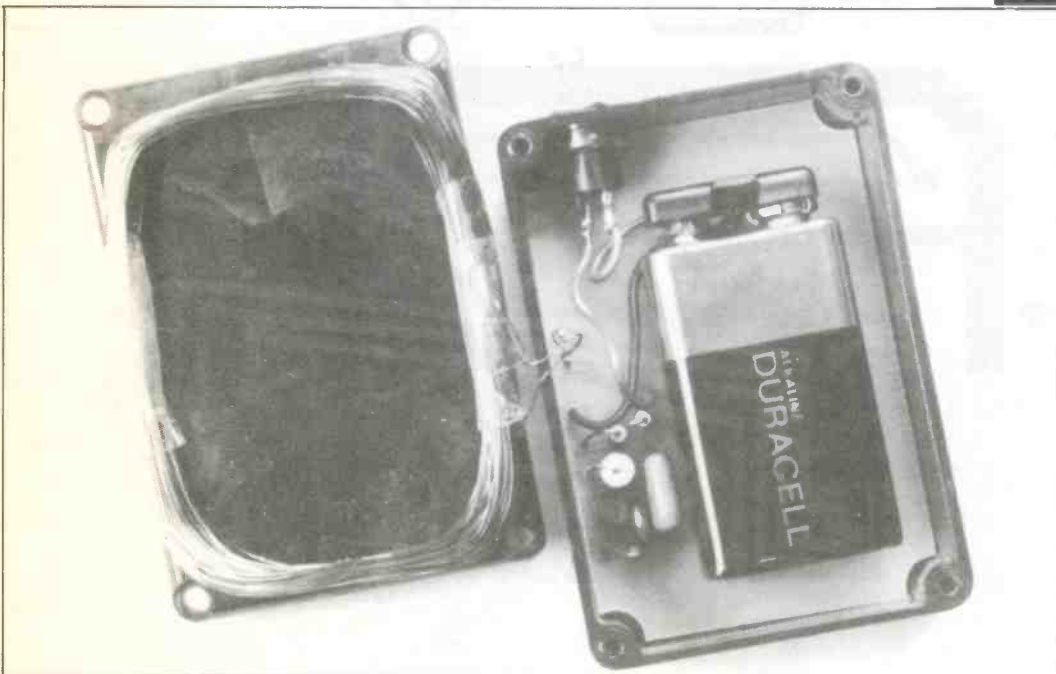
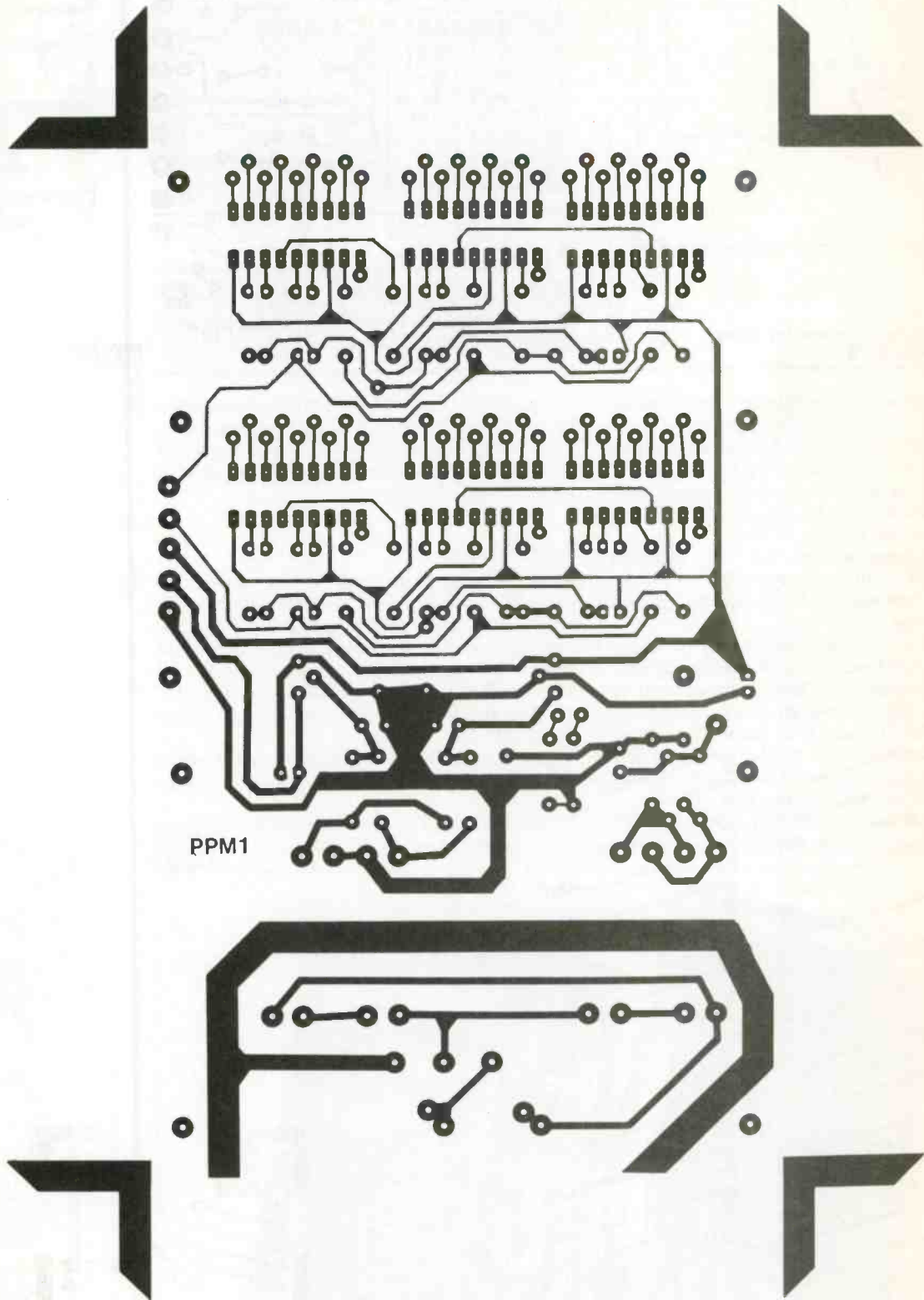
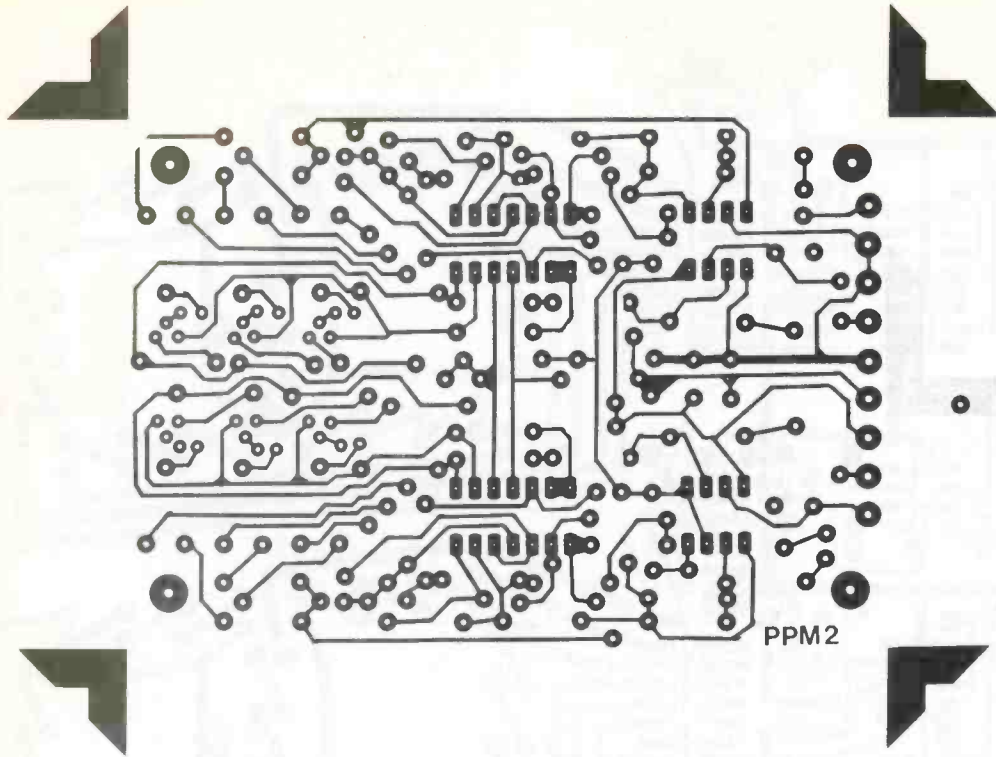


Fig. 3 Stripboard component overlay. Note there are no track cuts required for this design

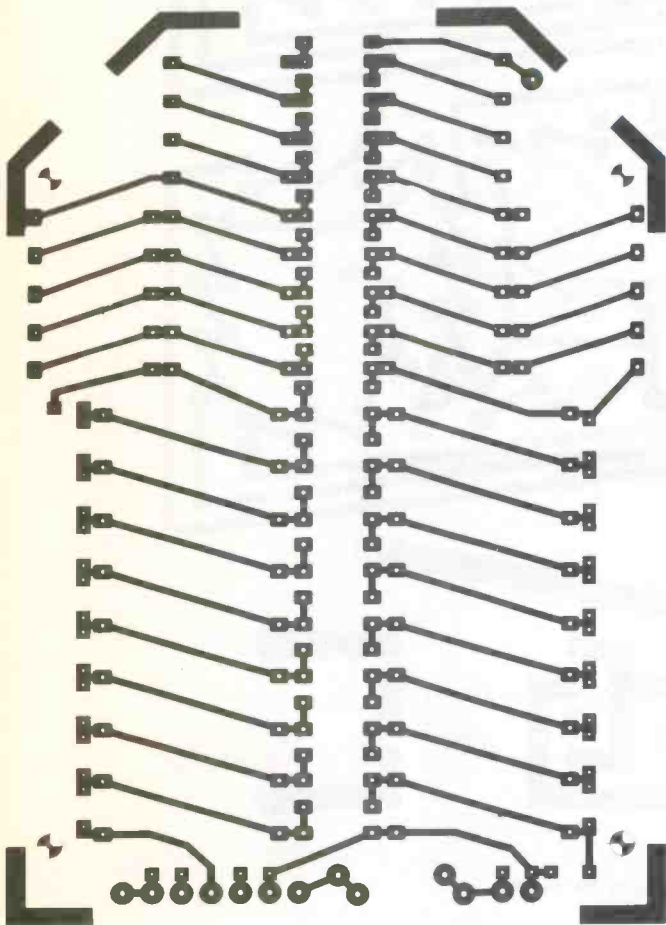
PCB FOIL PATTERNS



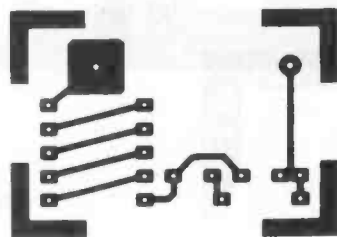
The Peak Programme Meter main board



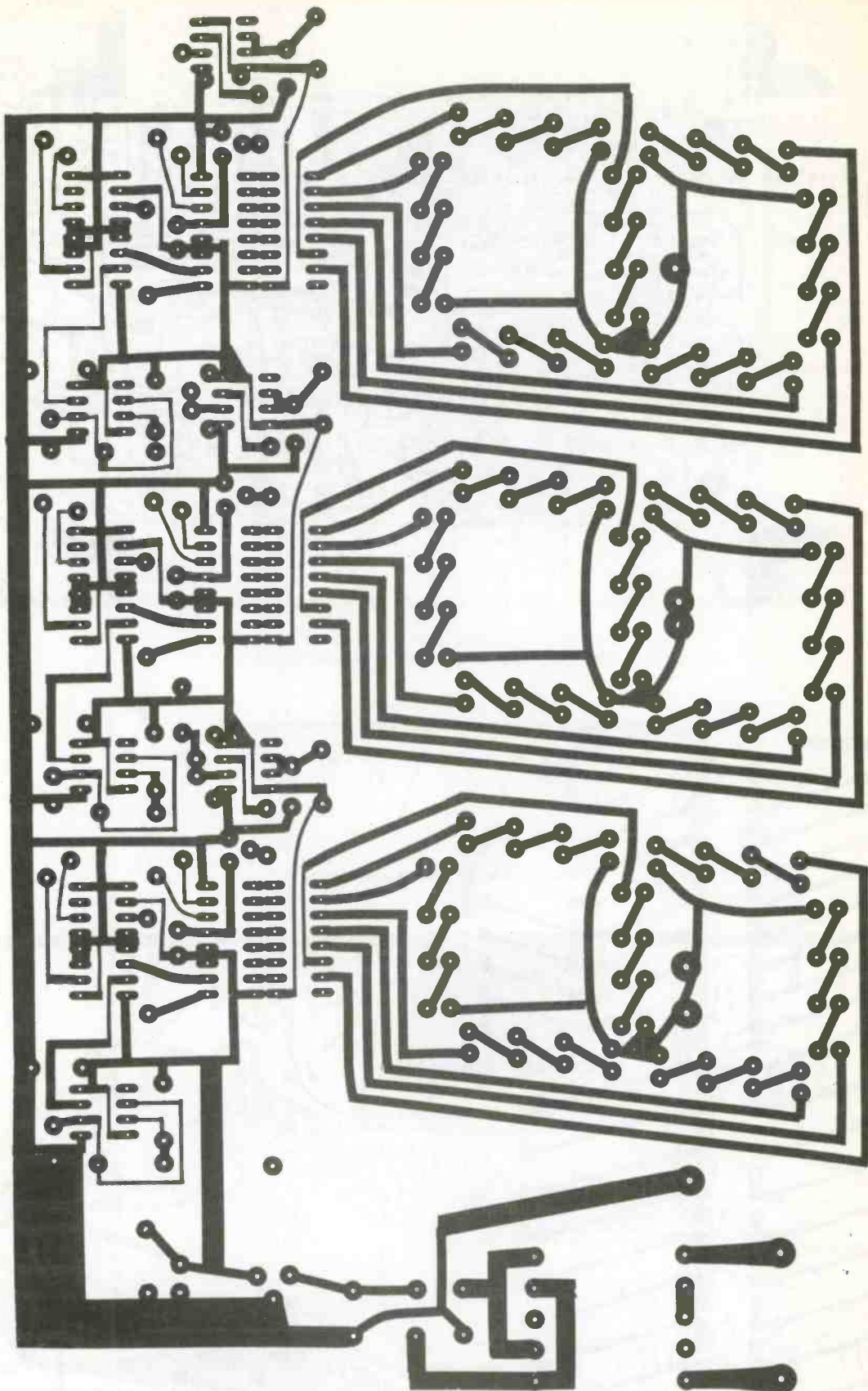
The Peak Programme Meter secondary board



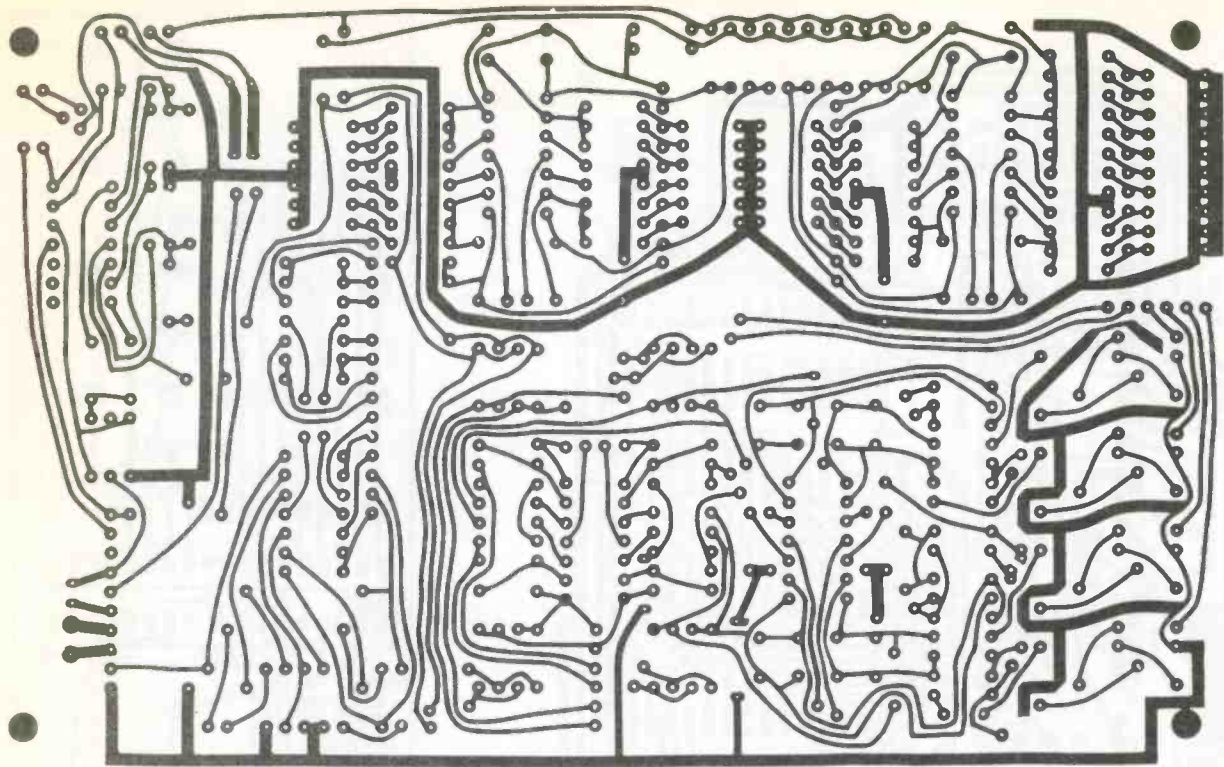
The Variat-Ion main board



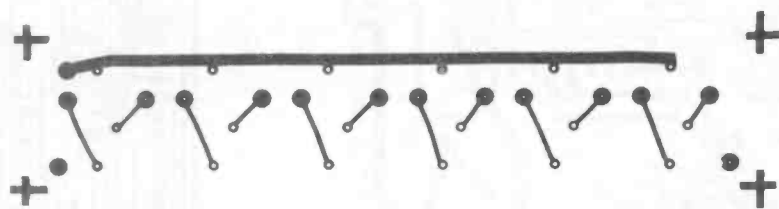
The Variat-Ion emitter board



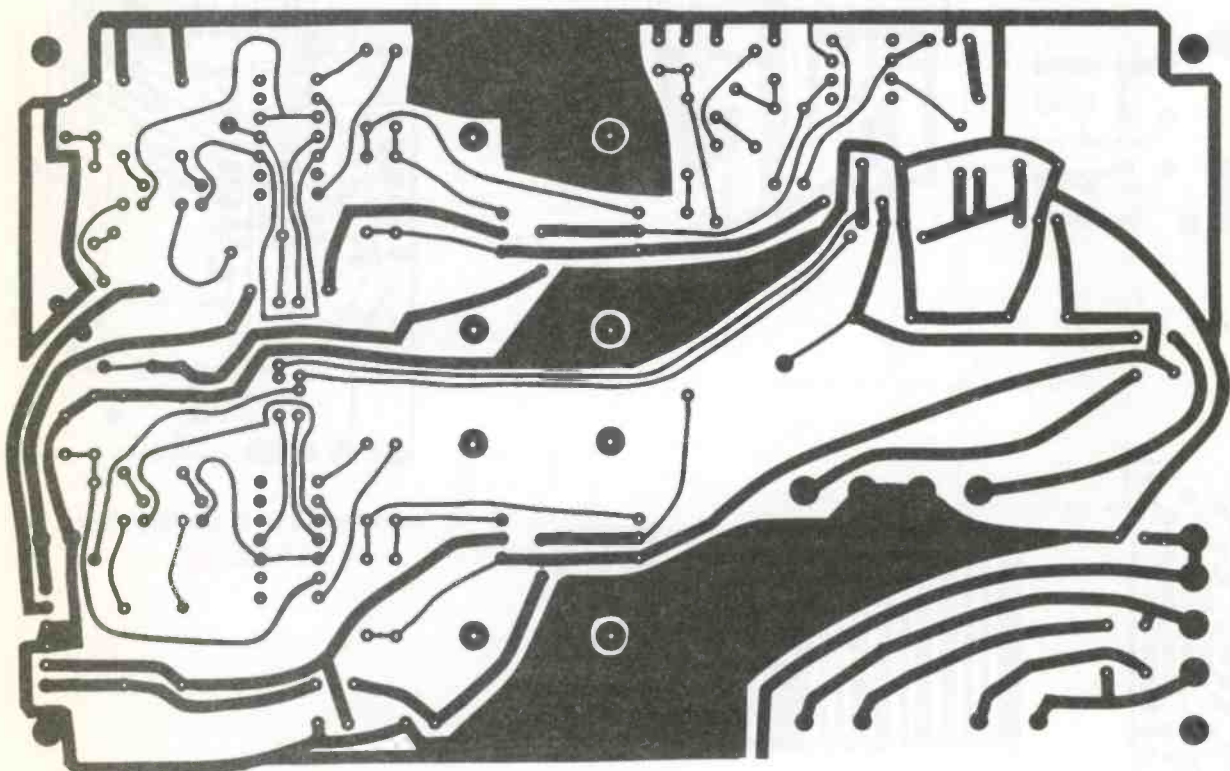
The Random Number Display foil pattern



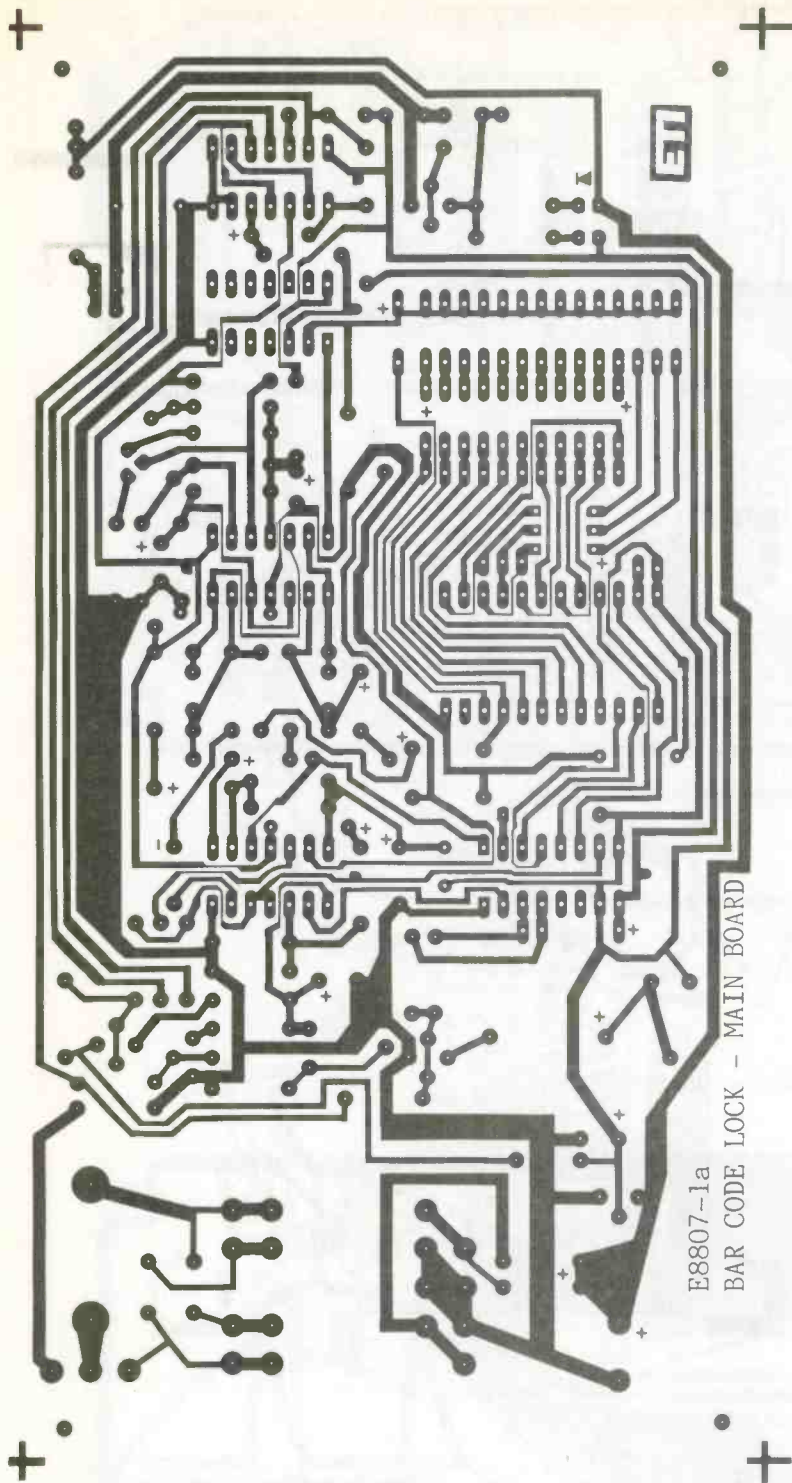
The Analogue Computer main board



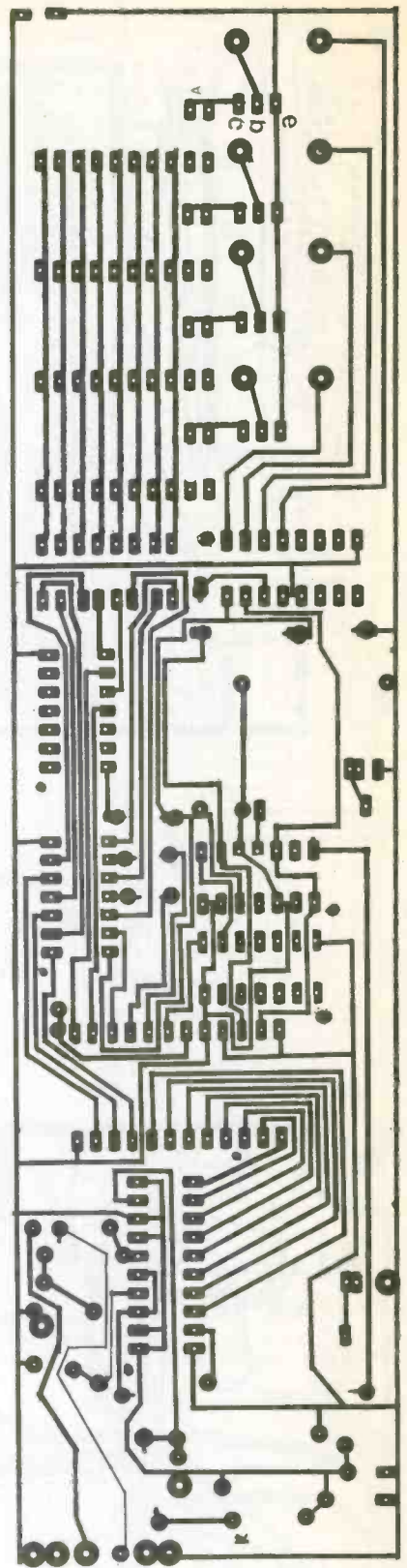
The Analogue Computer pot board



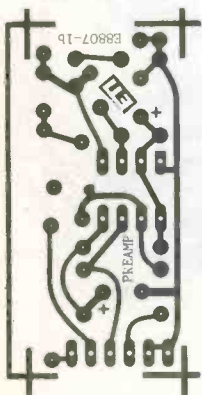
The Analogue Computer power supply board



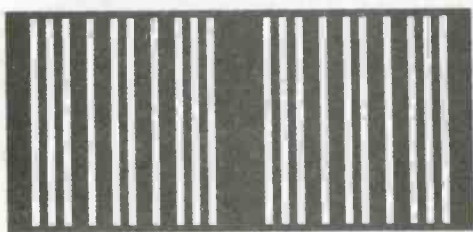
The Bar Code Lock main board

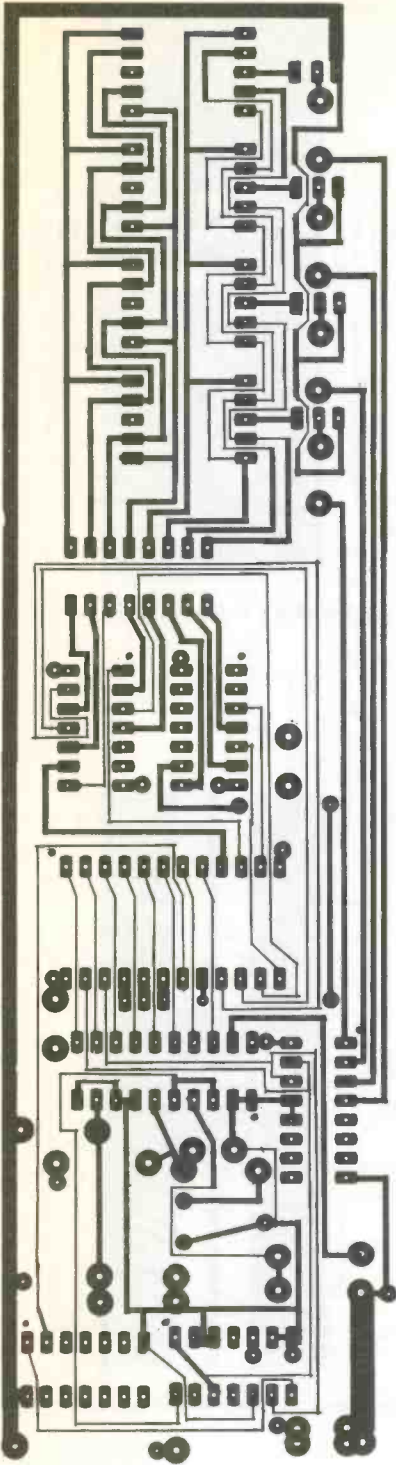


The Universal Bar Graph Panel Meter board

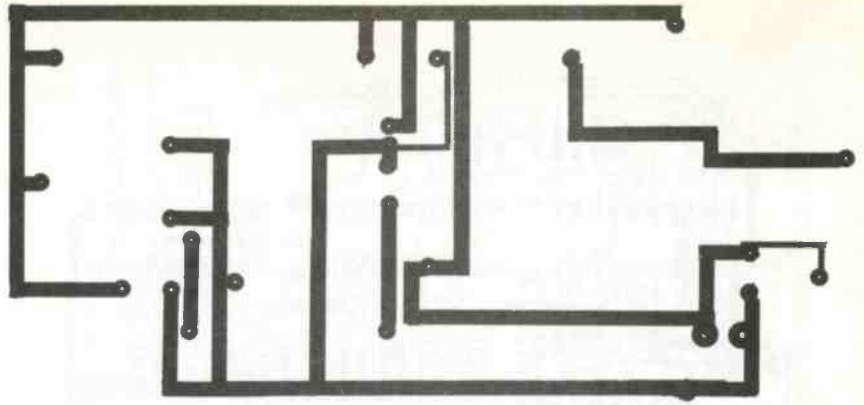


The Bar Code pre-amp board

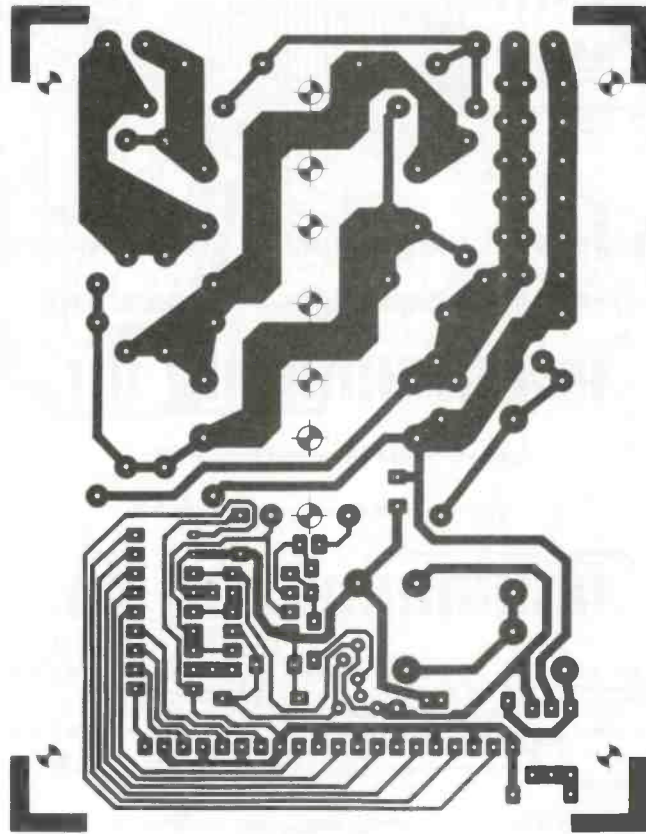




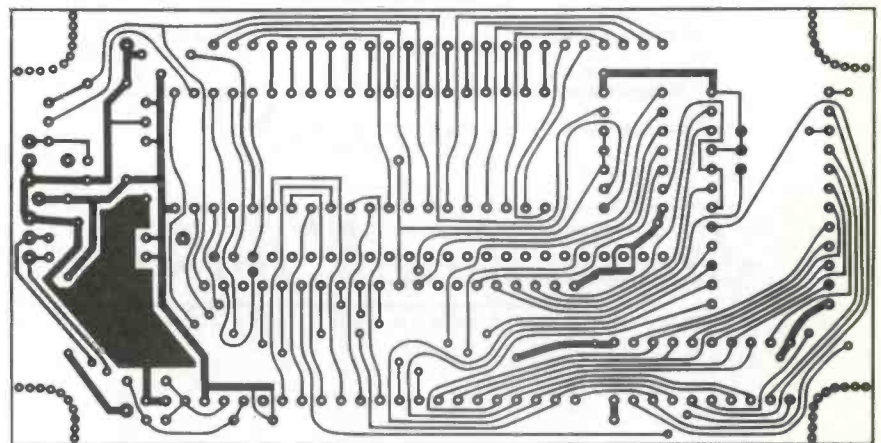
The Universal Digital Panel Meter Solderside foil



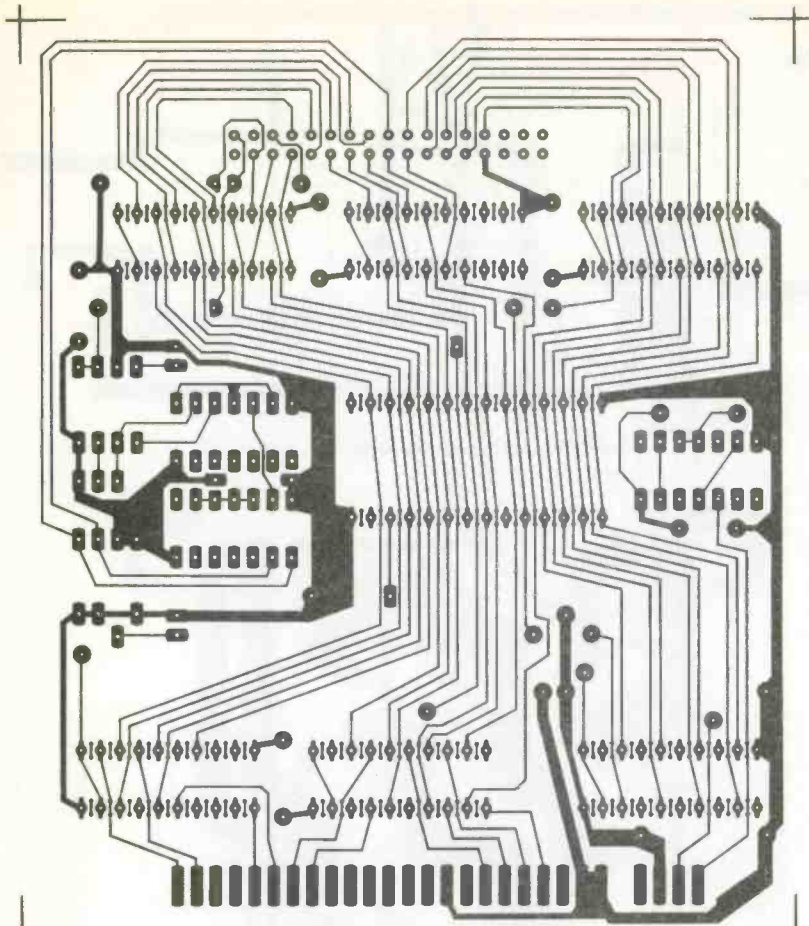
The Universal Digital Panel Meter topside foil



The Power Conditioner foil

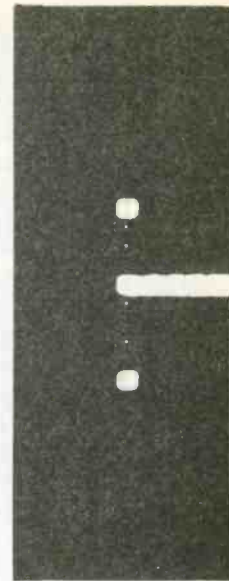
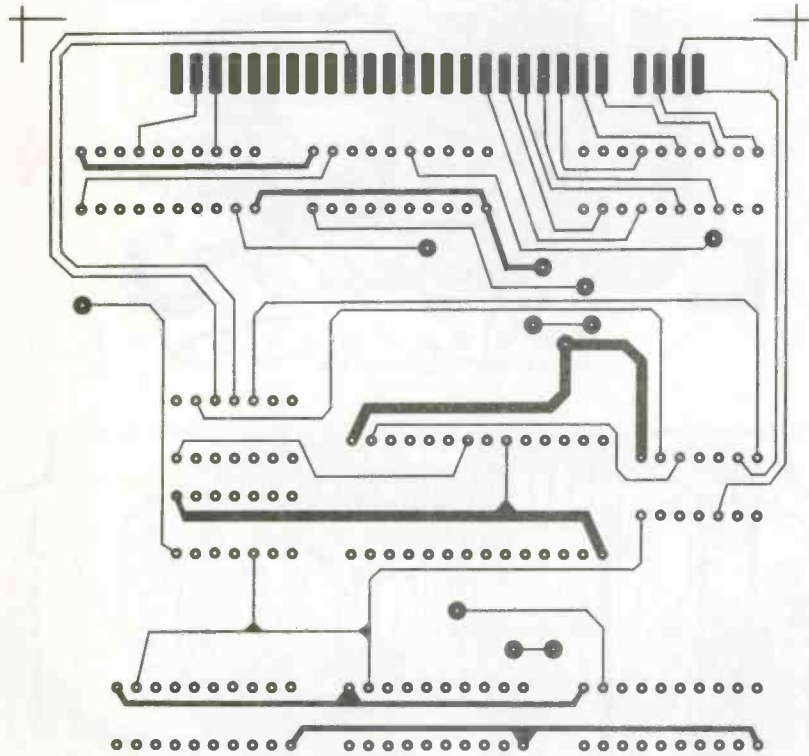


The Bicycle Speedometer foil

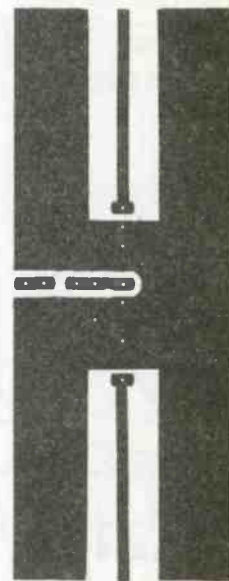


The Spectrum EPROM Emulator topside foil

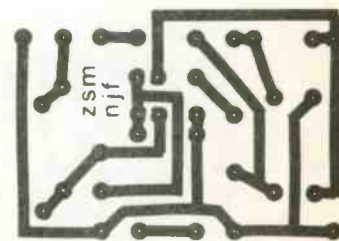
The Spectrum EPROM Emulator solderside foil



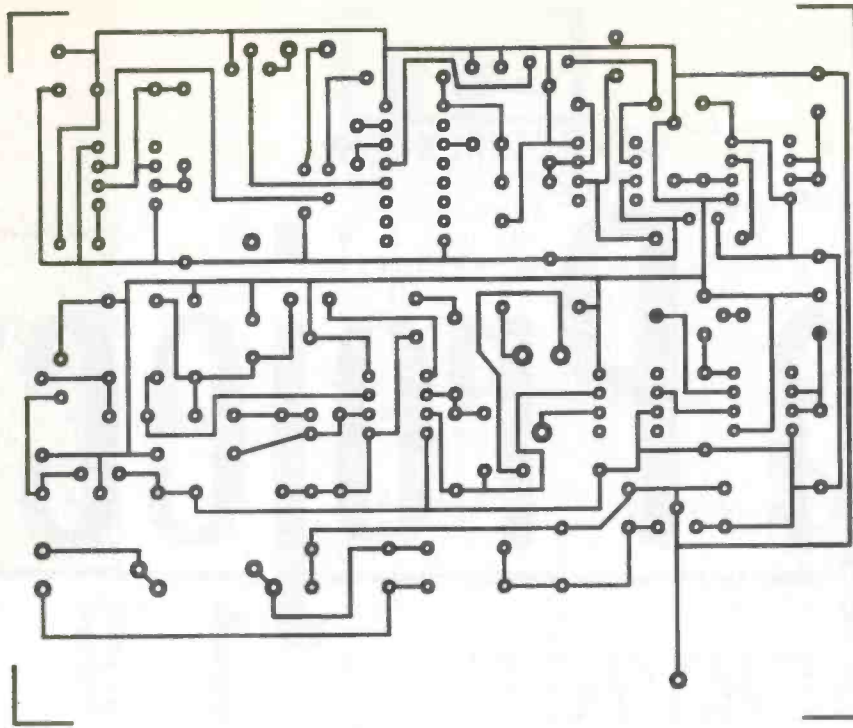
The Traveller's Aerial Amp topside foil



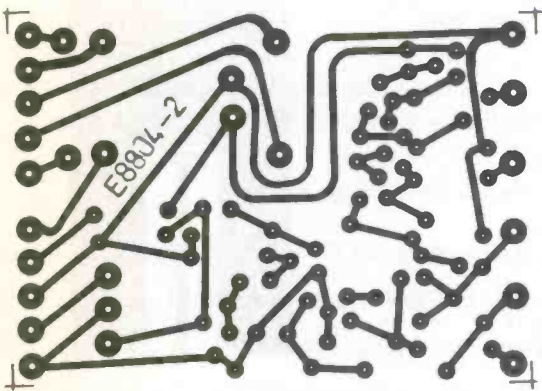
The Traveller's Aerial Amp solderside foil



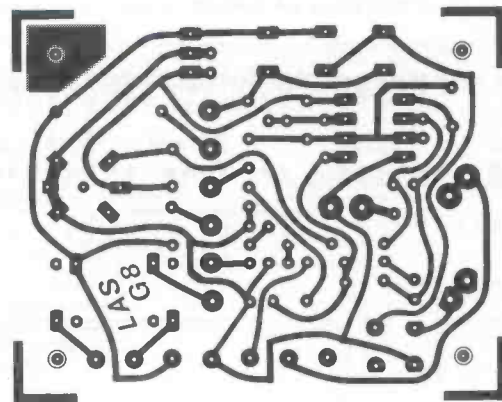
The Bicycle Dynamo Battery Backup board



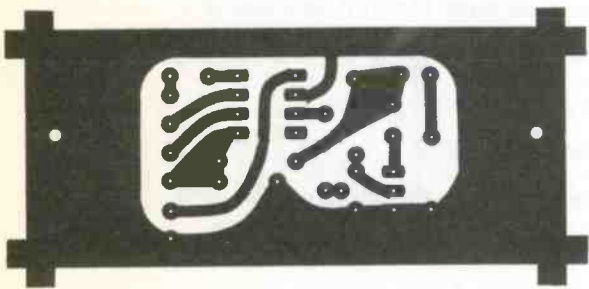
The Passive Infra-Red Alarm foil



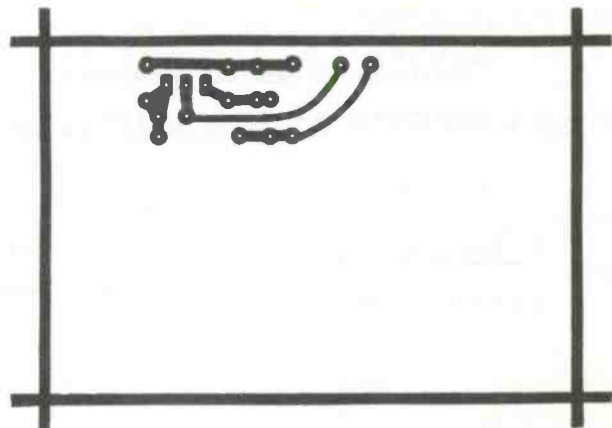
The Combo-Lock foil pattern



The Gas Alert PCB foil



The Gerrada Marweh Bikebell PCB



The Metal Detector foil

Super Woofer

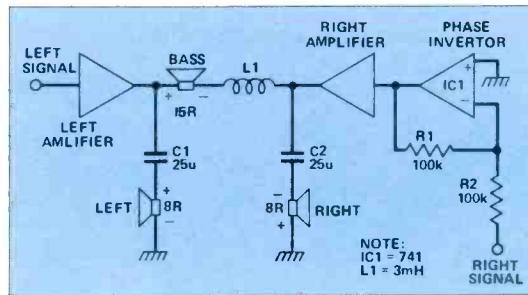
Philip Day,
Ponteland, Tyne and Wear.

This circuit enables a single centrally placed woofer to be added to a stereo system. This gives a cost effective bass enhancer which still preserves the stereo picture via the original speakers.

The right channel is driven in antiphase and the right hand speaker is reverse connected to restore the phase.

C1 and C2 as shown give a crossover at about 800Hz — other values could be tried.

The single bass speaker is bridge connected across the antiphase outputs via inductor L1. This has



the incidental advantage of cancelling out in-phase hum and vertical turntable rumble.

Note that for a system playing records only, the inverting IC circuit could be removed by reversing one half of the stereo cartridge.

Spectral Spectrum 128

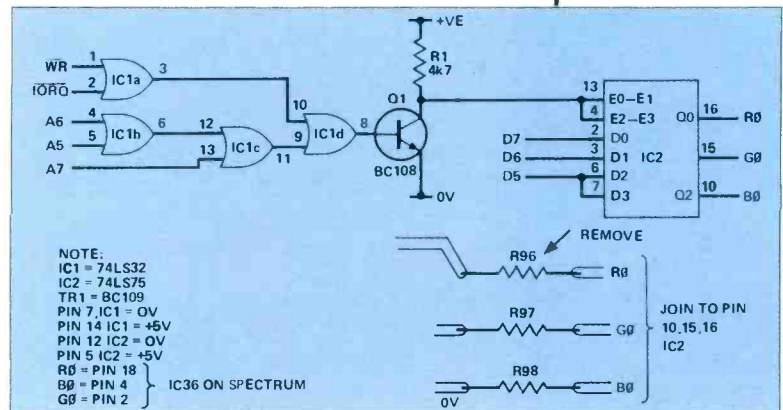
K. D. Hedger,
Gt Yarmouth, Norfolk.

This circuit modifies the Spectrum 128 to allow selection of any one of eight different palettes, each with eight colours. This makes full use of the 64 colours available from the Spectrum 128's video chip, the TEA2000. The palettes are selected by a simple 'OUT' instruction from either BASIC or machine code.

Inside the Spectrum 128, you will see that the three unused inputs of the TEA2000 (IC36) are tied to ground with R96, R97 and R98. With these resistors carefully removed, this circuit ORs WR, $\overline{\text{ORQ}}$, A6, A5 and A4 together to detect an 'OUT 31' instruction. The corresponding data is latched from D5, 6 and 7 onto the outputs of the enabled IC2. These outputs (R0, G0 and B0) connect to the right hand pads of the

removed resistors and so to the colour inputs of IC36.

The four components fit on a small piece of stripboard which can sit in the Spectrum case.



Envelope Generator

T. Allgood,
Hornchurch, Essex.

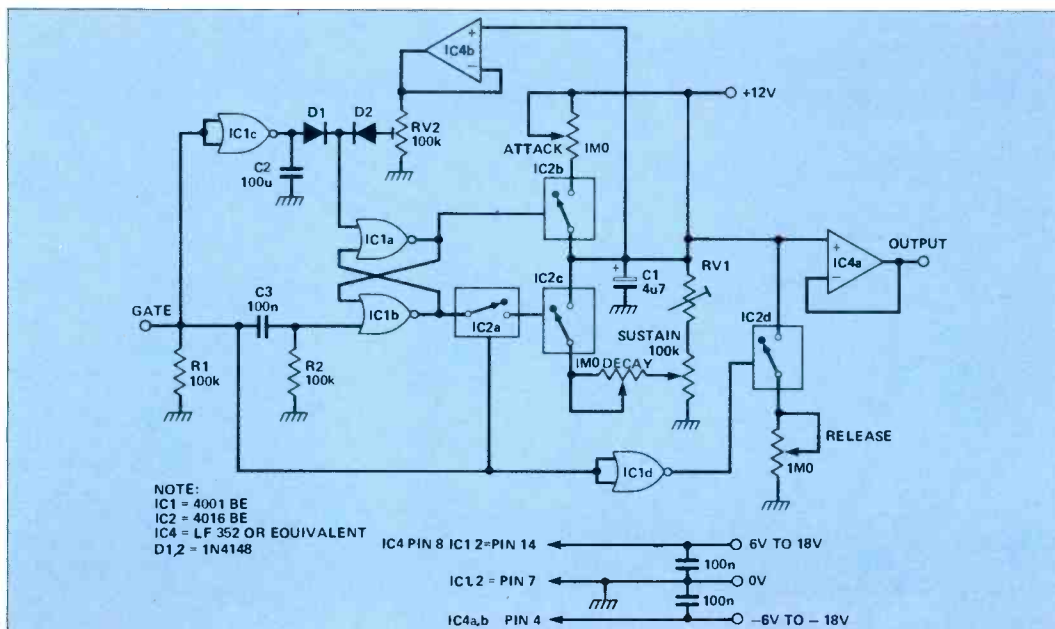
This envelope generator was designed to boost the performance of my ancient monophonic synthesizer which came equipped with only one. This way I can control either the VCA or VCF with each generator. It's a no frills ADSR generator and it's small and cheap.

C1 charges at a rate set by the attack pot when

the gate goes high (at the start of a note). At a certain voltage (set by RV2), the flip-flop of IC1a,b resets and C1 discharges at a rate set by the decay pot until it reaches the voltage set by the sustain pot. When the gate is removed (note off) C1 discharges through the release pot.

RV1 sets the maximum sustain level which should be set to match the voltage controlled device. IC4 buffers the voltage across C1 for the output.

I used this circuit with a Moog Rogue with excellent results.



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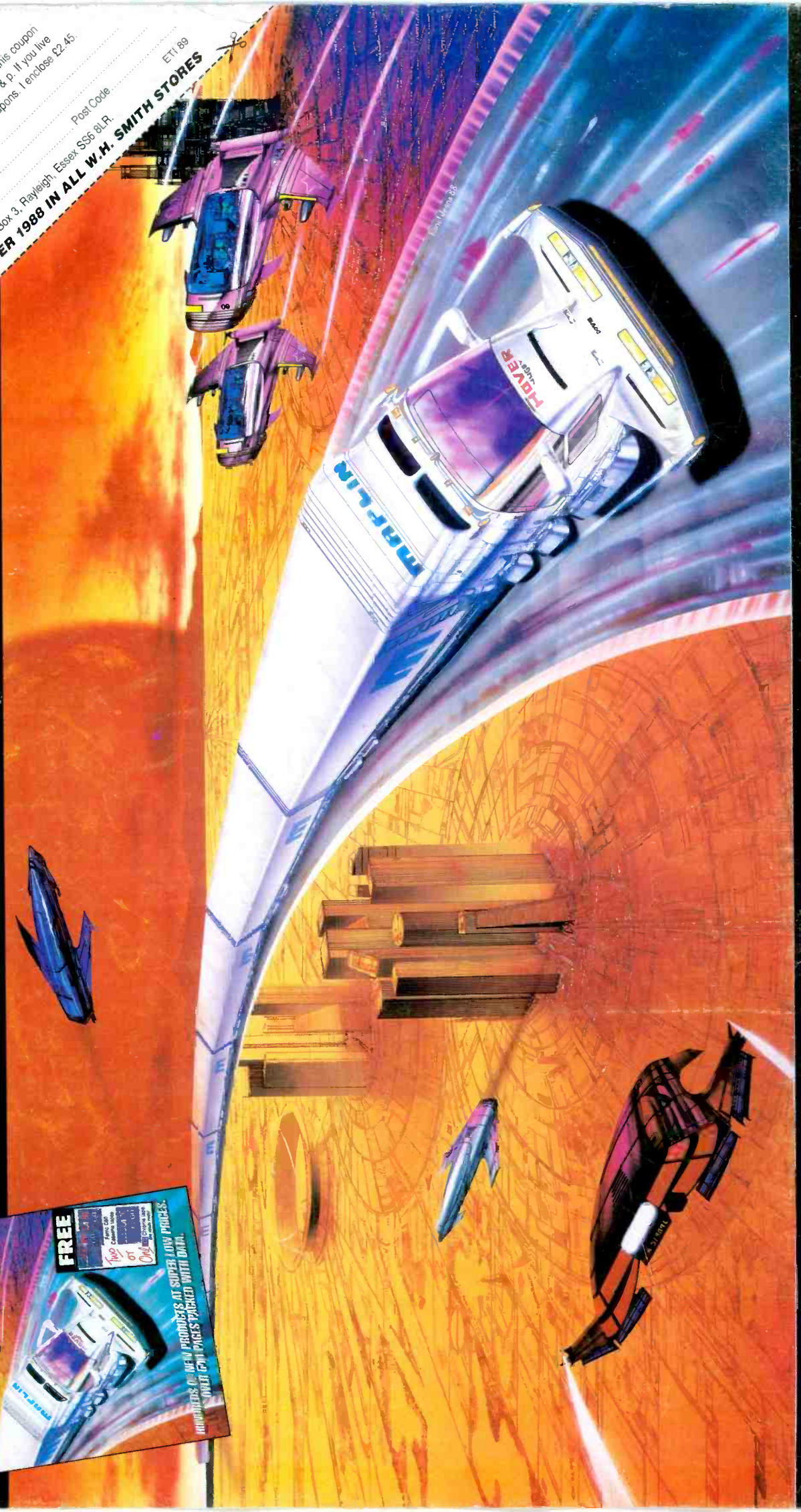
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